Helwan University
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Sustainable Rating System for Architectural Evaluation of Bridges in Egypt

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Architectural Engineering

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اسال كل من يتلقي رسالة الماجيستير الدعاء
لوالدي العميد/ اسامة سيد احمد بالرحمة و الغفران
و ان يتقبل العمل كصدقة جارية.

بسم الله الرحمن الرحيم

"قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا
إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ"

صدق الله العظيم

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The Researcher

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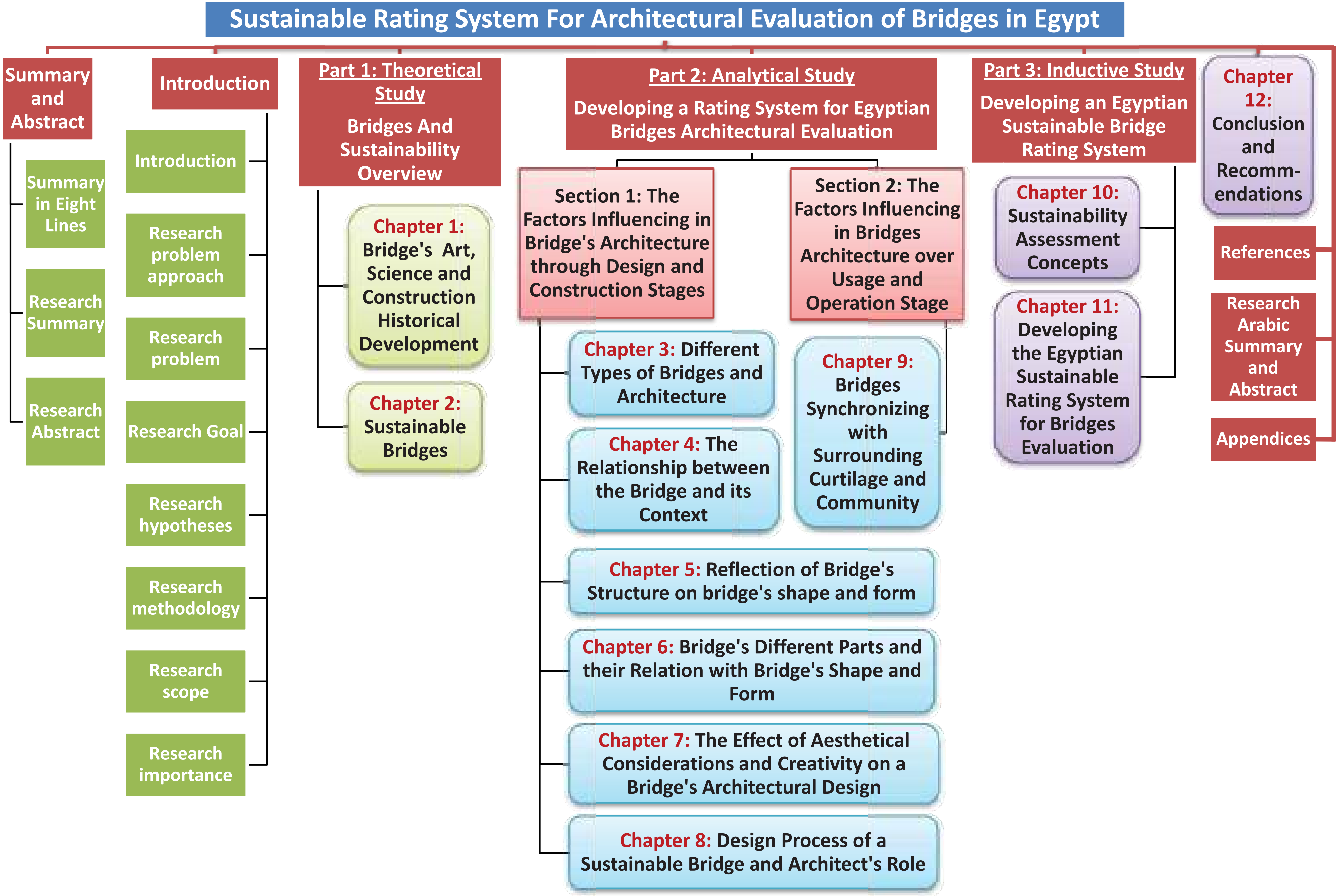
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Summary in Eight Lines

Most of Egyptian bridges have functional, aesthetical and sustainability problems which need to be figured in new construction bridges* . Also architects are excluded from bridge design, construction and operation process and all these processes are fully delegated to structural engineer who is concerned only with bridge safety and cost regardless of bridge shape, form, sustainability and original or further functions. The main goal from this study is to develop a Sustainable Rating System For Architectural Evaluation of Bridges in Egypt. This rating system will be considered as a guideline to instruct bridge design team to overcome these previously mentioned problems in new construction bridge.

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*New construction: Projects in design stage (Not existing or already constructed bridges) from LEED Reference guide: LEED Principles and Green Associate Study Guide , Green Building Education Services, USA, 2014.

Research Summary

Bridge is considered one of the most important structural facilities in Egypt. Most of the Egyptian bridges have undergo functional, aesthetical and sustainable problems which need to be addressed in new construction bridges. So to reach this goal, a Sustainable Rating System For Architectural Evaluation of Bridges in Egypt is to be developed through this research. In order to develop this ratings system, the research is divided to three main parts:

Part 1: Theoretical Study
Bridges and Sustainability Overview

This part is divided into two chapters: Chapter 1: Bridge's Art, Science and Construction Historical Development. and Chapter 2: Sustainable Bridges.

Chapter 1: Bridge's Art, Science and Construction Historical Development.

In this chapter, the basic definitions of bridges are discussed, Also bridges global and Egyptian history are discussed to track the scientific and aesthetical development through eras and to define the relationship between Egyptian bridges and global bridges from past to present.

Also, the relationship between the architecture of bridges and the global architectural trends is discussed all over the world through studying remarkable examples from different eras.

At the end of this chapter the related prerequisites and credits to bridges history and architectural schools and trends are concluded to measure the bridge connectivity to the history and to measure the ability to keep the bridge up with the state of the art and technologies also to define the adopts architectural school.

Chapter 2: Sustainable Bridges.

The aim of this chapter is to trace the hierarchy from sustainability general concepts to sustainable bridge through viewing sustainability definitions, treble bottom line, sustainable design, sustainable architecture, sustainable building and sustainable construction.

Also, constructability definition and the connection between sustainability and constructability are summarized. To achieve sustainability through bridges sustainable city, sustainable transportation and green architecture are to be introduced.

By the end of this chapter, two questions will be answered: why sustainable bridges are constructed? and what are the principles for determining the criteria of a sustainable bridge?

Part 2: Analytical Study
Developing a Rating System for Egyptian Bridges Architectural Evaluation

This part is divided into two sections: the first section discusses bridge design and construction stages consisting of 6 chapters, and the second section discusses bridge operation and usage stage including 1 chapter.

Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages

In this Section, Bridge's function, type, context, natural and constructed delimiters, structure system, construction materials and methods, parts and aesthetical considerations are studied.

Chapter 3: Different Types of Bridges and Architecture.

In this chapter, different types of bridges are studied. Also bridge movement or constancy and its advantages and disadvantages are discussed.

At the end of this chapter, prerequisites and credits are concluded to evaluate the bridge functional success.

Chapter 4: The Relationship between the Bridge and Its Context.

In this chapter bridge site is deliberated through studying the bridge natural and constructed delimiters, the surrounded urban context, the relationship between new bridge and existing or historical bridge or facility.

Because of the Nile river importance for Egypt, living bridges are overviewed and studied.

Also, bridge as a whole aesthetical design is studied based on its location, crossed obstacle, interchanges and scenic/ environmentally sensitive sites.

At the end, the related prerequisites and credits to bridge site are concluded to evaluate the relationship between bridge and its surrounding context.

Chapter 5: Reflection of Bridge's Structure on Bridge's Shape and Form.

One of the most important affecting factors on bridge shape and form is bridge structure.

After determining bridge function and studying bridge site, the next step is to select a structure system to fully achieve bridge function, span and sustain the calculated loads on bridge. Also bridge construction materials and construction methods selection to suit the structure system and carry calculated loads on bridge will be studied.

So in this chapter, bridge structure systems, construction materials and construction methods and loads are studied, Also the related prerequisites and credits are concluded to evaluate bridge structural decisions and their affect on bridge's shape and form.

Chapter 6: Bridge Different Parts and their Relationwith Bridge's Shape and Form.

In this chapter, both of structural (superstructure and sub-structure) and non-structural bridges parts including (parapets, railing, safety screens, etc..) are studied. The most important bridges parts design considerations are introduced to guarantee bridge good architecture.

At the end of this chapter, prerequisites and credits are concluded to assure the best choices of bridge parts according to the bridge design.

Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design.

In this chapter, the fundamentals of aesthetical design and aesthetical qualities including (proportions, rhythm, order, harmony, etc..) are studied Also aesthetical design objectives such as (functional clarity, scale and proportion, order and balance, etc..) will be discussed to help designers visualize and evaluate bridge design articulation.

The used factors to differentiate between bridges are studied in this chapter. These factors are bridge visual design elements including (colors, textures, ornamentations, etc..). Also

there are visual characteristics of the bridge (How does the beholder conceive the bridge?) which are also discussed in this chapter.

Finally, creativity in a bridge design is discussed through defining creativity, studying the relationship between creativity and bridges knowing the characters of creative process and types of creativity.

At the end of this chapter, some prerequisites and credits are concluded to evaluate the bridge's aesthetics and creativity.

Chapter 8: Design Process of a Sustainable Bridge and Architect's Role.

It should be noted that two major factors are affecting the sustainable bridge design. These factors are sustainable bridge integrated team and sustainable bridge integrative process.

So in this chapter, bridge design philosophies are overviewed. The involved parties in a bridge design are introduced together with their relationship to each other and to the final shape of the bridge.

Also, the importance of architect role in a bridge design in Egypt and worldwide is discussed with examples of bridges designed by global architects. Also the importance of bridges design competitions to improve the bridge design industry is overviewed.

There is a remarkable deference between conventional bridge team/ design process and sustainable integrated team/ design process which will be discussed in details in this chapter.

One of the most important reasons of the delayed improvement of bridge design field in Egypt is the bridge economical evaluation which will be studied in this chapter taking into consideration value engineering and beautiful/ green bridge cost versus conventional bridge costs.

At the end of this chapter, prerequisites and credits are concluded to assimilate the importance of architects, integrated team members, etc.. in bridge integrated design process.

Section 2: The Factors influencing in Bridges Architecture over Usage and Operation Stage

Chapter 9 : Bridges Synchronizing with Surrounding Curtilage and Community.

In this chapter the effect of constructed bridges after operation and usage in the surrounding curtilage is studied from different perspectives.

The influence of bridges on the city's visual image and the effect on the city's character are obvious all over the world. Also bridges representing deploy worldwide and reflecting city's evolution or backwardness.

The consequence of bridge usage on the surrounding curtilage which consists of the area under and around the bridge is discussed through global an Egyptian instances.

Also, the incorporate factors affecting bridge surrounding usage in Egypt are discussed.

At this end of the chapter, prerequisites and credits to exhibit the bridge architecture as a whole through well using of its curtilage are concluded.

Part 3: Inductive Study
Developing an Egyptian Sustainable Bridge Rating System

The goal of this part is to develop a sustainable rating system to evaluate the new construction Egyptian bridges. There are two stages to reach this goal: the first stage (chapter 10) is to study the previous experiences in the sustainability field and overview the major sustainability rating systems in the global market (sustainable buildings rating systems and sustainable roads construction and transportations rating systems), and the second stage (chapter 11) is to choose the most appropriate rating systems both for sustainable buildings and transportation (LEED and Greenroads), as well as studying these rating systems and selecting the most appropriate prerequisites and credits to be developed for the Egyptian rating system.

Chapter 10: Sustainability Assessment Concepts.

In this chapter, sustainability assessment concepts are overviewed through having an introduction to environmental classification systems. Also tools for environmental evaluation (analytical and operational environmental evaluation tools) are studied. Criteria for evaluating and selecting rating systems and major sustainability rating systems are discussed. Most of the global market sustainability rating systems (sustainable buildings rating systems and sustainable roads construction and transportations rating systems) are overviewed.

Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation.

The goal of this chapter is to develop a rating system to evaluate bridge sustainability. To reach this goal, current bridges sustainable practices are studied. Also previous sustainable bridges rating systems trials are studied.

Two rating systems are selected to develop the new rating system (LEED as a most popular sustainable rating system for buildings in the world an in Egypt and Greenroads as an updated academic sustainable rating system for roads). Also the reason for choosing these rating systems, a summary of these rating systems and the need for a new rating system are introduced.

Chapter 12: Conclusion and Recommendations.

In this chapter, The most important findings of the study are drawn. Finally, recommendations are suggested including implications for future studies with respect to architecture and sustainability in bridges design.

Appendices:

All developed Architecture and Sustainability prerequisites and credits in the score card are explained. At every prerequisite/credit, the intent of this prerequisite/credit is demonstrated. Also requirements to achieve this prerequisite/credit is explained. Scoring criteria will be explained including (certified, silver, green and platinum) to facilitate the rating system usage.

Research Abstract

Bridges traverse environmentally and ecologically sensitive sites, culturally or visually significant areas. They have visually prominent features in communities and other developed settings. They also function socially and symbolically as vital factors in their communities and environments.
Research problem could be accomplished as most of Egyptian bridges have functional, aesthetical and sustainability problems which need to be addressed in the new construction bridges* (Future bridges projects). Also architects are excluded from bridge design, construction and operation processes and all bridge design/ construction process is fully delegated to structure engineers who are concerned only with bridge safety and cost regardless of its architecture and sustainability.

The main goal of this study is proposing an Egyptian sustainable rating system for architectural evaluation of bridges as they require intensive site preparations on large scale, use of massive materials, with remarkable effects on the visual image of the city.
This rating system is considered a guideline to instruct bridge design team to overcome these previously mentioned bridges functional, aesthetical and sustainability problems in new construction bridge design, construction and operation.

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*New construction : Projects in design stage (Not existing or already constructed bridges) from LEED Reference guide: LEED Principles and Green Associate Study Guide , Green Building Education Services, USA, 2014.

Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

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- Research Problem
- Research Goal
- Research Hypotheses
- Research Methodology
- Research Scope
- Research Importance

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Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

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Introduction

Bridges have always played a crucial role in the establishment and defense of both cities and civilizations. They had an undeniable civic role as well, and were the location of many historical events and are the prominent feature of many landscapes. In addition to the transportation purpose for which they were created. Bridges have also a public role. From ancient days, people always form a physical, social and even emotional connection with the bridge as a built form. Being an architectural element, though of a smaller scale, Bridges have been the subject of an ongoing evolution due to the exploration of new technologies and building materials.

"Bridges are among the most visible and important pieces of engineered construction in our environment. They are essential components of our public works foundations, our infrastructure."[1]

According to the above quote, bridges are considered environmentally and ecologically sensitive sites, culturally or visually significant areas and visually prominent feature in communities and other developed settings. They also function socially and symbolically as vital factors in their communities and environments. Although bridges can have negative impacts on these environments, they can also be created in such a way that they are pleasing and a much welcomed addition to the landscape. Furthermore, bridges have now become places where the public gather for different social and economic activities. Thus, the design of bridges has to be more than how to get to the other side. Therefore, bridge architecture is a necessity because people need it to improve and develop their social lifestyle. Bridges help us build communities, to find spaces to interact, and to experience a new world within the confines of a construction.

Bridges are considered one of the most important civil facilities in Egypt, Most bridges will be seen by millions of people and, therefore, should be designed as attractively as possible. Unfortunately, bridge engineers generally consider the esthetic evaluation of a bridge to be too subjective in nature.

As per latest studies issued on June 2014 by the Egyptian Central Agency for Public Mobilization and Statistics (CAPMAS), Egypt has 2370 bridges. These bridges are divided into fixed and movable bridges, with more than 40% of these bridges requiring immediate maintenance.[2] 50% of these bridges carry extra loads above their capacity.[3]

Research Problem Approach

"A weak bridge is admittedly more dangerous than an ugly one, but to seek strength at the lowest cost with no regard for appearance is only one degree worse than it would be to attempt a beautiful design without thought of stability."

This concern voiced by the late C.S. Whitney[4]

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[1] - Richard Weingardt: "Bridges and Our Environment," Concrete Construction , (1990) ,p 942- 946.

[2] - http://www.capmas.gov.eg/

[3] - http://www.ahram.org.eg/NewsPrint/259584.aspx

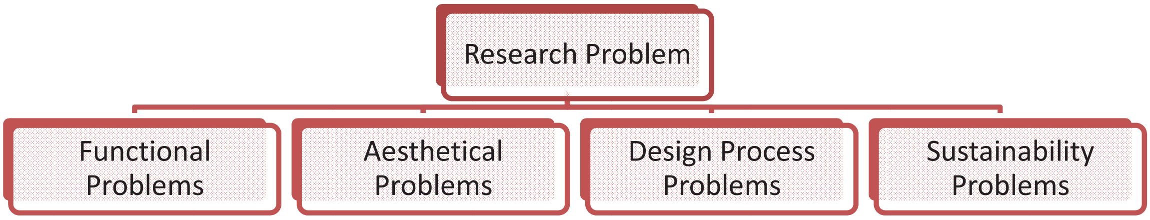
[4] - E. Cohen: "In the Eye of the Beholder" Esthetics in Concrete Bridge Design, MP-1- American Concrete Institute- Detroit- 1990, p11.

In his treatise on architecture, the Roman architect; Vitruvius declared that there were three principles of good architecture:
(Durability) – It should stand up robustly and remain in good condition.
(Utility) – It should be useful and function well for the people using it.
(Beauty) – It should delight people and raise their spirits.
And recently **Sustainability** could be considered as a forth principle of good architecture.

Bridge, as a Kind of architectural facility, is a structure that should be both functional and elegant at the same time. One essential point to consider in any bridge is the environmental harmony. Bridges became part of the environment in time. Therefore, a very careful and precise study should be carried out during bridge design.
Bridges are considered both engineering and architectural masterpieces, bridges have held a crucial place in the civilization of mankind and in modern life. One must be well aware of the fact that bridges are structures that affect people more than any structure. Hence, The design and maintenance should include these principles.

Research Problem

In addition on the treatise of the Roman architect Vitruvius, and over studying many Egyptian case studies, there are dominate problems were classified under four categories :



- Although Most of Egyptian bridges were designed and constructed to achieve a function regardless of aesthetics, sustainability and creativity, most of these bridges did not fully achieve their designed function.
- Usually, Egyptian community add various functions to already constructed bridges, As pedestrians on vehicles bridges, street vendors on most of pedestrian bridges, formality and informality usage of area under bridges, etc.. which effect on original bridge's function success.
- For pedestrian bridges, Excluding elevators and escalators from bridge designs due to economical consideration which eliminate old and unable people from using these bridges which deficient the bridge function.
- Unstudied affects of bridges on surrounding cartilage (Land uses, surrounding buildings, Historical sites, etc..) during bridge's design stage, which affecting both bridge function and bridge aesthetics.
- Totally neglecting bridges Aesthetical elements, aesthetical values and architectural details from bridge design because of economical and time schedule circumstances.
- Failure to examine bridge location and site determinates leading to create an odd bridge have no architectural character and doesn't belong to the surrounding area.

- Full delegating of the bridge design to structural engineers and exclusion architects from the design process which lead to aesthetical values neglect ion and only construct a safe structure with lowest cost.
- Although structure engineer is the only controller of bridge design, yet most of Egyptian bridges are deprived of any structural innovation which leads to poor, repeated and non-aesthetical bridge forms.
- Bridges designers do not take sustainability into consideration during bridge design, construction and maintenance neither in bridges site, materials, usage and energy nor in bridge end of life.

Consequently, research problem could be summed up as follow: Most of Egyptian bridges have functional, aesthetical and sustainable problems which need to be figured in new construction bridges (future bridges projects). Also architects are excluded from bridge design, construction and operation process and all bridge design/ construction process is fully delegated to structural engineer who are concerned only with bridge safety and cost regardless of architecture and sustainability considerations.

Research Goal

The main goal of the present study is to conclude a Sustainable Rating System For Architectural Evaluation of Bridges in Egypt. This rating system is considered a guideline to instruct bridge design team to overcome these previously mentioned bridges related functional, aesthetical and sustainable problems in new construction bridge* design, construction and operation. To reach this main goal, There are many secondary goals required to be achieved. Salient of which are:

- Reaching to the bridge's function design approach for new construction bridges during design stage by studying designed functions and Community developed functions of already built similar bridges and compare it with new bridge functional design approach.
- Concluding an expert system for aesthetic rating of bridges through deep understanding of the influencing factors on bridges shape and form design.
- Developing a framework for more sustainable design and construction processes for new bridges and applying sustainable maintenance for these bridges.
- Highlighting the role of architects in bridges design, and how architects innovate, develop and invent future designs of bridges to be compatible with construction evolution in an Egyptian framework.

Research Hypotheses

Thorough the research a hypotheses validation will be checked. Hypotheses could be concluded as below :

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* New construction: Projects in design stage (Not existing or already constructed bridges) from LEED Reference guide: LEED Principles and Green Associate Study Guide , Green Building Education Services, USA, 2014.

Following of the developed Sustainable Rating System For Architectural Evaluation of Bridges in Egypt score card and integrating architects into bridge design, construction and operation will solve many architectural, functional and sustainable problems in new construction bridges

Research Methodology

The research is divided into three main parts :

First Part (Theoretical Study) Bridges and Sustainability Overview:

The study begin with an overview of the history of bridges ,well understanding the past to understand the development mechanism, main definitions of bridges, a sustainability overview, sustainable bridges, etc. Every chapter is followed by the concluded architectural prerequisites and credits which will be combined at the final score card.

Second Part (Analytical Study) Developing a Rating System for Egyptian Bridges Architectural Evaluation:

Analyze the current available bridges aesthetical guidelines, some bridges examples to conclude some results which drive us to imagine future proposals of bridges. Enable us to conclude architectural rating system for bridges evaluation. After every chapter there will be the concluded architectural prerequisites and credits which will be combined at the final score card.

Third Part (Inductive Study) Developing a Rating System for Egyptian bridges Sustainability Evaluation:

In this part, Some of the available sustainability rating systems (Buildings an roads rating systems) will be studied, refined and developed to exclude the Egyptian sustainable bridges rating systems.

The previously concluded prerequisites and credits in every chapter conclusion and selected prerequisites and credits from LEED and Greenroads rating systems will be combined and arranged. A final score card will be developed from these proposals to be followed for designing new construction sustainable, beautiful bridges in a creative way. This score card will be simplified and elucidated in the Appendices.

These Approaches Will be Used During the Research :

Descriptive Analytical Approach:

This approach is used at the first part of the research during studying the history of bridges, describing major definitions and an approach to sustainability. The goal of the first part is to know the basic theories of bridges design and analyze these theories to know the major factors affecting bridges design from architectural perspectives.

Inductive Analytical Approach :

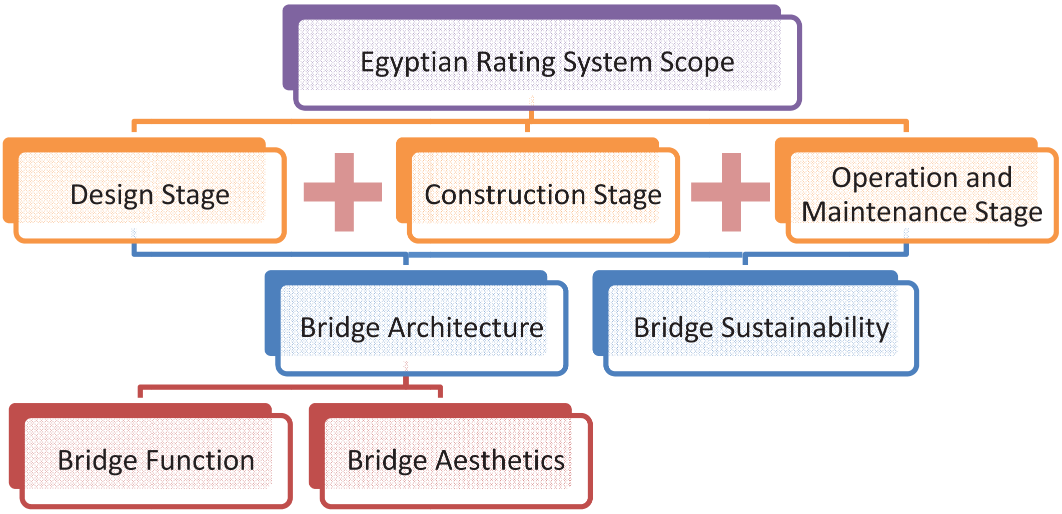
This approach is used at the second part of the research during studying bridges parts, structure, aesthetic elements and bridges global guidelines, etc.. and analyzing previous studies to deduct an architectural score card to evaluate both function and aesthetics of the bridges.

Analytical Comparative Approach :

This approach is used at the third part of the research through analyzing the previously sustainable practices of both bridges, buildings and roads, comparing these practices to conclude the most appropriate sustainable practices for Sustainable Rating System for Architectural Evaluation of Bridges in Egypt.

Research Scope

Developing an Egyptian rating system to evaluate New construction bridges* (pedestrian bridges, vehicle bridges, railway bridges, etc..) as they require the most site preparation, use a lot of materials, Strongly effect on visual image of the city.
Evaluation will be architectural (Functional and aesthetical) and Sustainability evaluation.



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Research Importance

First: Importance for the Community :

- Designing bridges to fully accommodate current and future functions.
- Saving people lives and making easier life for them either for pedestrians or passengers.
- Creating a pleasing structure to add a visual value to the city skyline.

Second: Importance for Future Studies :

- It is observed during data collection and throughout the whole study, the shortage of Egyptian encyclopedias in bridges aesthetics and sustainability. So This research is considered as a starting point for future development. This study to guarantee an appropriate approach to design an aesthetically and functionally successful bridge within a sustainable framework.

Third : Importance for Bridges Industry :

- The main goal is to achieve the unachievable through creating a beautiful, functional and sustainable bridge with maximum safety requirements and least financial resources in a creative and innovative way.

Forth : Importance for the Environment :

- Commitment to green and sustainable architecture principles is one of the main targets of this study through striking a balance between economy, society and environment. And through conservation of locations, materials, water and energy.

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[*] New construction: Projects in design stage (Not existing or already constructed bridges) from LEED Reference guide: LEED Principles and Green Associate Study Guide , Green Building Education Services, USA, 2014.

Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

Introduction

Introduction
Research Problem Approach
Research Problem
Research Goal
Research Hypotheses
Research Methodology
Research Scope
Research Importance

Part 1 : Theoretical Study

Bridges And Sustainability Overview

Chapter 1: Bridge's Art, Science and Construction Historical Development

Chapter 2: Sustainable Bridges

Part 2: Analytical Study

Developing a Rating System for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages

Chapter 3: Different Types of Bridges and Architecture

Chapter 4: The Relationship between the Bridge and its Context

Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form

Chapter 6: Bridge's Different Parts and their Relation with Bridge's Shape and Form

Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design.

Chapter 8: Design Process of a Sustainable Bridge and Architect's Role

SECTION 2

Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community

Part 3: Inductive Study

Developing an Egyptian Sustainable Bridge Rating System

Chapter 10: Sustainability Assessment Concepts

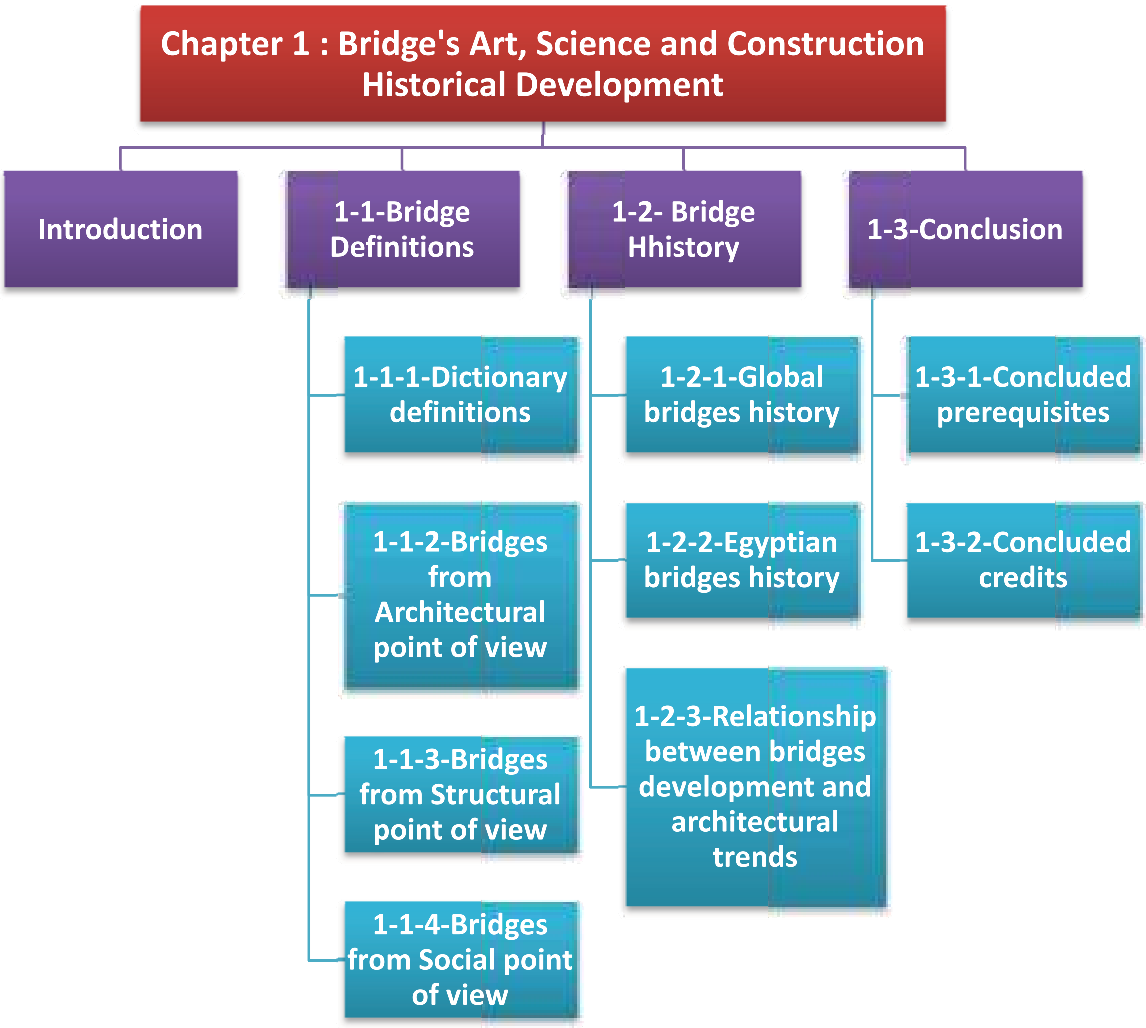
Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Chapter 12 : Conclusion and recommendations

Appendices

Part 1: Bridges and Sustainability Overview

Chapter 1 : Bridge's Art, Science and Construction Historical Development



Chapter 1 structure: Bridge's Art, Science and Construction Historical Development

Chapter 1: Bridge's Art, Science and Construction Historical Development

Introduction

It will never be known who built the first actual bridge structure. Our knowledge of past days fades the further we look back into time. We can but assume that man, in his search for food and shelter from the elements and with his given curiosity, began exploring his natural environment. Crossing creeks and crevices with technical means thus was a matter of survival and progress, and bridges belong to the oldest structures ever built. The earliest bridges will have consisted of the natural materials available, namely wood and stone, and simple handmade ropes.

1-1- Bridge Definitions

There are many definitions for bridges according to different points of views:

1-1-1- Dictionary Definition

According to Encyclopedia Americana, a bridge is a structure providing passage over a waterway, a valley, a road or other obstruction, without closing the way beneath.

In Encyclopedia Britannica, another definition is provided for the word "bridge," as a structure surmounting an obstacle such as a river, road or railway and used as a passageway for pedestrian, motor or rail traffic.[1]

The Oxford English dictionary traces the origin of the word bridge to an old English word brycg.[2]

So, bridge main definition is a structure built to span physical obstacles without closing the way underneath such as a body of water, valley, or road, for the purpose of providing passage over the obstacle. There are many different designs that each serve a particular purpose and apply to different situations. Designs of bridges vary depending on the function of the bridge, the nature of the terrain where the bridge is constructed and anchored, the material used to make it, and the funds available to build it.

1-1-2 Bridges from Architectural Point of View

The main purpose from construction a bridge is how to achieve best function in a creative and aesthetical way within budget ?

Bridge is considered a "special construction " because of many reasons:

- The main function of any constructing is providing shelter, bridges main function is establishing a connection between two sides.
- The dimensions of bridges are larger than dimensions of usual **construction**.
- The big dimensions of bridges, causes the need of the advanced technology for the construction. This special techniques used in the construction can be the reason to be called as "special".
- Another point which makes the bridge a "special constructing" is the visual properties and aesthetic impact of the structure on people and on environment. They are structures standing in the middle of the environment and they have to be harmonious with their social surrounding.

Bridges are elements of architecture, but architecture of a very special kind.

Although they are invented to answer the very basic need of passing a gap, bridges have already reached beyond the limits of this purpose and are now one of the most important

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[1] - Encyclopedia Britannica. -Volume 4- Botha-Carthage. William Benton- Inc- UK- at www.britannica.com.

[2] -http://www.oxforddictionaries.com/

and unique structures in the construction world.[1]

Bridges are praised more for their architectural standing and artistic value than their engineering success. The reason for that is probably the social importance of bridges coming along with its history and impact on people who view them.

Bridges are the most intimate structures to people. Any kind of shelter or road or industrial structure may be serving without making themselves noticeable or they can make them noticeable with the dynamic structure of the space created below that shelter. However, bridges exist with their simpler function and their special form. When people passes a bridge, the feeling created by the structure is readily perceptible to the individual even many of them do not have a close surrounding.

These are the reasons why bridges stand out as special structures among other structures and have a distinctive place in architecture.[2]

1-1-3 Bridges from Structural point of view

The structural system is the first element of any technical discussion on bridges. Buildings and similar structures are based on a fundamental understanding of substructure and the designs are done according to these fundamental facts and codes. With bridges, the situation is somewhat different. On one hand, the idea of bridges carrying the load is very basic, since it is very similar to beams which are among the basic elements of construction. The way the system of any building works should be the same with bridge structure. On the other hand, bridges can be the most challenging structures in nature, having to cross large spans and carry heavy loads.[3]

1-1-4-Bridges from Social Point of View

Bridges, first of all, play a very important part in the landscape of a city or region. They may even define the entire view as the dominating structure in the whole ambience of the area. Throughout the history, bridges stayed as monuments that symbolize their community. In some cases, bridges were not only a symbol but also acted as the founder of an area or a region. Regions that are newly created need to be nourished by those that precede them. This nourishment was sometimes provided by bridges, which would bring civilization to the new and not yet developed areas, transforming them into developing and finally developed areas.

The most famous example for this in history is the Brooklyn Bridge in New York City, connecting Brooklyn to Manhattan Before the bridge, Brooklyn was a place no one wanted to inhabit and living there offered no charm at all. After the construction of Brooklyn Bridge, crowds flocked to the district invigorated by this architectural masterpiece, making Brooklyn one of the popular neighborhoods in New York.[4]

Also in Egypt, there are 23th of July axe which link 6th of October city with Cairo which makes easy transportation to and from 6th of October city. Also there are bridges which considered the city landmark as Stanly bridge at Alexandria which Considered a land mark of Alexandria. Figure (1-1)

1-2- Bridges History

In this part global and Egyptian and the relation between bridges and architectural

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[1] -C. Moore & G. Allen" Dimensions: Space, Shape and Scale in Architecture" Architectural Record Book. New York. USA.1996, p50.

[2] - Aysu Berk "Geometrical analysis of bridge forms and their feasibility in structural design" Master thesis- The graduate school of natural and applied sciences of middle east technical university- 2005- p 7-10.

[3] - Stephan Engelsmann & Stefania Casucci, "The Neglected Aspect of Urban Bridges as Public Spaces" Article- Proceedings of the 16th Congress of IABSE. 18-21 September 2000. Lucerne, Switzerland, at //www.researchgate.net

[4]- Frederick Gottemoeller "Bridgescape: The art of Designing Bridges"John Wiley & Sons Inc- USA-1998, p 11-15.

trends are studied.

1-2-1-Global Bridges History

In table (1-1) An Overview of Bridges Historical Development all over the World at Ancient Structures and Roman Stone Bridges was studied. In table (1-2), the historical development of Roman Viaducts Bridges and The Middle Ages Bridges was studied, in table (1-3) the historical development through the Renaissance, the 18th century and the 19th century was overviewed. Finally, in table (1-4) the 20th century bridges development was studied. These studies shows that many followed concepts during every century and their reflection on bridges design on these ages through some selected examples.

Brooklyn Bridge -New York[1] 26 of July axe - Cairo[2] Stanly bridge - Alexandria[3]

Figure 1-1: Examples of Bridges which have major social impacts.

1-2-2-Egyptian Bridges History

Because of the Nile River existence in Egypt, there was a need to cross it to connect east with west, but because of the Nile River nature and the changes of river banks boundaries there were not any bridges for a long time except Barrages.

Egyptians bridges history will be discussed through some examples from Egyptian bridges sorted by construction year and compare these bridges with most famous global bridge in same year to review our progress and tardiness to global bridges architecture.

These studies are separated to three parts. In the first part the history of Egyptian bridges compared to global bridges from the ancient ages to 1925 is studied as shown in table(1-5). Second comparison between Egyptian and global bridges is from 1925 to 1990 going through the 1952 revolution effects as shown in tables (1-6). The third comparison is from 1990 till now as shown in table (1-7). The conclusion from these comparisons is that, Egyptian bridges were followed global bridges till 1952 revolution. From 1952 revolution till now. The main factor affecting bridge's design is bridge's cost, So most of these bridges are lacked of aesthetical considerations.

1-2-3-Relation Between Bridges Development and Architectural Trends/ Schools.

A study is carried on different bridges examples built in different times to study the relationship between these bridges and the architectural trends and schools at these times as shown in table (1-8). The goal from this part is to study the extent of bridges as an important architectural facility keeping up with global architectural schools. As a conclusion, The architectural trends are reflected on bridges design development in both global and local bridges until the middle of the last century. Since the 1952 revolution (the middle of the last century), most of Egyptian bridges were not adopt any architectural school/ trend. Hence the main goal from most these bridges was creating a safe structure with minimum cost regardless the bridge aesthetical and Functional success.

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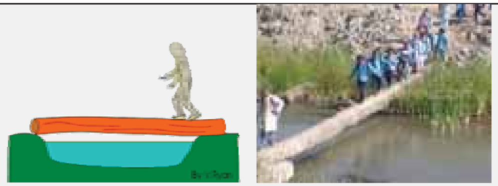
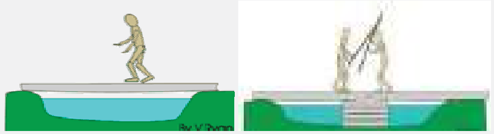
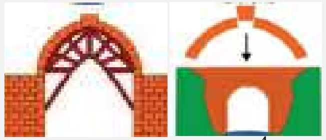
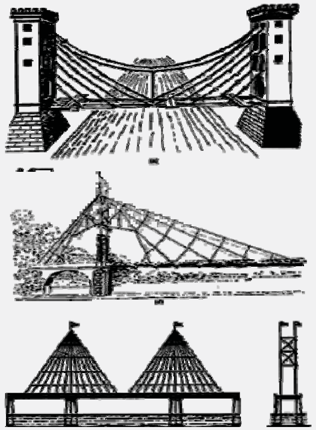
[1] - http://www.rokkorfiles.com/photos/AA-Brooklyn-Bridge.jpg

[2] - http://www.ahram.org.eg/Media/News/2014/2/6/2014-635273225632176645-217.jpg

[3] - http://www.arabcont.com/English/projects/project-126.aspx

Table 1-1: An Overview of Bridges Historical Development all over the World (Ancient Structures and Roman Stone Bridges)

<table>
<tr>
<td rowspan="2">Ancient Structures</td>
<td>Ancient Structural Principles</td>
<td>The simplest form of a bridge, A beam supported at its two ends, may have been the predecessor of any other kind of bridges.
Arches and cantilevers can be constructed of smaller pieces of materials, held together by the compressive force of their own gravity or by ropes.
Even suspension bridges are not new inventions of modern times but have already been in use for hundreds of years. Early examples are mentioned from many different places, such as India, Himalaya, China, and from an expedition to Belgian Congo in the early years of this century.[1]</td>
<td>
Wooden beam bridge

Tied wood to ropes

stone bridge</td>
<td>
Tarr Steps: An Ancient ‘Clapper Bridge’ in Somerset United kingdom[2]

Old arch bridges.[4]</td>
<td>
Historical suspension bridges (from top Chain bridge, Nienburg bridge and Gischlard Arnodin bridge) [3]</td>
</tr>
<tr>
<td>Earliest Beginni</td>
<td colspan="4">Earliest cultures to use bridges according to our current knowledge were the Sumerians in Mesopotamia and the Egyptians, who used corbelled stone arches for the vaults of tombs. A floating pontoon bridge was used by Persian King Xerxes to cross the Hellespont with his large army in the year 480 BC. Herodotus described the bridge in detail (bridge consisted of seven girders a girder was about 660 feet from Abydos to the land opposite).[5]</td>
</tr>
<tr>
<td>Roman era</td>
<td>Stone Bridges</td>
<td colspan="2">Stone masonry arch structures are examples of the outstanding skills of the ancient Romans. The Roman stone arches where built on wooden false work or centering which could be reused for the next arch once one had been completed.[6] The arches used were voussoir arches, which are put together of tapered stones with a keystone that closes the arch.</td>
<td></td>
<td>Arkadiko Bridge in Greece(13th century BC), one of the oldest arch bridges in the world.</td>
</tr>
</table>

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[1] - Brown, D. J : " Bridges"- Macmillan Publishing Company- New York- USA-1993 .p 15,28,29.

[2] - http://www.amusingplanet.com/2016/01/tarr-steps-ancient-clapper-bridge-in.html

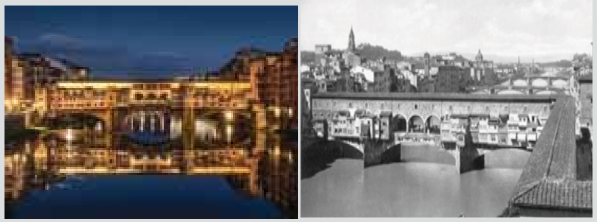
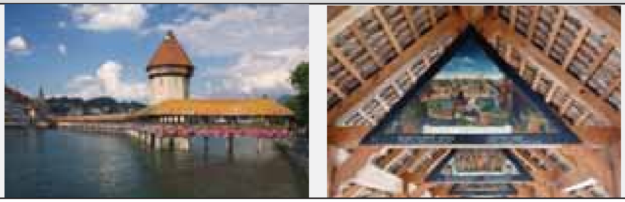
[3] Roger L. Brockenbrough & Frederick S. Merritt: "Structural Steel Designer's Handbook"- Section 15 Arch bridges- AISC, AASHTO, AISI, ASTM, AREMA, and ASCE-07 Design Standards- Fourth Edition- Mcgraw-Hill publications- USA- 2000, P 15.1

[4] - http://arab-training.net/vb/t7597.html

[5] - Davide Grene: "Herodotus: The History"- The University of Chicago Press- Chicago- USA- 1987. p482.

[6] - Colin O'Connor: "Roman Bridges"- Cambridge University Press- Cambridge - Great Britain- UK- 199- p27..

Table 1-2: An Overview of Bridges Historical Development all over the World (Roman Viaducts Bridges and The Middle Ages Bridges)

Roman Bridges	**Aqueducts and viaducts**	The Roman infrastructure system was very well developed. It served both military and civil uses by providing an extensive network of roads. Aqueducts and viaducts of the Roman era can still be found scattered over the former Roman Empire, primarily in Italy, France, and Spain. Some Roman bridges or their remainders are also located in England, Africa and Asia. Probably the best-known Roman aqueduct is the Pont du Gard near Nîmes in Southern France, Built by Marcus Vipsanius Agrippa (64 - 12 BC). this structure was part of an aqueduct carrying water over more than 40 km.[1]	 The Pont du Gard Nîmes bridge, France[2] (lift)/ Le Puente de Alcántara bridge- Spain[3] (right)
The Middle Ages	**Middle-East and**	The term Middle Ages refers to the period of time between the fifth and the late fifteenth century; other authors may set somewhat different limits. The eleventh to the sixteenth century[4] Persian rulers built pointed brick arches, and the coming blossom of bridge building reached as far as China. The Chinese skillfully built elegant segmental stone arches with roadways that followed the swinging shape of the arch, and they also built cantilevers of timber on stone piers.[5]	
	European bridge	The Ponte Vecchio crosses the River Arno with three shallow arch spans, of which the middle span reaches 30 m length. The Pont Valentré at Cahors in France, is about 150 years younger than the Pont d'Avignon. It resembles its older brother with its pointed slender arches and the triangular cutwaters, but has been preserved completely. Six regular arches of 16.5 m span length and three watchtowers at its ends and in its middle.[6]	 The Pont Valentré, Cahors, France  The Ponte Vecchio, Florence, Italy
	Notable bridges	Several other medieval bridges are worth being mentioned in this overview of medieval bridge building. The Kapellbrücke in Switzerland 1333 and has its name from a nearby chapel of St. Peter.	 The Kapellbrücke bridge in Switzerland

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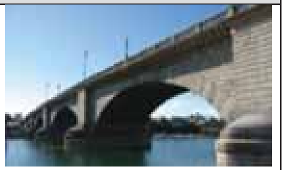
1 - Liebenberg, A. C: "Concrete Bridges: Design and Construction"- Longman Scientific and Technical- Longman Group - Great Britain -UK-1992- p58.
2 - http://www.sablethome.com/wp-content/uploads/2012/04/Aqueduct_PontDuGard_Nimes.jpg
3 - https://www.fundacioniberdrolaespana.org/webfund/corporativa/iberdrola?idpag=esfunareartiluotripa
4 - Troitsky, M. S: "Planning and Design of Bridges"- John Wiley and Sons- New York- USA-1994. p66.
5 - Gies, J. - "Bridges and Men. With drawings by Jane Orth Ware"-Doubleday and Company- Garden City- NY-USA-1963. p90.
6 - Leonhardt F. : " Brücken: Ästhetik und Gestaltung". (In German and English, translated title: Bridges: Aesthetics and Design.) The MIT Press- Cambridge- UK-1984. p89.

Table 1-3: An Overview of Bridges Historical Development all over the World (The Renaissance, The 18th century and the 19th century)

The Renaissance	**French Renaissance Bridges**	The renaissance is the truly start of bridges. During the Renaissance, the truss system was developed further for use in bridge construction. Known since Roman times, the truss now was finally seen as a means of superstructure in itself. France became an important location of bridge building in the Renaissance. The Pont de Neuilly incorporated a relatively new shape of tapered arch bridge called corne de vache created a shadow that underlined the arches and made their front view appear even shallower.	 The Rialto Bridge, Venice, Italy  The Point Neuf and The Pont de la Concorde,France  Pont de Neuilly bridge, France The Rialto Bridge in Venice, Italy, over the Canal Grande, built 1587 - 1591 when a previous bridge over the Grand Canal was to be replaced because of obsolescence.
The Industrial Revolution 18th Century		The country in which the Industrial Revolution took its beginning was England. The development of spinning and weaving machines and the development of the steam engine and later of the steam locomotive all fall into this time. England had rich resources in coal and iron ore that supported the progress of industrialization. With growing industrial production, railway tracks were spreading across the country and required building many new bridges to cross natural obstacles.	 The Ironbridge, , Great Britain[1]  The Craigellachie Bridge, Great Britain[2]  New London Bridge, London, England[3]  The Menai Strait Bridge, Great Britain[4]
The 19th Century		This century is considered the starting of bridges development, As many iron, pre-stressed concrete and developed structures were used. Also Movable bridges were invented in the 19th century.	 The St. Louis bridge, St. Louis, U.S.A  Brooklyn bridge, New York  Forth bridge, Scotland[5]  Blue bridge, Amsterdam

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[1] - http://whc.unesco.org/?cid=31 andl=en andid_site=371 andgallery=1 and andindex=13 andmaxrows=12

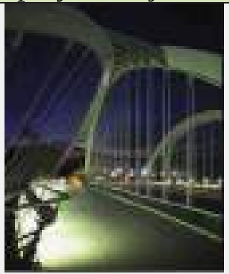
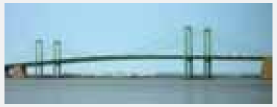
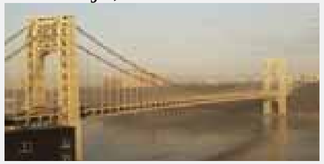
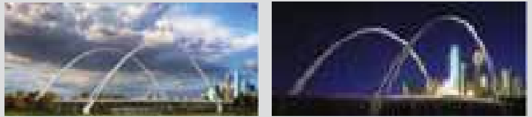
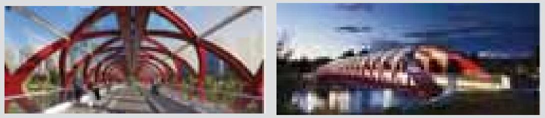
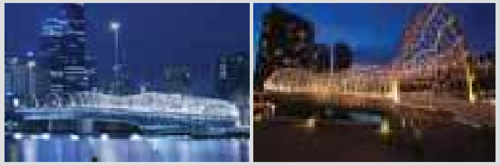
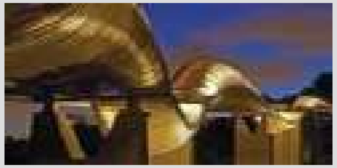
[2] - http://c8.alamy.com/comp/ACBENY/craigellachie-bridge-grampian-region-telford-architect-river-spey-ACBENY.jpg

[3] - https://upload.wikimedia.org/wikipedia/commons/f/f8/London_Bridge,_Lake_Havasu_City,_Arizona_(3227888290).jpg

[4] - http://menaibridges.co.uk/new/wp-content/uploads/slideshow-gallery/front5.jpg

[5] - https://architessica.wordpress.com/2011/03/24/nineteenth-century-suspension-bridges/

Table 1-4: An Overview of Bridges Historical Development all over the World (20^{th} Century Bridges and Future Bridges).

	Architects played major rule in 20th century bridges, as Norman foster, Zaha Hadid and Santiago Caltrava
20^{th} Century bridges	 Trinity Footbridge - 1995- Manchester  Bac de Roda- Felip II bridge 1987 Barcelona  Lusitania bridge- 1995 Merida  Puente del Alamillo viadukt La Cartuja, Sevilla - 1992  campo volantin footbridge - 1997 Santiago caltrava- Bilbao  Delaware Memorial Bridge- USA- 1951  Zaha Hadid bridge- Abu Dhabi [1]  George Washington Bridge-USA- 1931  Puetro bridge- 1995-Ondarroa  Golden Gate Bridge - USA- 1937[2](left) Pont de l'Europe - Santiago Caltrava 1996 Orleans (right)   Manrique footbridge- 1999 - Murcia (left) The Chesapeake Bay Bridge -USA- 1952 (right) 
Future Bridges	Bridges future attributes are Improvements in Design, Construction, Maintenance, and Rehabilitation. Smart bridges are bridges that incorporate control systems to measure environmental conditions, high-Performance materials Strength and other mechanical Properties (workability, durability and composites) and innovative Structural Concepts are used. [3]  Margaret Mcdermott bridges 2011- Dallas(Left) and Peace Bridge Calgary, 2012 - France (Right)   Randstad rail station Bridge - 2006- Netherlands[4]  Webb bridge Australia[5]  Henderson Waves Bridge, Singapore

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[1] - http://www.calatrava.com/projects.html?all=yes

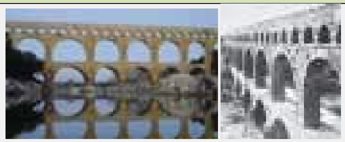
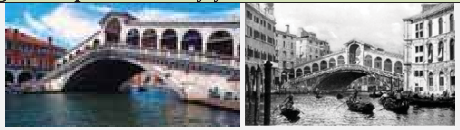
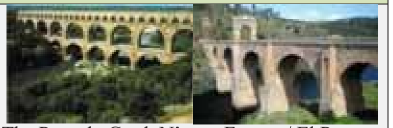
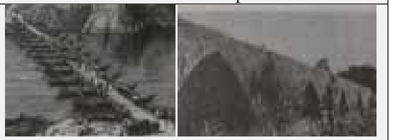
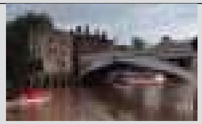
[2] - Peter Bishop : "Bridge" - Reaktion Books- UK- 2008.p9.

[3] - Gunnar Lucko: "Means and Methods Analysis of a Cast-In-Place Balanced Cantilever Segmental Bridge"- Master of Science-Civil Engineering-Virginia Polytechnic Institute and State University-USA-1999.p75-94.

[4] - Van Chris Uffelen: "Masterpieces: Bridge Architecture and Design" 1st edition - Book- Braun Publish- 2009. ,p 209- 211.

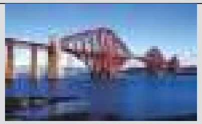
[5] - http://www.dentoncorkermarshall.com/projects/webb-bridge/

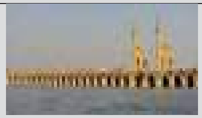
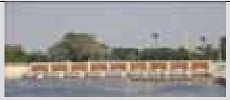
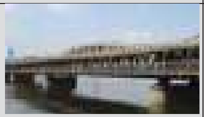
Table 1-5: History of Egyptian Bridges Compared to Global Bridges (from the Ancient Ages to 1925).

<table>
<tr><th></th><th>Summary of Egyptian bridges</th><th></th><th colspan="6">bridge examples sorted by year of construction</th></tr>
<tr><td rowspan="2">Ancient times</td><td rowspan="2">before 1800 AC.
because of the continuous changes of the Nile River in Egypt, there were not historical bridges except temporary bridges made of wooden boats which covered with wooden panels used by the army to cross form El-Fostat city to El-Roda island and to Giza city.
These bridges were built and demolished several times, Also there were many barrages which were constructed on the Egyptian bays.
As a conclusion before 19th century there were not bridges architecture in Egypt. except these shown examples.</td><td>Global bridges</td><td colspan="2">
Pont du Gard, (French: "bridge of the Gard- 19 bC)</td><td colspan="2">
Rialto bridge, Ponte di Rialto, Venice, 1588 to 1591.</td><td colspan="2">
The Pont du Gard, Nîmes, France / El Puente de Alcántara- Spain</td></tr>
<tr><td>Egyptian bridges</td><td colspan="2">As an example on boats bridge, There was boats bridge built by Roman to connect El-Roda island with Cairo and another to Giza (in place of Abbas bridge).
This bridge was consisted of thirty boats and on the other side was another bridge consisted of sixty boats to connect El-Roda with Giza. These bridges as mentioned by Elwardy were consisted of tied boats with wooden planks covered by dust, these bridges were destroyed and reconstructed several times.</td><td colspan="2">Roman Ages: boats bridge first construction, Crossed by Amro ben Elaas Through Islamic conquest.
825-832: bridge reconstruction
975: Was reconstructed by Elmoez
1240: Was reconstructed by Elmalek Elsaleh
1265: Was reconstructed by biebers
1798: Was reconstructed by French army.
1819: Was reconstructed by Ibrahim pasha.
Abbas bridge History</td><td colspan="2">
Elroda boats bridge- Egyptian pay barrage</td></tr>
<tr><td rowspan="3">From 1800 to 1900</td><td rowspan="2">From 1800 to 1900 AC
The 19th century in Egypt was the modern renaissance by Mohamed Ali. It was a movement in Egyptian architecture specially in the architecture of bridges. Mohamed Ali hired many architects and designers to construct bridges which simulate the global bridges, Also Mohamed Ali's sons took the same path specially the khedive Ismail who changed the Nile River path several times and built several bridges and barrages.</td><td>Global bridges</td><td>1861

Lendal bridge-England</td><td>1863

burton bridge- England</td><td>1872

battersea bridge- England</td><td>1889

Capilano bridge, North Vancouver, England</td><td>1890

Forth bridge-Scotland</td><td>1897

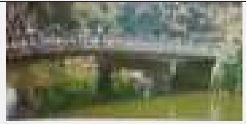
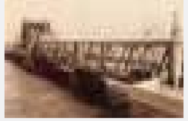
Sutliff bridge-USA</td></tr>
<tr><td>Egyptian bridges</td><td>
Charity barrages bridge</td><td>
Fam-Elryah barrages bridge</td><td>
Kasr-Elnile bridge</td><td>
Fam Elryeah Eltawfeeky new barrages bridge</td><td>
Embaba bridge</td><td>
Naga Hamady Old bridge</td></tr>
<tr><td colspan="8">So the conclusion from this time, Egyptian bridges architecture followed the global bridges architecture also these bridges construction systems and methods were as same as universal bridges at this time.</td></tr>
<tr><td rowspan="2">From 1900 to 1925</td><td rowspan="2">From 1900 to 1925 (Revolution):
The first part of 20th century: Although the duration between the beginning of 20th century and the first world war was not big, but many changes took in place in Egypt, As the spread of railway bridges over the Nile River, and connecting the two river banks by bridges.</td><td>Global bridges</td><td>1903

Sydney Pyrmont bridge</td><td>1906

Vauxhall bridge-London, England</td><td>1908

Quebec bridge-Canada</td><td>
Manhattan bridge-New York City</td><td>1912

Seven Mile bridge-USA</td><td>1914

Ponte Pensil-São Vicente-brazil</td></tr>
<tr><td>Egyptian bridges</td><td>
Assiout barrages bridge</td><td>
Zefta bridge</td><td>
Abbas old bridge</td><td>
Mohamed Ali barrage bridge</td><td>
boulak Abo Elelaa bridge</td><td>
New Elgalaa bridge</td></tr>
<tr><td>Reference</td><td colspan="8">http://www.britannica.com/topic/Pont-du-Gard
http://europeforvisitors.com/venice/articles/rialto_bridge.htm
http://www.sablethome.com/wp-content/uploads/2012/04/Aqueduct_PontDuGard_Nimes.jpg
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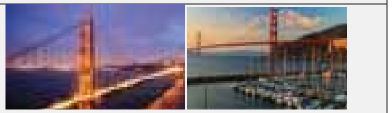
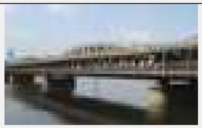
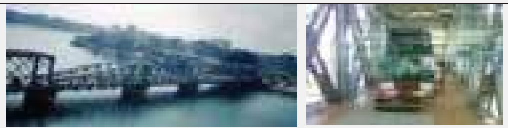
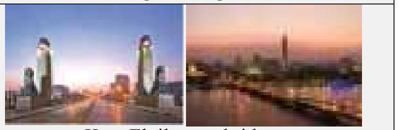
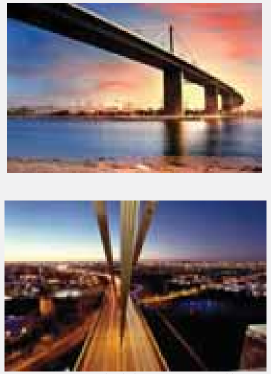
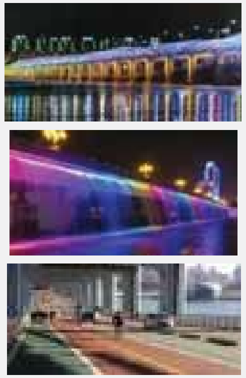
https://images0.masress.com/youm7/102081
http://www.boweryboyshistory.com/2009/08/picture-perfect-irving-underhill-and.html</td></tr>
</table>

Table 1-6: History of Egyptian Bridges Compared to Global Bridges (from the 1925 ,The 1952 Revolution and from 1952 to 1990).

			1925	1929		1931	1933
From 1925 to 1952	These bridges architecture followed the universal bridges architecture.	**Global bridge**	 The brooklyn bridge	 USA- Colorado-Royal bridge	 Isabella bridge at Spain	 California-ceader creek bridge	 Golden gate bridge- USA
		Egyptian bridges	 Embaba new bridge	 Dumitta new bridge before and after renovation		 Edfina bridge	 Kasr Elnile new bridge

			1958	1970	1976	1980	1987	1990
From 1952 revolution till now	The 1952 revolution After the 1952 revolution, many bridges were built to solve traffic problems, but the bridges architecture Deterioration started from this period, As most of these bridges main goal was constructing the cheapest and safest bridge to achieve main function (mostly to facilitate traffic) regardless of its shape, form and aesthetics, Also most of these bridges designs did not consider the future expansions. So, most of these bridges are unattractive bridges which did not follow universal bridges architecture and did not achieve there functions.	**Global bridges**	 Canada- Ironworkers memorial bridge-Vancouver	 Westgate bridge- Australia	 Jamsu bridge- Korea	 Sunshine Skyway bridge-Florida	 Alamillo bridge-Spain by Santiago Calatrava	 Olympic bridge Korea
		Egyptian bridges	 El gamaa bridge	 Giza bridge (Abbas bridge)	 6th of October bridge	 Ahmed orabi bridge	 Azhar bridge	 15th May bridge

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http://www.ahram.org.eg/Media/News/2015/10/29/2015-635817525619852029-985.jpg
http://gereports.com.au/post/26-09-2013/how-pyrmont-bridge-spun-into-history
http://i.vimeocdn.com/video/110117347_1280x720.jpg
http://static.panoramio.com/photos/large/34812175.jpg
http://idr200.com/wp-content/uploads/2015/01/Royal_Gorge_bridge_2010.jpg
http://www.alamy.com/stock-photo/isabella-bridge.html
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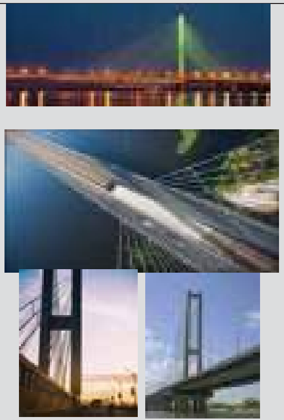
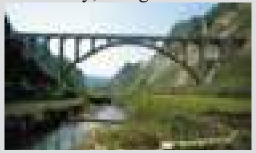
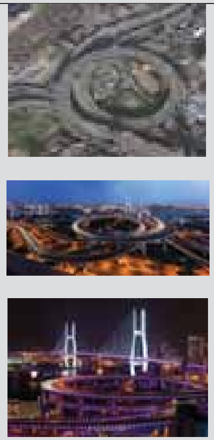
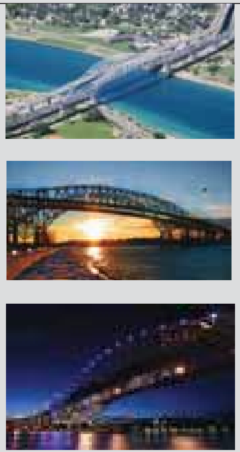
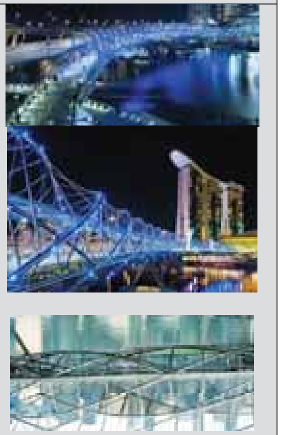
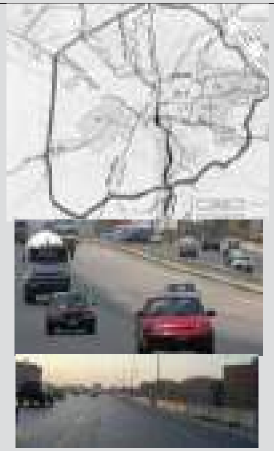
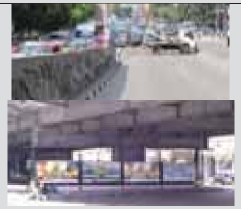
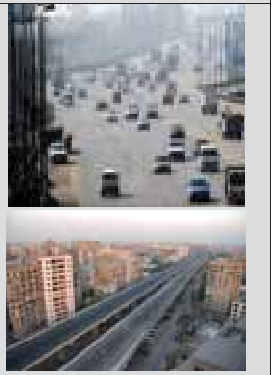
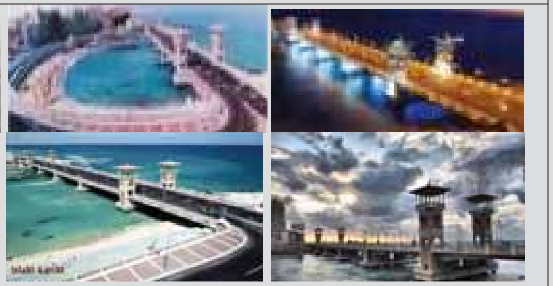
Table 1-7: History of Egyptian Bridges Compared to Global Bridges (from 1990 till Now).

<table>
<tr><th></th><th colspan="2">1990</th><th>1991</th><th>1999</th><th>1997</th><th>2001</th><th>2010</th></tr>
<tr><td>Global bridges</td><td>The Pivdennyi (Southern) bridge-Ukraine</td><td>Alsea bay bridge Lincoln County, Oregon- USA
Niaochao River bridge- China</td><td>Nanpu bridge- Shanghai</td><td>The blue Water bridge- U.S.A-</td><td>Third Kurushima Kaikyo bridge- Japan</td><td>Pedestrian bogdan Khmelnitsky bridge-Moscow
Python bridge, Amsterdam</td><td>The (Double) Helix bridge– Singapore</td></tr>
<tr><th></th><th colspan="2">1990</th><th>1991</th><th>1999</th><th colspan="2">1997</th><th>2010</th></tr>
<tr><td rowspan="3">Egyptian bridges</td><td rowspan="3">The ring road design started</td><td rowspan="3">Dokki bridge
Fangari bridge</td><td>Rod Elfarag bridge</td><td>Luxor bridge</td><td colspan="2" rowspan="3">Zagazig bridge</td><td rowspan="3">The ring road- marriotia corridor</td></tr>
<tr><td colspan="2">2001</td></tr>
<tr><td>Elsalam bridge</td><td>Stanly bridge</td></tr>
</table>

http://www.ouregypt.us/socity.news/emages/bridge.jpg
http://farm5.static.flickr.com/4142/4924611323_8778d4e304.jpg
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http://www.thousandwonders.net/Nanpu+bridge+Interchange
https://upload.wikimedia.org/wikipedia/commons/0/0f/bluewater_bridge.JPG
http://bestbridge.net/Asia_ekurushima-kaikyo-bridge.phtml
https://www.pinterest.com/waltergreed/7-bridges/
http://www.west8.nl/projects/bridges_borneo_sporenburg/ http://www.vetogate.com/upload/photo/gallery/100/5/560x1000/400.jpg
http://www.e-architect.co.uk/images/jpgs/singapore/helix_bridge_w100810_cfj1.jpg
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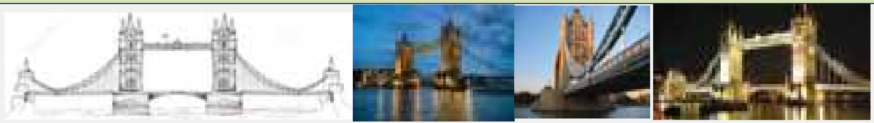
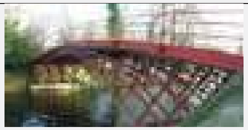
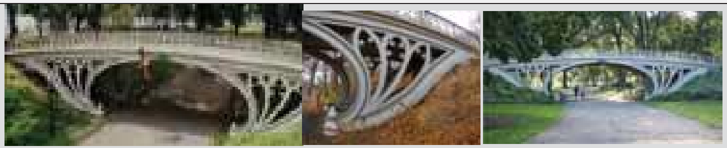
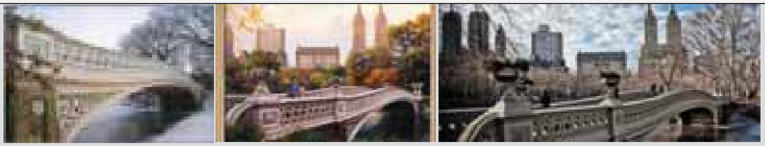
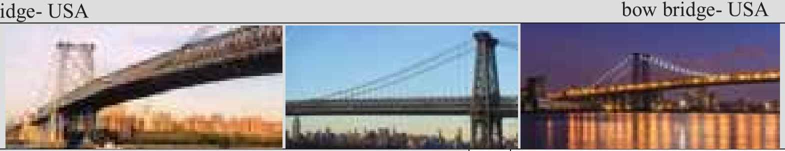
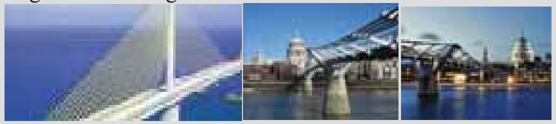
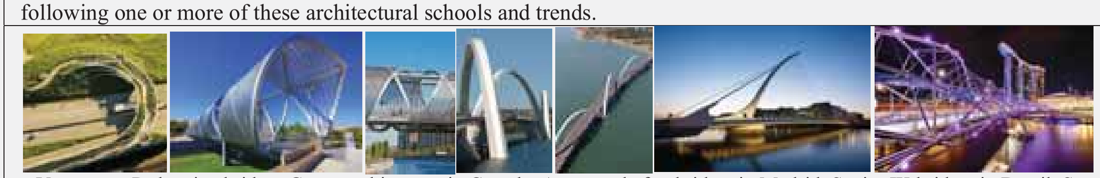
محمد السيد محمود الابراشي- دراسة تطور عمارة الكباري المصرية و مدي تاثرها بالاتجاهات المعمارية العالمية, رسالة ماجستير, قسم عمارة, كلية الهندسة, جامعة القاهرة - ٢٠١٠- ص١٥٠

Table 1-8: The Reflectivity of Architectural Trends and Schools on Bridges Design and Architecture.

	Architectural Trends and schools	Examples
Romantic classic	- More details, ornaments and sculptures were used at these ages to cover the main steel body of the bridge. Towers were used as bridges entrances.	 Tower bridge- London 1984  Le pont mirabeau bridge- France
The call for simplicity	- The main concept was to get rid of all non structure details and only show the bridges structure system. Here are some examples of Early iron bridges- (Call for simplicity)	 Hohe brücke, gardens of Charlottenburg palace, berlin, Germany-1802  Craigellachie bridge, near Aberlour, Moray, Scotland, UK- 1814  Aldford Iron bridge over river Dee, Cheshire, England, UK- 1824  Holt Fleet bridge, Holt, Worcestershire, England, UK- 1828  Mythe bridge, Tewkesbury, Gloucestershire, England, UK- 1826  The first Iron bridge over the River Severn,, England, UK - 1779
The art Nouveau	- In this architecture trend, natural and curve lines, more details were used to highlight bridge design.	 Reservoir Central-Park-Gothic-bridge- USA  bow bridge- USA
German. Workers	**Association of German workers movement** This movement did not come with a new but came to confirm the direction of abstraction bridges of decoration.	 Williamsburg bridge- New York-1903
Modernism	The modernism goal was to highlight bridges original shape where simplicity, function and structural balance. bridges plans and elevations were straight, have no decoration and constructed with new materials	 Golden gate bridge- USA, The present Oakland bay bridge- san Francisco- and George Washington bridge - USA (From left to right)
Late modernism	bridges were greatly affected by late modernism, as the late modernism architecture main concept was volumetric and technology dazzling, which resulted in many of magnificence bridges.	 New sunshine skyway bridge in USA and Millennium bridge in London (From left to right)
Post modernism	bridges piers and plans were more liberated and more symbolic at post modernism, So new designs and new structure systems were created.	 Alamillo bridge in Spain, Gateshead Millennium bridge in UK and Chunhua footbridge in Shenzhen, China (From left to right)
	Most deconstruction bridges were pedestrian bridges because it had minimum loads than vehicles bridges. Many of these bridges were just sketches and concepts. this enabled many architects to create free shapes and forms	 Sheikh Zayed bridge by Zaha hadid in Emirates, BP bridge in Millennium Park of Chicago by Frank gehry in USA and Zaragoza bridge Pavilion by Zaha Hadid in Spain. (From left to right)
Future bridges	Green, Sustainable, smart, Fractal and Minimalism architecture, etc.. all these shaped under future architecture which have great impact on bridges design. A lot of pedestrian bridges these days which have a main purpose to be a landmark are following one or more of these architectural schools and trends.	 Vancouver Pedestrian bridge- Green architecture in Canada, Arganzuela footbridge, in Madrid, Spain, JK bridge, in Brazil, Samuel beckett bridge in Dublin, and The Double Helix bridge in Singapore (From left to right)

http://images.fineartamerica.com/images-medium-large-5/tower-bridge-of-london-franko-brkac.jpg
http://www.bikertony.org/ThumbsCountry/ThumbsbritainAll.htm
http://www.panoramio.com/photo/74015843
https://www.pinterest.com/pin/266697609155471151/
http://www.arch2o.com/zaragoza-bridge-pavillon-zaha-hadid/
http://www.dezeen.com/2013/04/07/sheikh-zayed-bridge-by-zaha-hadid-photographed-by-huftoncrow/
http://www.archdaily.com/357798/sheikh-zayed-bridge-zaha-hadid-architects-2
http://onthesetofnewyork.com/enchanted.html
http://nyc-architecture.com/CP/cp014.htm
http://www.nyc.gov/html/dot/html/infrastructure/williamsburg-bridge.shtml
http://www.52perfectdays.com/wp-content/uploads/2015/08/george-washington-bridge.jpg
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https://www.flickr.com/photos/newportcollier/galleries/72157629790001718/
http://www.billionairesnewswire.com/ar/incredible-unique-bridges-across-globe/

1-3-Conclusion

At this chapter, A summary of bridge's art, science and construction historical development was discussed through three main points, the first point was discussing the bridge definitions from different points of views, the second point was studying bridges history all over the world and bridges history in Egypt to see the difference between bridges architectural development locally and globally.

The third point was studying the relationship between bridge's architecture and architectural schools and trends.

As hown at previous historical study, main points were concluded:

- Bridge's architecture development is considered a reflection of different factors development (materials, technology, needs, etc..).
- Bridge's shape and form is mainly affected by structure system and construction material.
- In Egypt, Bridge social and cultural connection to the surroundings is decreased over time.

1-3-1- Concluded Prerequisites

AP: Bridge Site Background and Analysis
AP: Synchronizing with Surroundings.

1-3-2- Concluded Credits

CR: Bridge Architectural Development.
CR: Following an Architectural School.

Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

Introduction

- Introduction
- Research Problem Approach
- Research Problem
- Research Goal
- Research Hypotheses
- Research Methodology
- Research Scope
- Research Importance

Part 1 : Theoretical Study

Bridges And Sustainability Overview

- Chapter 1: Bridge's Art, Science and Construction Historical Development
- **Chapter 2: Sustainable Bridges**

Part 2: Analytical Study

Developing a Rating System for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages

- Chapter 3: Different Types of Bridges and Architecture
- Chapter 4: The Relationship between the Bridge and its Context
- Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form
- Chapter 6: Bridge's Different Parts and their Relation with Bridge's Shape and Form
- Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design.
- Chapter 8: Design Process of a Sustainable Bridge and Architect's Role

SECTION 2

Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

- Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community

Part 3: Inductive Study

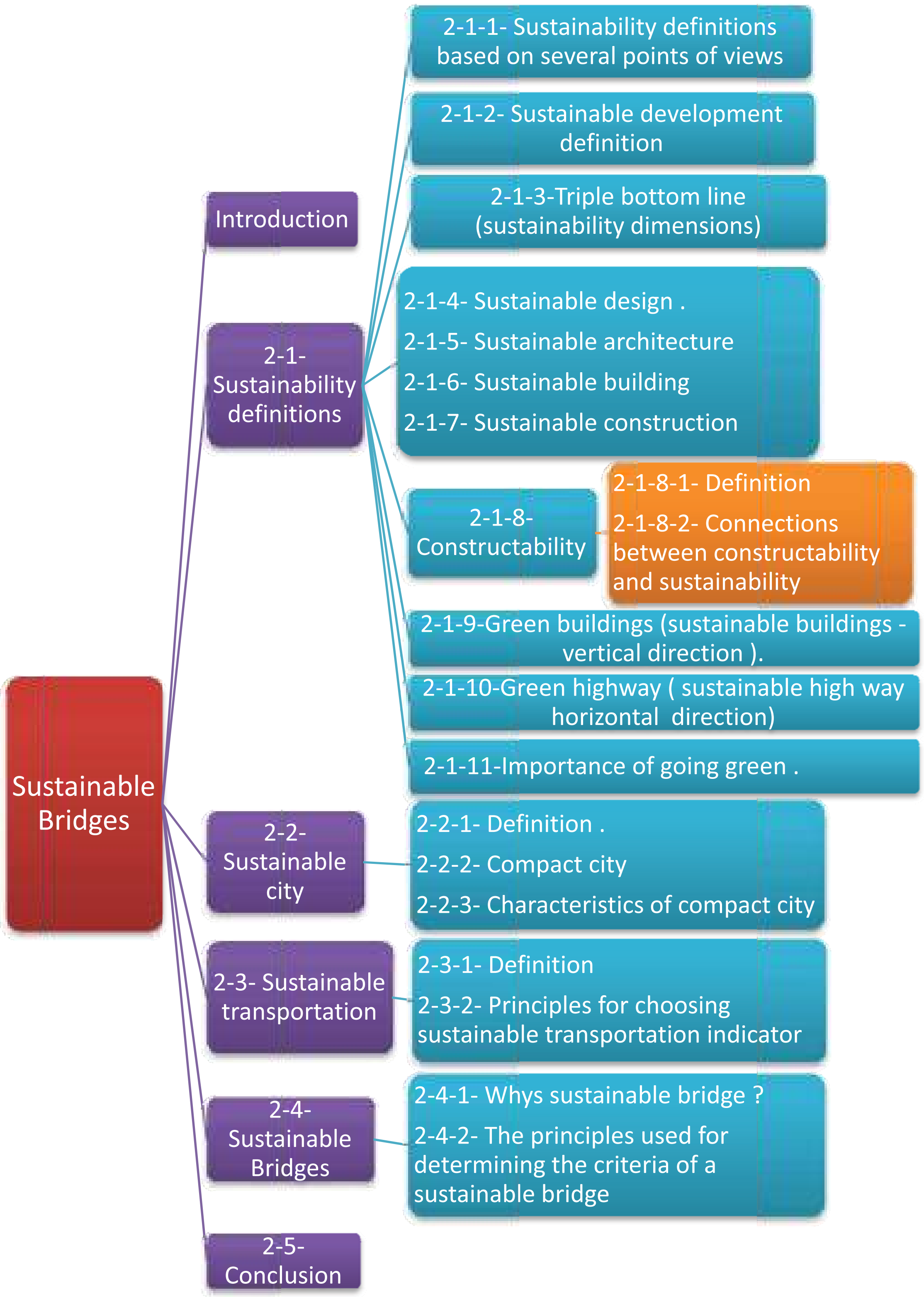
Developing an Egyptian Sustainable Bridge Rating System

- Chapter 10: Sustainability Assessment Concepts
- Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Chapter 12 : Conclusion and recommendations

Appendices

Chapter 2 : Sustainable Bridges



Chapter 2 structure: Sustainable Bridges

Chapter 2: Sustainable Bridges

Introduction

"Go Green!" This statement is one that has been heard in almost every aspect in our lives within the past few years. It relates to sustainable lifestyles and to a mindset that must be adopted by everyone for true success. As the world continues to develop its definition of sustainability, each engineering discipline has tried to focus its efforts to improve the quality of life while maintaining and improving, if possible, the environment and other areas of social interest. Bridges field is not exempt from "going green." bridges designers and engineers are responsible for bettering the lives of the public through infrastructure. They are responsible for accomplishing this in an efficient and cost-effective way, and now it must also be done in a sustainable or "green "manner.

2-1- Sustainability Definitions

In an effort to clarify exactly what sustainability means, a number of formal definitions and descriptions have been put forward. But sustainability is a multifaceted concern, so it may well be more productive to look for a defining framework with several dimensions, rather than for a single-point definition.

2-1-1-Sustainability Definitions Based on Several Points of Views

- **Dictionary Definition**

Sustainable: (adjective) Environment maintaining an ecological balance: exploiting natural resources without destroying the ecological balance of a particular area.[1]

- **Other definitions based on different points of views**

As shown in table (2-1) other sustainability definitions based on different points of views are discussed. So As a conclusion from these definitions, sustainability could be defined as The systems approach to design and construction for facilities, systems, and equipment that insures consideration of the optimization of ecological and human issues in light of well-grounded acceptable economic constraints.

Table 2-1: Sustainability definitions based on different points of view

HOK Definition[2]	**A balance that accommodates human needs without diminishing the health and productivity of natural systems.**
AIA (American institute of Architects) Definition[3]	The ability of society to continue functioning into the future without being forced into decline through exhaustion or overloading of the key resource on which that system depends
Brundtland Commission definition[4]	Sustainability is briefly defined by Brundtland Commission as "meeting the needs of the present without compromising the needs of the future" [5]

2-1-2- Sustainable Development Definition

The most accepted worldwide definition of sustainable development is: Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations.[1]

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1 - http://www.oxforddictionaries.com/

2 - A Global Design, Architecture, Engineering and Planning Firm office website (http://www.hok.com/)

3 - http://www.aia.org/

4 - Formally known as the World Commission on Environment and Development (WCED)

5 -Jason F. McLennan: "The Philosophy of Sustainable Design" (First Edition)- Ecotone Publishing- USA- 2004-p69.

We can Also define It as a sum of many resources that seek to meet the human needs, while at the same time preserving the environment. In order, to let these needs for the future generations not only the present generation. [2]

2-1-3- Triple Bottom line (Sustainability Dimensions)

There are three aspects make up the triple bottom line, these aspects are:

Environment- Sustainable environmental practices. Organizations should endeavor to benefit the planet as much as possible and consider negative externalities to the environment

Social Responsibility- Improving the lives of those with whom the building interacts. The well- being of a building's workers, occupants, community members, neighbors, and other stakeholder interests should be interdependent.[3]

Economics- Economic bottom line of a company that produces a long-term, positive economic impact. As shown in table (2 -2) Dimensions of the Three key aspects of sustainability are studied.

Table 2-2: Dimensions of the Three key aspects of sustainability

Environmental Aspect	Social Aspect	Economic Aspect
The environmental dimension concentrates on the following: 1. Decreasing the influence on human health 2. Utilizing renewable raw materials 3. Abstract toxic substances 4. Decreasing waste, streaming generations, and release to the environment	Social dimension is concerned about the peoples need and please their satisfaction. Sustainability plays a role in supplying good education, upgrading the community consultations and enhance the interest of the different fields. The social dimension concentrates on the following: 1. National and international laws 2. Labors safety and health 3. Transportation and urban planning 4. Local and individual lifestyles 5. The link between human development and human rights 6. Environmental justice and company powers 7. Citizens job and global poverty 8. Effect on local communities and the life quality 9. Advantages of handicapped and low earners	The economical dimension is concerned about the economic growth. Elaborating within the space of the nature environment. The economic dimension concentrates on the following: 1. Integrating ecological interests with economic and social ones 2. Improving the life quality 3. Supplying opportunities for local businesses 4. Maximizing market shaft, to improve the public image 5. Creating new opportunities and markets for sale growth 6. Minimizing cost through progressing efficiency and minimizing energy and raw material chip 7. Make additional added value

2-1-4- Sustainable Design.

Is a design philosophy that aims to maximize the quality of the built environment, eliminating or reducing the negative impact to the natural environment. It does not

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1- Robert W. Kates, Thomas M. Parris, and Anthony A. Leiserowitz: "what is sustainable development? goals, indicators, values, and practice"- Article- Issue of Environment: Science and Policy for Sustainable Development- Volume 47-2005,p8–21.

2 - Osama Mohamed Elsaid Omar: "Advanced Daylight Technologies For Sustainable Architectural Design" - master Thesis- Department Of Architecture- Faculty of Engineering- Alexandria university- 2008-p 8,9.

3 - LEED Principles and Green Associate Study Guide- Green Building Education Services -USA- 2014- p 30-31.

include only environmental considerations, but how it integrates with maintenance, schedule, operations cost and workers considerations. Sustainable Design encourages the use of renewable resources and promotes the use of efficient resources over the life of a project. [1]

2-1-5- Sustainable Architecture

Sustainable Architecture is an architecture replying and interacting with environmental and local conditions and it is trying to apply contexts ecological abilities to create desirable environmental conditions. [2] Consequently, it is ecological equilibrium means it has minimum damages on ecology in addition to its flexibility, adaptability and continuity to changes and needs. Also, the basic definition of sustainable architecture extends that of sustainability itself, an architecture that meets the needs of the present without compromising the ability of future generations to meet their own needs. Those needs differ from society to society and region to region and are best defined by the people involved. [3]

2-1-6- Sustainable Building

Sustainable building as a part of a sustainable development, which aims to deliver built property that heightens quality of life and offers customer satisfaction, flexibility and the potential to provide user changes in the future and support desirable social and natural environments and maximizes the efficient use of resources.

Sustainable building is a substitution approach to construction, based on ecological principles and efficient resources.

A sustainable building is a building with the lowest inadaptability with artificial and natural environment and it is including the building itself, surrounding environment, regional and global environment In general and comprehensive definition.[4]

2-1-7- Sustainable Construction

Construction organizations have an important role in delivering a sustainable building project. Many opportunities exist during construction to improve sustainable objectives and maximize project performance. Opportunities can be found in eliminating construction waste, decreasing site disturbance, buying of materials, health and safety of workers and improvement of indoor air quality. by integrating experts in that discipline and key stakeholders from the early stage of a project, even if the design process are difficult. [5]

Sustainable Construction is Defined as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles".

The OECD (The Organization for Economic Cooperation and Development Project) has identified five objectives for sustainable buildings:

1. Resource Efficiency.
2. Energy Efficiency (including Greenhouse Gas Emissions Reduction).
3. Pollution Prevention (including Indoor Air Quality and Noise Abatement).
4. Harmonization with Environment (including Environmental Assessment).
5. Integrated and Systemic Approaches (including Environmental Management System).[6]

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1 - Hossein Zabihi, Farah Habib and Leila Mirsaeedie: "Sustainability in Building and Construction: Revising Definitions and Concepts"- Department of Art and Architecture- Science and Research Branch- Islamic Azad University- Tehran- Iran- 2012 -p 571-574

٢ - علاء ياسين : اثر المناخ في شكل العماره العربيه, مجلة عالم البناء, مركز الدراسات التخطيطيه و المعماريه- عدد ١٠١ -١٩٨٩- ص ٣٢.

3 - Report of the World Commission on Environment and Development (WCED) by united nations, USA, http://www.un-documents.net/our-common-future.pdf

4 - Hossein Zabihi, Farah Habib and Leila Mirsaeedie: "Sustainability in Building and Construction: Revising Definitions and Concepts"- Department of Art and Architecture- Science and Research Branch- Islamic Azad University- Tehran- Iran- 2012 - p 571-574

5- Pulaski, M: "The alignment of sustainability and constructability"- A continuous value enhancement process-2005. p 55.

6 - http://www.oecd.org/

The aims of sustainability in environmental design are as follows:

- Maximizing the human comfort.
- Efficient planning.
- Design for change.
- Minimizing waste of spaces.
- Minimizing construction expenses.
- Minimizing buildings maintenance expenses.
- Protecting (keeping) and improving natural values. [1]

2-1-8- Constructability

2-1-8-1- Definition

constructability is a project management technique that analyzes the construction processes from start to finish during the pre-construction phase. It is known as Buildability in the UK. Also it is a project management technique that includes an elaborated study of models, design drawings, specifications and construction procedures. It will help to indentify the obstacles before a project is actually built. As a result, it tends to prevent, delays, errors and cost excessive.

The concept of constructability was first introduced by the Construction Industry Institute (CII)[2] in year 1986, where it stated" **Constructability** is the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives" The value of integrating construction knowledge early in the design process has been widely examined.[3]

2-1-8-2-Connections between Constructability and Sustainability

Constructability and Sustainability are two concepts that seek for the efficient use of resources through minimizing waste. Constructability focuses on waste in terms of the efficient use of materials and personnel, by finding easier ways to undertake construction. Constructability concepts are typically used to ease the construction process, but they also influence the design. On the other hand, Sustainability seeks to reduce wasted energy, water and material during the construction and operation processes.

The Five Areas of the Current Connections

The five areas are techniques for constructability and if integrated in a project, sustainability is achieved. Pulaski did not show the explicit connection between both concepts, and how sustainability can be achieved. these areas are:

1. Integrating organizational structures and contracting strategies.
2. Project management practices to manage both sustainability and constructability.
3. Principles that reduce waste by simplifying the construction process and enhancing the level of sustainability.
4. Systems level design decisions that optimize performance of the entire facility.
5. Material selections that reduce physical waste and process waste. [4]

2-1-9-Green Buildings (Sustainable Buildings - Vertical Direction). [5]

Green building is the practice of creating structures and using processes that are environmentally responsible and resource efficient throughout a building's life cycle.

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[1] Soflayi.f: "Today Building for Tomorrow (A review of basics and projects of sustainable architecture)"- forth international seminar of fuel consumption optimization in building- Tehran-Iran-2006- p 30.

[2] CII: A consortium of leading owners and contractors who have joined together to find better ways of planning and executing capital construction programs. https://www.construction-institute.org/scriptcontent/index.cfm

[3] George Jergeas Peng and Van der Put John: "Benefits of constructability on construction projects"- paper- Alberta construction industry through University of published in journal of construction engineering and management - july /august 2001 Calgary, Austin- Texas- USA- p 282- 290.

[4] Sarah Hisham Aboul Seoud: "Toward Achieving Sustainability in Constructability As a tool For Reducing Project Waste"- Bachelor Thesis- Faculty of Engineering- The British University In Egypt- 2013.- p 21

[5] الفت عبد الغني سليمان حلوة : "منهجية التصميم المعماري و العمارة المستقبلية" - رسالة دكتوراة- قسم عمارة- كلية الهندسة بالمطرية- جامعة حلوان- ٢٠٠٦.ص٨٢-٨٣.

That life cycle respectfully analyzes and integrates site selection through design, construction, operation, maintenance, renovation and deconstruction. The practice expands and also complements the classical building design concerns of economy, utility, durability, and comfort, Green buildings are specifically designed structures that reduce the overall negative impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, land, and materials
- Protecting occupant health and improving employee productivity
- Reducing waste and pollution from each green building
- Continuously looking for ways to improve performance [1]

High-Performance Green Buildings address sustainable development throughout the building's entire life cycle – from the beginning with the building's site selection and design all the way through to the end of the building's life. Sustainable buildings are significantly better than standard buildings. They use less energy, save money over time, provide better occupant health, comfort and are better for the environment.[2]

Also we call any construction as a Sustainable construction, while green building focuses on vertical construction. [3]

Green Building Definition: The careful design, construction, operation, and reuse or removal of the built environment in an environmentally, energy-efficient, and sustainable manner; may be used interchangeably with high performance building, green construction, whole building design, sustainable building, and sustainable design.[4]

2-1-10- Green Highway (Sustainable Highway - Horizontal direction)

In the transportation industry, projects and systems serve many different and sometimes competing objectives, including safety, mobility, environmental protection, livability, and asset management. A sustainable approach seeks to meet all of these needs while hitting economic targets for cost effectiveness throughout a highway's life cycle. For the Federal Highway Administration (FHWA), a sustainable approach to highways means helping decision makers to make balanced choices among environmental, economical, and social values (the triple bottom line of sustainability) that will benefit current and future road users. A sustainable approach looks at access (not just mobility), movement of people and goods (not just vehicles), and provision of transportation choices, such as safe and comfortable routes for walking, bicycling, and transit. Sustainability encapsulates a diversity of concepts as well, including efficient use of funding, incentives for construction quality, regional air quality, climate change considerations, livability, and environmental management systems.[5]

2-1-11- Importance of Going Green

Green bridges design and construction practices that meet specified standards will help resolve much of the negative impact that bridge have on their occupants and on the environment, but reducing impacts is not the end goal. Remember that building green bridge is constantly changing and progressing. Today's new idea may become tomorrow's standard practice. Green is already moving to the next level by striving for regenerative design. These would be projects that do not end, but rather renew resources for future use. [6] As shown in figure (2-1) petroleum products consumption in Egypt in 2012-2013 according to purpose of usages which illustrates that transportation use 33%

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[1] - Sim Van, Der Ryn and Stuart Cowan: "Ecological Design"10th edition- Island Press- Washington- USA- 1996-p19.

[2] - LEED Principles and Green Associate Study Guide- Green Building Education Services -USA- 2014-p11-12.

[3]- Liv Haselbach: "The engineering guide to LEED-new construction - sustainable construction for engineers (green source)"- 2nd edition- Mcgraw-Hill books- USA- 2010.-p10.

[4] - National Association of Homebuilders NAHAB: "Model green homebuilding guidelines"- by national association of home builders- USA- 2006- p15.

[5] - https://www.sustainablehighways.dot.gov/overview.aspx

[6] - LEED Principles and Green Associate Study Guide- Green Building Education Services -USA- 2014- p11-12

of petroleum products in Egypt is discussed. Also as shown in figure (2-2) the electricity usage in Egypt in 2011-2012 which illustrates that public lighting use about 9% of electricity in Egypt is overviewed. And as shown in figure (2-3) Carbon dioxide emissions from fossil fuel combustion according to purpose of usage is discussed. These latest Egyptian studies of petroleum and electricity consumption showing that if we design a sustainable bridge will contribute to decrease electricity and petroleum products consumption by roads and transportation which illustrate the importance of going green in Egypt.

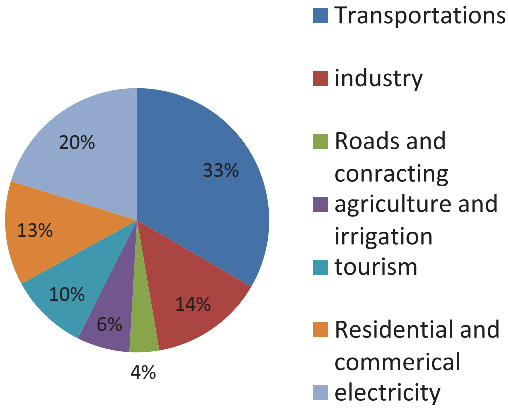

Figure 2-1: Petroleum products consumption in Egypt in 2012-2013

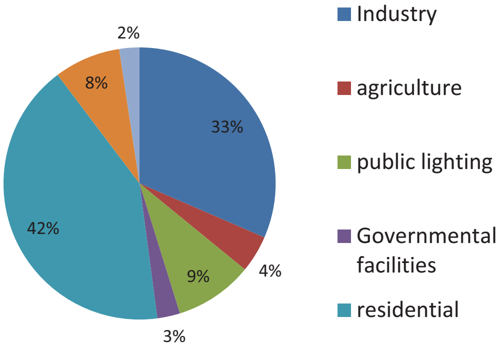

Figure 2-2: Electricity Usage in Egypt in 2011-2012[1]

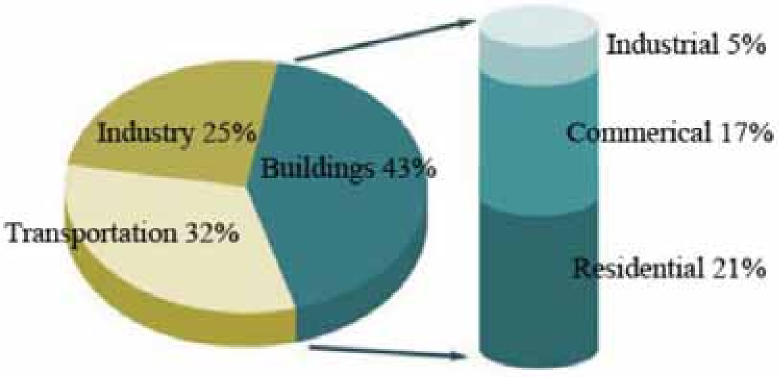

Figure 2-3: Carbon Dioxide Emissions from Fossil Fuel Combustion according to Purpose of Usage[2]

2-2- Sustainable City

There has been a considerable amount of researches that defines and characterizes the form of the sustainable city, and which urban forms may most affect sustainability.

2-2-1- Definition:

The physical dimensions of urban form may include its size, shape, land uses, configuration and distribution of open space a composite of a multitude of characteristics, including a city's transportation systems and urban design features.

However, its sustainability depends on more abstract issues including transport, social and economic.[3]

Yet much of the debate about the sustainability of cities and urban forms has focused on increasing the density of development, ensuring a mix of uses, containing urban 'sprawl' Achieving social and economic diversity and vitality often characterized as the

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١-مستقبل الطاقة في مصر - تقرير الهيئه العامه للتعبئه و الاحصاء -٢٠١٤ - ص٣٣.

2 - Egyptian Electricity Holding Company- Annual Report - Arab Republic of Egypt Ministry of Electricity and Energy- 2012-p36

3 - Jenks.mike, jones and colin: "Dimensions of the Sustainable City" - Springer Science +Business Media- UK- 2010- p13.

concept of a 'compact city'.[1] In this part, Compact city is reviewed as one of sustainable cities form.

2-2-2- Compact City:

The compact city concept was seen as an approach that could end "the evil of urban sprawl" In this regard, the sustainable urban development policy, which makes it possible to achieve maximum quality of urban life with the given resources and energy, should be vitally introduced to cities in developing countries.

The compact city approach seemed to be appropriate to achieve the goals of:

(1) Saving resources and energy (land use, transportation, pollutant emission, wastes).

(2) Revitalization inner city to control an infinite expansion to the suburbs of urban area resulted from automobile dependent society. [2] As shown in table (2-3) The aims of the compact city are introduced according to Dantzig and Saaty's advocacy.

Table 2-3: Dantzig and Saaty's Advocacy of Compact City[3]

Urban form	(1) High dense settlements (2) Less dependence on automobile (high density) (3) Clear boundary from surrounding areas
Spatial characteristics	(4) Mixed land use (5) Diversity of life (mixed-land use) (6) Clear identity
Social functions	(7) Social fairness (high dense settlements) (8) Self-sufficiency of daily life (9) Independence of government (clear boundary)

The purpose of a compact city policy in developing countries:-

- Infrastructure supply
- Close urban-rural linkage
- Social equity

A compact city policy has to be applied as urban development strategy to control urban expansion caused by a rapid population growth [4]

As shown in figure (2-4) principles of green urbanism to create a sustainable city are illustrated.

Figure 2-4: The outlined principles of Green Urbanism aim to guide urban designers[5]

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[1] - Susan. Handy: " Methodologies for exploring the link between urban form and travel behavior"- Transportation Research University of California- USA- 1996-p151.

[2] - Hidehiko Kanegae, Kenichi Ishibashi,Nobuhiro Hara: " Compact City and Developing Countries, Is Compact City Approach Appropriate as an Urban Development Policy for Cities in Developing Countries?"- Prepared for presentation at the Open Meeting of the Global Environmental Change Research Community- Montreal- Canada- 2003 - p 3,4

[3] - Nicola Dempsey: "Revisiting the compact city"- Article- Built environment magazine -Vol 36- No 1- 2010- p5

[4] - J-J Lin and A-T: "Does the compact-city paradigm foster sustainability? An empirical study in Taiwan" -Environment and Planning, Department of geography- National Taiwan University-2006-p365

[5] - Steffen Lehmann: "What is Green Urbanism? Holistic Principles to Transform Cities for Sustainability"- Climate Change - Research and Technology for Adaptation and Mitigation- 2011- http://www.intechopen.com/books/climate-change-research.

2-2-3- Characteristics of Compact Cities:

As shown in figure (2 -5) characteristics and concepts of compact city are introduced. [1]

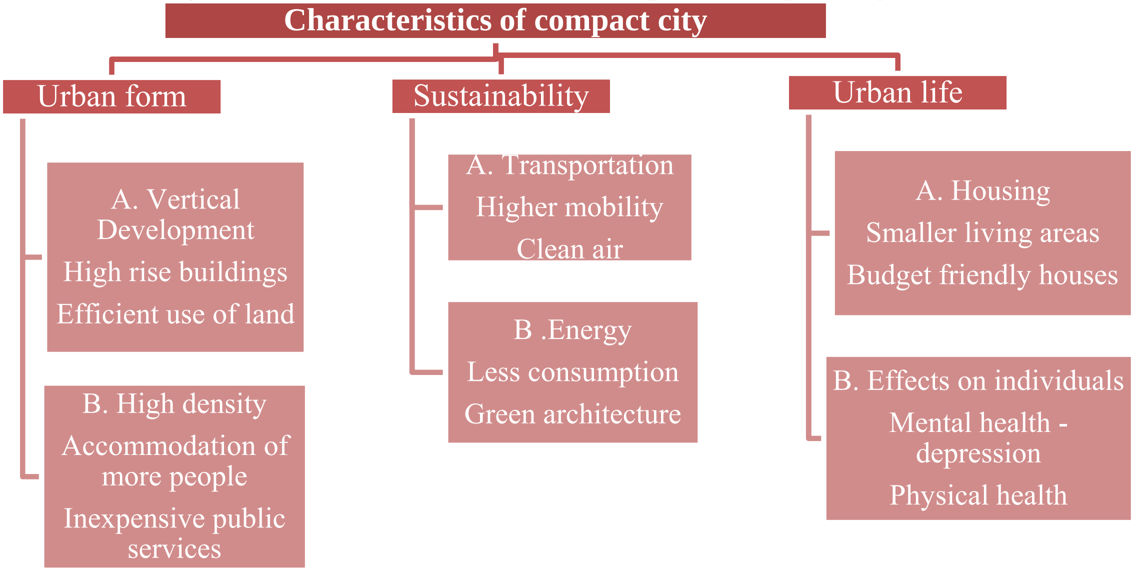

Figure 2-5: Characteristics of compact cities

2-3- Sustainable Transportation

2-3-1- Definition

- Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
- Is affordable, operates fairly and efficiently, offers a choice of transport mode and supports a competitive economy, as well as balanced regional development
- Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise.[2]

2-3-2- Principles for Selecting Sustainable Transportation Indicators

For comprehensive and balanced analysis, Sustainable transportations indicators sets should include indicators from each of the major categories of issues, such as those listed in Table (2-4) For example, it is important to have indicators of transportation cost efficiency (economic), equity and livability (social), and pollution emissions (environmental). [3]

Table 2-4: Sustainable Transportation Indicators

Economic	Social	Environmental
Accessibility quality	Equity / fairness	Air pollution
Traffic congestion	Impacts on mobility	Climate change
Infrastructure costs	Affordability	Noise pollution
Consumer costs	Human health impacts	Water pollution
Mobility barriers	Community cohesion	Hydrologic impacts
Accident damages	Community livability	Habitat and ecological degradation
	Aesthetics	

As shown in figure (2-6) Sustainable transportation system Framework is illustrated.

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[1] - Neslihan Gülfer Belce, Burak Belli and Nursel İdil Gümüs: " Characteristics of Compact Cities"- Master thesis- Urban and Regional Planning- Faculty of engineering- Istanbul University- 2014 -p2-3.

[2]- ECMT: "Assessment and Decision Making for Sustainable Transport" - European Conference of Ministers of Transportation- Organization of Economic Coordination and Development (www.oecd.org)- 2004.

[3] - Robert T. Clemen: "Making Hard Decisions An Introduction to Decision Analysis"- Second Edition- Duxbury Press- UK- 1996-p60.

Also as shown in Figure (2-7) Sustainable Transportation Examples are introduces.

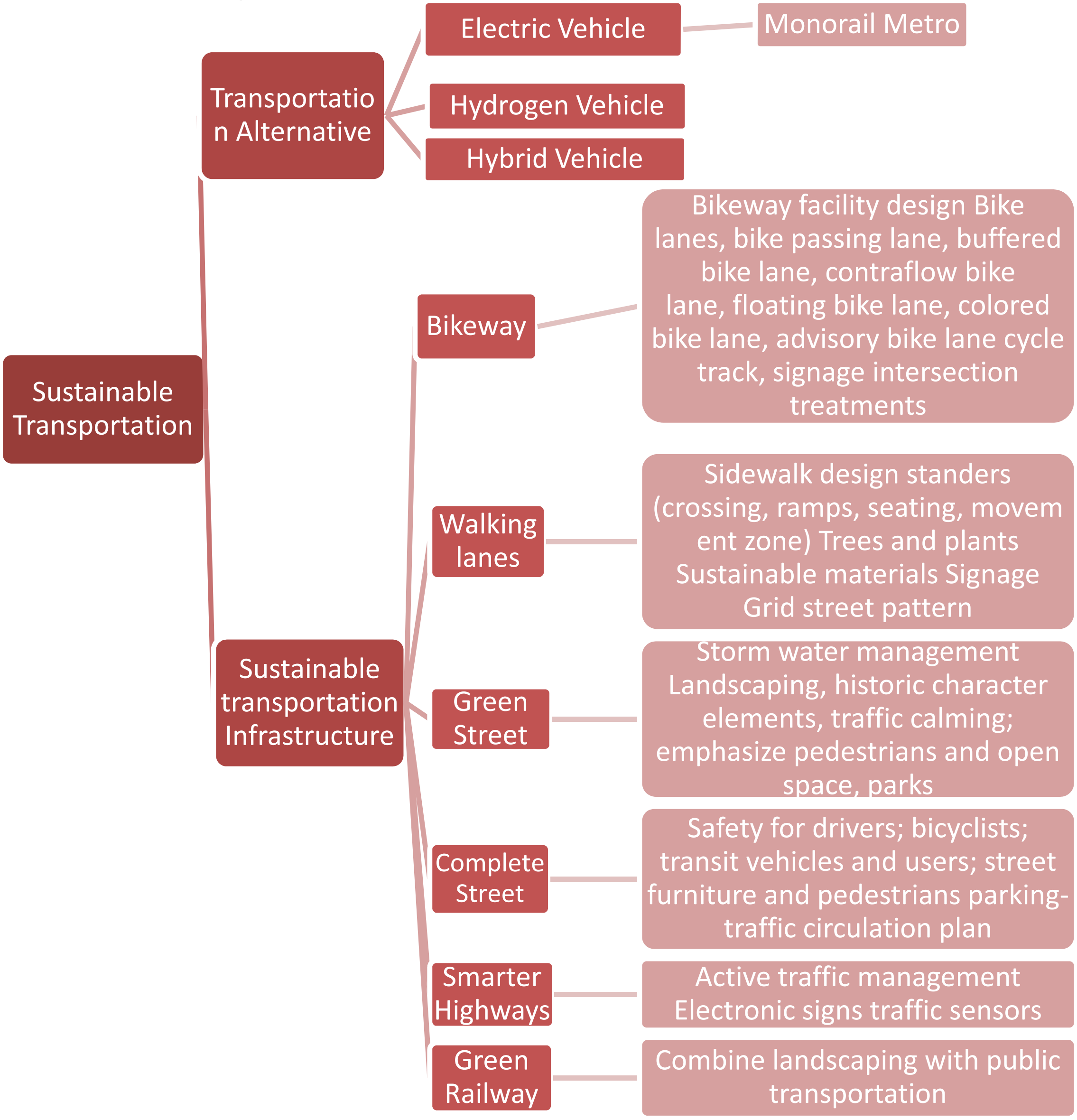

Figure 2-6: Sustainable transportation system Framework[1]


MonoMetro as a sustainable transportation system application Green railway – France Green railway - Qatar

Figure 2-7: Sustainable Transportation Examples [2]

2-4- Sustainable Bridges

A Sustainable bridge can be defined as the one that is “conceived, designed, constructed, and maintained, and eventually put out of service in such a fashion that these activities demand as little as possible from the natural, material, and energy

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[1] - Reman mohamed Rehan Hussein: "Towards Sustainable Urban Transportation Case Studies" World Academy of Science, Engineering and Technology International Journal of Social- Behavioral- Educational- Economic- Business and Industrial Engineering- Vol7- No9- 2013.

[2] - http://www.monometro.com

resources from the surrounding community". Sustainability can be explained under:

Environmental Sustainability in the context of bridges: Environmental sustainability deals with the environmental impacts of the product or the process in all life cycle stages of the bridge. To measure the environmental impacts and performance of the product or process over the design, construction, use, maintenance, and disposal stages.[1] Although structural sustainability is important, the focus is on environmental sustainability of bridges.

The structural sustainability: in the American Concrete Institution (ACI) Fall 2010 Convention, it is stated as, "A structural sustainable concrete bridge should provide an overall life of 100 to 150 years"; "They should have minimum of shrinkage (plastic, drying, chemical shrinkage) and cracking". For example use high performance concrete (HPC) to minimize dry shrinkage and use saturated lightweight aggregates for internal curing for the promotion of hydration in order to minimize shrinkage and cracking. HPC should have other optimum concrete characteristics such as low water/cement ratio and high flexural strength. "Long service life of bridge decks over 100 years can be achieved with low shrinkage, low permeability HPC, compared to only 20 years for normal strength concrete decks.".

2-6-1- Why Sustainable Bridge ?

sustainable bridge design is important looking into future for decreasing carbon footprint and increasing lifetime and use of important and expensive civil infrastructure. The largest environmental impacts for bridges are the location, materials and traffic using bridges.[2]

2-6-2- The Principles Used for Determining the Criteria of a Sustainable Bridge:

- Minimize location impacts (choosing sites tie directly into existing routes, Not using virgin sites and not affecting historical sites).
- Minimize material impacts (reducing materials needed, using material with low embodied energy, using recycled material and waste, allowing for future expansion, embodied energy during construction for various structural forms and materials).
- Minimize traffic by (provide HOV "High occupancy vehicle", pedestrian, bike lanes and reduce time cars are idling.[3]

2-5- Conclusion

Sustainable practices are a key component to almost every aspect of our lives. "Going Green" is incorporated into everything from food to buildings to cars. The civil engineering community is also responsible for becoming more sustainable in its practices, and this should include the bridges that are built. There have been many advances in bridge technology over the last hundred years, but sustainable bridge design is still a new and different area of focus. There have been minimal attempts to make bridges more sustainable through material improvements and design enhancements, but to be holistically sustainable in terms of the environment, the people and the economics, further advancements are still needed. The researcher traced the different definitions from sustainability to sustainable bridges going through sustainable development, sustainable architecture, sustainable design, green architecture, etc..

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1 - Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012- p 7-8.

2 - Annie Farbman and Leslie Tillman: "How can we design a sustainable bridge" -Presentation project for ENES216- FLEXUS Women in Engineering Seminar- 2012.

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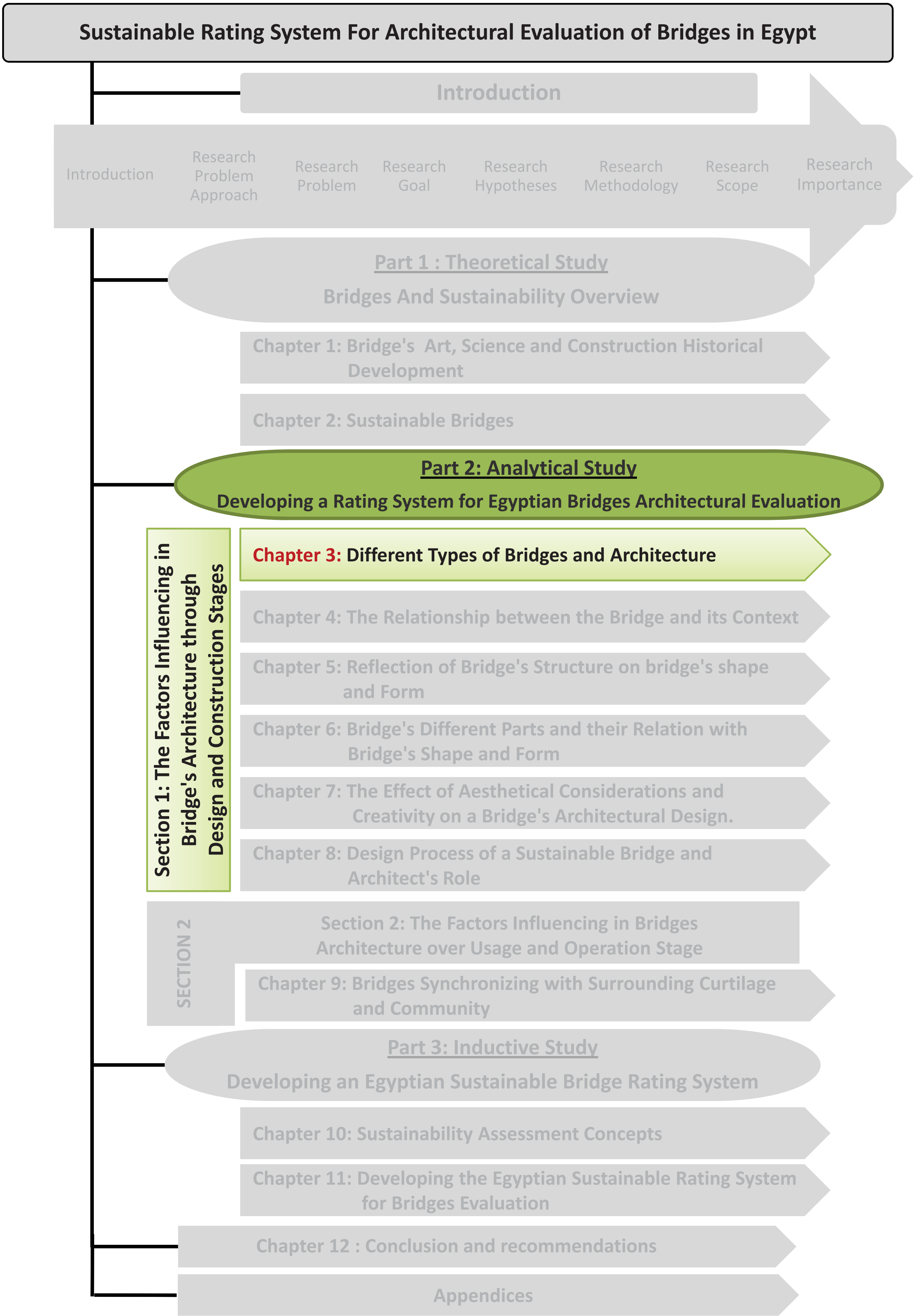

Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

Introduction

Introduction
Research Problem Approach
Research Problem
Research Goal
Research Hypotheses
Research Methodology
Research Scope
Research Importance

Part 1 : Theoretical Study
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Chapter 2: Sustainable Bridges

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Developing a Rating System for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages

Chapter 3: Different Types of Bridges and Architecture

Chapter 4: The Relationship between the Bridge and its Context

Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form

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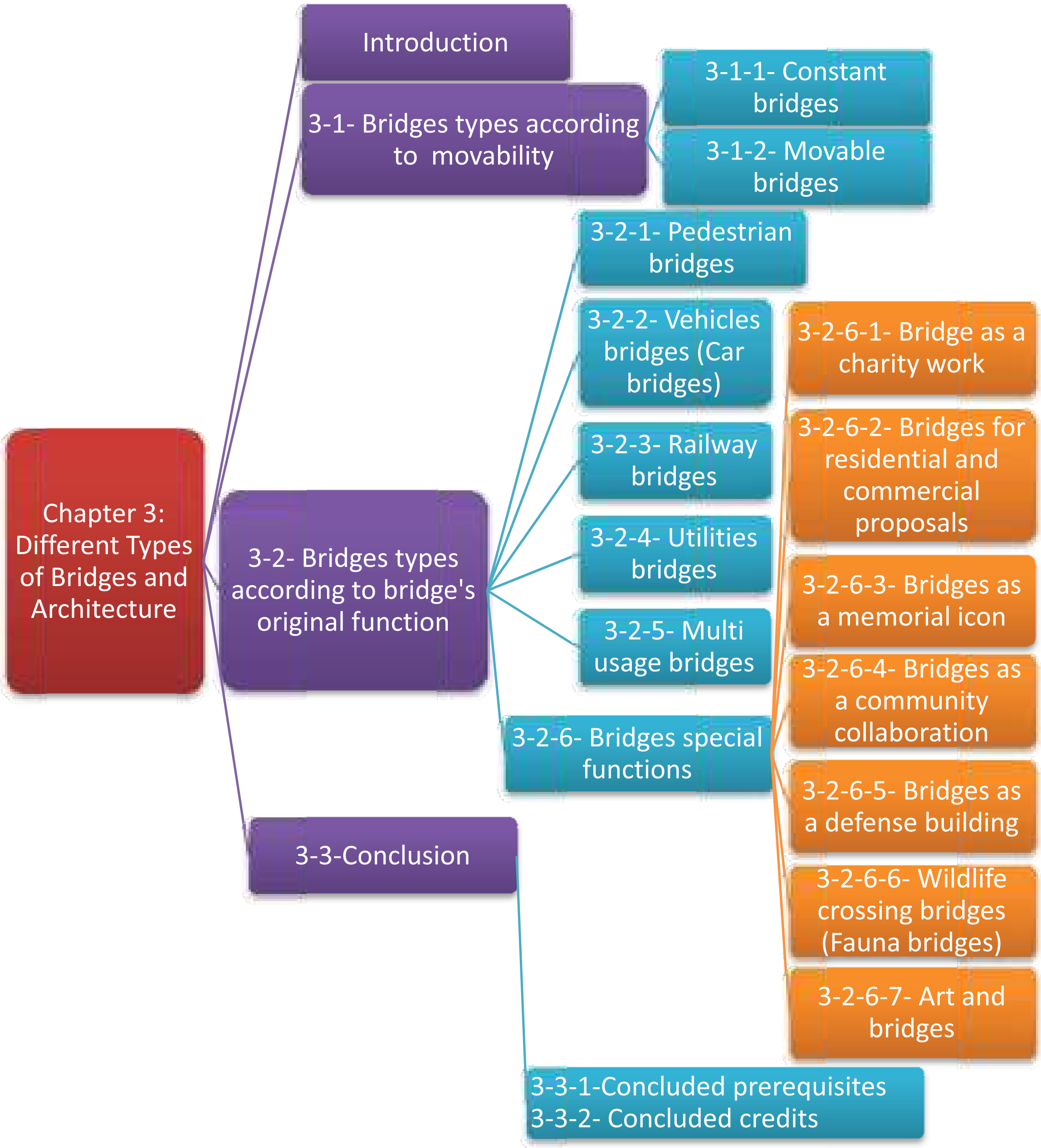
Part 2: Developing a Rating system for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridges Architecture through Design and Construction Stages

Chapter 3 : Different Types of Bridges and Architecture.



Chapter 3 structure: Different Types of Bridges and Architecture

Chapter 3: Different Types of Bridges and Architecture.

Introduction

Bridges may be classified according to many factors, the most important factors are bridge 's move-ability and bridge original function.

Bridge original function could be defined as the main purpose for bridge construction. For example pedestrian bridge main purpose is enabling people to cross between two points over any obstacle.

3-1- Bridges Types according to Move-ability

There are two kinds of bridges according to movement and constancy perspectives:

- **3-1-1- Constant Bridge**: Is a bridge that its deck is constant. It enables passengers to cross over and beneath it in the same time
- **3-1-2- Moveable Bridge:** Is a bridge that its deck moves to clear a navigation channel to allow passage from crossing beneath it.

As shown in Table (3-1) Constant and movable bridges types are studied to help bridge designer to make the move-ability best decision during bridge design. As an advantage of making bridges moveable is the lower cost, due to the absence of high piers and long approaches also most of movable bridges is pedestrian bridges because of light loads could be held out by the bridge. The principal disadvantage is that the traffic on the bridge must be halted when it is opened for passages. Moveable bridges are powered by electric motors, whether operating winches, gearing, or hydraulic pistons. While moveable bridges in their entirety may be quite long, the length of the moveable portion is restricted by engineering and cost considerations to a few hundred feet.[1]

3-2- Bridges Types according to Bridge Original Function

There are different functions of bridges, the main purpose of any bridge is crossing any obstacle. but the difference between bridges is who uses the bridge ? (pedestrians, cars, trains etc..) and the obstacle itself (river, railway, highway). The bridge function effects on bridge shape, form, structure, loads and whole bridge's architecture. [2] Figure (3-1).

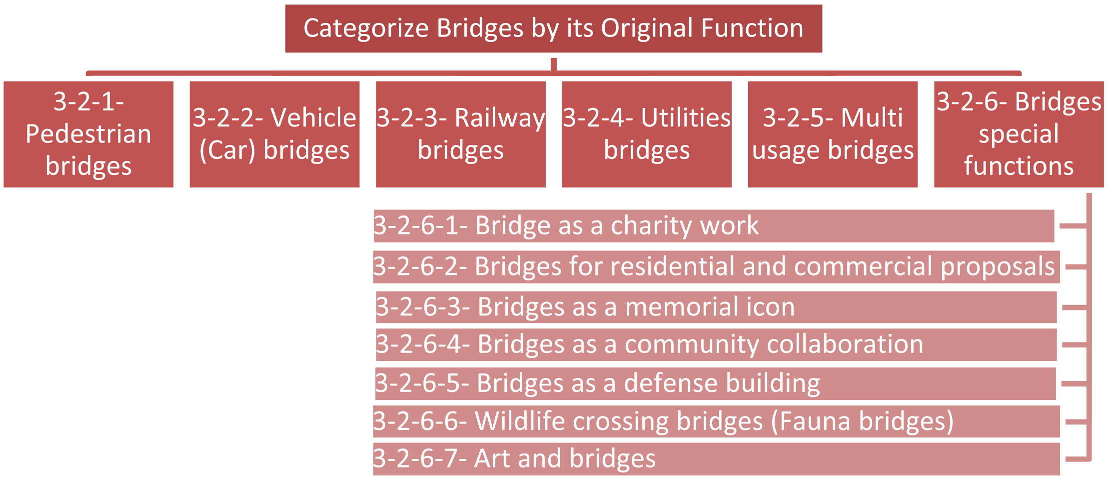


Figure 3-1: Categorize Bridges According to its Original Function

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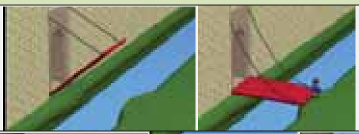
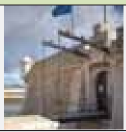
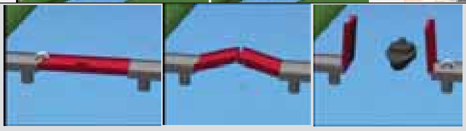
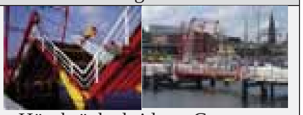
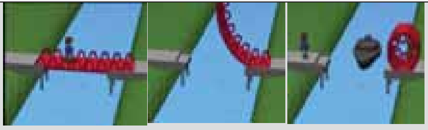
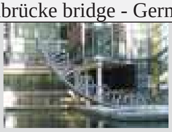
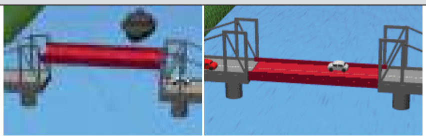
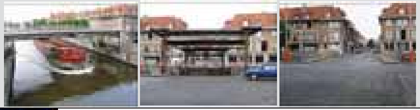
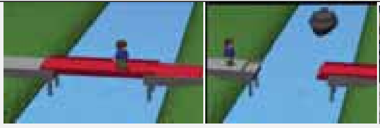
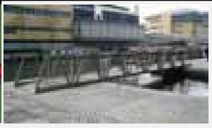
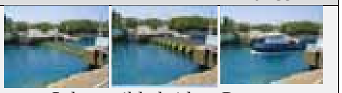
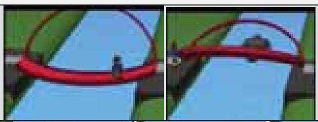
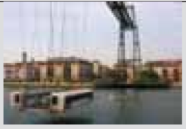
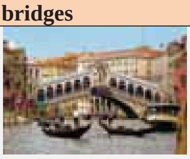
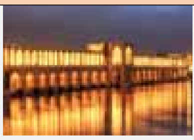
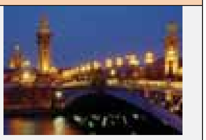
1 - "ICE Manual of Bridge Engineering" -Institution of Civil Engineers-UK- 2008- p421. http://www.icemanuals.com/

٢ - وليد محمد طلعت محمد ابراهيم الخريبي: ابراز البعد البيئي في تصميم كباري المشاه المعدنيه - دراسة تطبيقيه لتاثير جماليات الطابع الاسلامي- رسالة ماجستير- قسم الاثاث و الانشائات المعدنيه و الحديديه- كلية الفنون التطبيقية- جامعة حلوان- ٢٠٠٨- ص ٣٣-٣٨.

Table 3-1 : Bridges Types according to Move-ability.

	Moveable bridge	
	Definition	Sketches and examples
Draw bridge	Is a type of movable bridge typically associated with the entrance of a castle surrounded by a moat.	  Drawbridge at the fort of Ponta da Bandeira, Lagos, Portugal
Bascule bridge	Is a moveable bridge with a counterweight that continuously balances a span, or "leaf", throughout its upward swing to provide clearance for boat traffic. It may be single or double leafed.	  Tower Bridge 1886-London
Folded bridge	Is a movable bridge with a deck divided to several folded parts. usually, it is a three-segment bascule bridge that folds in the shape of the letter N	  Hörnbrücke bridge - Germany
Curling bridge	It is a moveable bridge which have a unique rolled deck. Curling bridge in London Is completed in 2004 as part of the Grand Union Canal office & retail development project at Paddington Basin, London.	  2004 curling bridge - London
Vertical-lift bridge	is a type of movable bridge in which a span rises vertically while remaining parallel with the deck.	  Pont Jacques Chaban- Delmas- 2013
Table bridge	Is a moveable bridge in which the deck moves along the vertical axis. Hydraulic pillars under the bridge raise the bridge deck to allow barge traffic to pass beneath it.	 
Retractable bridge	It is a type of movable bridge in which the deck can be rolled or slid backwards to open a gap while traffic crosses, usually a ship on a waterway. its also called a thrust bridge	  London Bridges: 19. Rolling Bridge, Paddington
Rolling bascule	It is a movable bridge which has a swing deck to allow traffic to cross beneath it. Pegasus Bridge, over the Caen Canal. The tower is staffed by operators who open the bridge for canal traffic	  Rolling lift Pegasus Bridge over the Caen Canal, Normandy, France
Submersible	is a type of movable bridge that lowers the bridge deck below the water level to permit waterborne traffic to use the waterway.	  Submersible bridge-Greece
Tilt bridge	is a type of moveable bridge which rotates about fixed endpoints rather than lifting or bending, as with a drawbridge.	  Gateshead Millennium Bridge
Swing bridge	It has as a primary structural support in a vertical locating pin and support ring, usually at or near to its center of gravity, about which the turning span can then pivot horizontally as shown in the illustration to the right.	  Government Bridge - USA
Transporter bridge	also known as a ferry bridge or aerial transfer bridge, is a type of movable bridge that carries a segment of roadway across a river.	  Vizcaya Bridge, Biscay, Spain

Constant bridges

					
Chengyang Bridge,China-1916	Langkawi Sky Bridge, Malaysia	Stari Most, Bosnia-1566	Rialto Bridge, Italy-1181	Khaju Bridge, Iran-17th century	Pont Alexandre III, France-1869

References : http://list25.com/25-of-the-worlds-most-unique-bridges/5/
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Stanford, Harold Melvin, ed. "Castle". The Standard Reference Work for the Home, School and Library-1921- p96.
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http://www.detail-online.com/inspiration/pedestrian-bridge-in-hoern-kiel-109250.html
http://10mosttoday.com/10-most-amazing-movable-bridges-in-the-world/
http://www.heatherwick.com/rolling-bridge/
https://en.wikipedia.org/wiki/Moveable_bridge
https://www.gamber.net/cyclebel/escaut.htm
http://happypontist.blogspot.com.eg/2011/12/london-bridges-19-rolling-bridge.html
http://cromwell-intl.com/travel/france/normandy/pegasus-bridge.html
http://www.amusingplanet.com/2013/09/submersible-bridges-at-corinth-canal.html
http://www.ramboll.co.uk/projects/ruk/gateshead%20millennium%20bridge

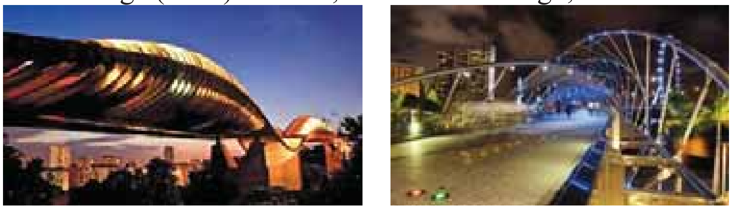
3-2-1- Pedestrian Bridges

These bridges used by pedestrians to cross from side to another side, these bridge's structural parts are small because of the small loads on them, also these bridges used as an architectural elements at parks.[1]Figure (3-2)

London Millennium Footbridge (2000) London,

BP Pedestrian bridge (2004) Chicago, USA

Arganzuela Footbridge (2010) Madrid, Spain



Henderson Wave bridge (2008) Singapore

The (Double) Helix bridge (2010) Singapore

These are some of Top Pedestrian bridges rated by Landscape Architects Network all over the world.[2]

Figure 3-2: Pedestrian Bridge's Examples

Pedestrian bridges is one of the most important bridges types because its important function Also the pedestrian spend a long time on these bridge with their slow motion during walking. During pedestrian bridge design, there are some taken consideration to guarantee best bridge's function and beautiful shape and form.

- **Design flexibility**: Pedestrian bridges carry lighter loads than vehicular bridges: this allows the designer to exploit greater flexibility in the shape and proportion of the bridge, within a reasonable budget, which can lead to great variety and character.

• Consider how a bridge can reflect local character, provide a milestone on a journey, form a gateway to an area, create a focal point or celebrate something.

• Depending on context, the rules normally applicable to road bridges may be stretched when using cable stay, truss, arch and suspension which are suitable for light loads.
Consider the use of lighting to both emphasize the form of the bridge and distinguish it by night within the constraints of cost, surrounding properties and adjacent light fixtures.

- **View:** Pedestrians and cyclists spend more time on a pedestrian and shared path bridge than a traffic bridge: therefore the view from the. bridge takes on added significance and detail and materials are more closely appreciated.

• Provide adequate space on the bridge to allow stopping and viewing without significantly interrupting pedestrian and cycle movement.

• Avoid hidden or secluded spaces which, if present, will make it more difficult to monitor personal safety.

• Advertising and signage on or near a bridge is not desirable but, where it is considered appropriate it should not obscure the form of the bridge, the surveillance of pedestrians or views from the bridge.[3] Figure (3-3)

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1 -"Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012 -p 102-112.

2 - http://landarchs.com/top-10-pedestrian-bridges/

3 - "Oregon Bicycle and pedestrian Design guide" 3rd edition- Oregon highway design manual- Appendix N- Oregon department of transportation Bicycle and pedestrian program-USA-2011-p 3-1 to 7-1.

The ramp and bridge proposal connection on this pedestrian bridge is seamless

Using seven cables instead of three required structurally create an attractive Albury bridge

Structurally expressive form using modern materials is evident in this space-frame bridge- Australia

A bridge at Billinudgel uses the safety screen as a design feature, wrapping the whole girder and creating a distinctive tube effect.

The Volantin footbridge in Bilbao by Calatrava is a stunning modern example bridge which has a great view. (Right pic.)

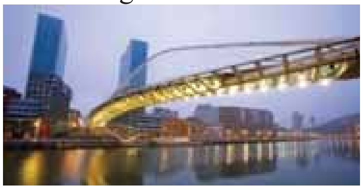

Figure 3-3: Design Flexibility and views in Australian Pedestrian Bridges.[1]

- **Ramps:** Ramp design can be innovative but should not dominate views or detract from the expression of the essential element of the bridge and its span. If ramps are needed, now or in the future, for access and connection to surroundings.

- Attempt to locate the bridge where the ramp can be its shortest possible length.
- Where a road is at a grade the approach ramps on the uphill side can be relatively short
- If an elevated constructed ramp is required the design must be carefully considered due to its visual prominence. The design of ramp and bridge should be integrated and unified in appearance.
- Use planting to integrate ramps with their surroundings and reduce their visual impacts
- Connections between ramp and superstructure must be as simple as possible.
- Ramp design and geometry should be simple and thoughtfully done.
- Consider the aesthetic impact of standards relating to ramp slope and frequency of landings (required for disabled and cyclist use) which may increase ramp length and interrupt the desired smooth lines of the structure. It may be necessary to obscure the landings by a higher than necessary parapet wall.
- Consider visually separating the ramp and span, by integrating the ramp into the adjacent land form.

- **Lifts and stairs:** Where the site is very constricted, or ramps would be excessively long, lifts could be provided. It is important to locate lifts carefully and design them as part of the whole structure. The same applies to the use of stairs to access a pedestrian bridge. Where space is limited or lifts stairs are required their design should be simple and compact and appear as light and slender as possible.

- The use of at least one transparent glass wall should be considered. This reduces the visual bulk of the lift, provides views and gives a feeling of good passive surveillance to and from the surroundings

- **Safety screens:** In the design of these it is important to avoid a caged feeling when bridges are narrow It provides a platform for vandal access and creates an oppressive feeling of enclosure. In terms of comfort in using the bridge the following to be

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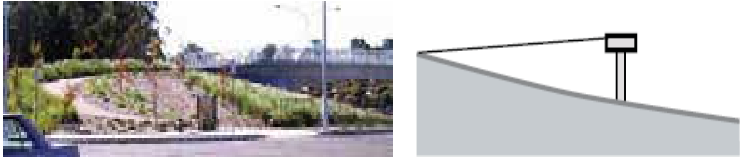
[1] - https://www.theguardian.com/artanddesign/australia-culture-blog/gallery/2014/oct/02/twelve-beautiful-australian-bridges-in-pictures

considered. If a closed system cannot be avoided then the design and shape of the cage should ensure that the experience of crossing the bridge is not oppressive.

- Feature lighting should be considered to make the crossing attractive and well lit.[1] Figure (3-4)



Pedestrian bridge ramp at Faulcon bridge over the Great Western Highway- Australia

The form and fencing, colors and use of the lift shaft as a pier are visually strong. Transparent lift shafts can be attractive as shown at these examples

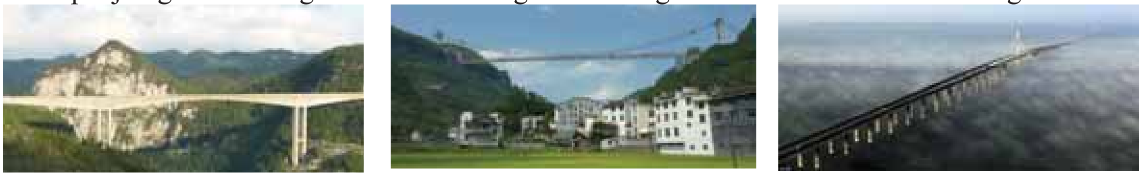
The bridge at Billinudgel has an open feel even through it is caged

Figure 3-4: Ramps, lifts, Elevators and Safety screen in Australian Pedestrian Bridges.[2]

3-2-2- Vehicle (Car bridges)

This kind of bridges is the most popular bridges in the world, and it used to cross rivers or to facilitate the traffic by cars or any vehicles. Figure (3-5)

Beipanjiang River bridge Baling River bridge Aizhai bridge



Liuguanghe bridge Zhijinghe River bridge Jiaozhou Bay bridge[3]

Figure 3-5: Car Bridges Examples (List of Longest Span Vehicle Bridges in China)[4]

3-2-3- Railway Bridges

These bridges shapes are different than any other bridges because of the different actions and loads on them as they looks heavier and bigger than any other bridge also their structure looks stronger than any other bridge. They mainly used to cross rivers or mountainous areas.[5] Figure (3-6)

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[1] -"Oregon Bicycle and pedestrian Design guide" 3rd edition- Oregon highway design manual- Appendix N- Oregon department of transportation Bicycle and pedestrian program-USA-2011-p 3-1 to 7-1.

[2] - http://www.australiangeographic.com.au/topics/history-culture/2015/10/top-ten-aussie-bridges

[3] -http://www.dailymail.co.uk/news/article-2009748/That-bridge-far-Worlds-longest-sea-bridge-opens-traffic-China--hold-title-years.

[4] - http://10mosttoday.com/10-highest-bridges-in-the-world/

[5] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p 102-112.

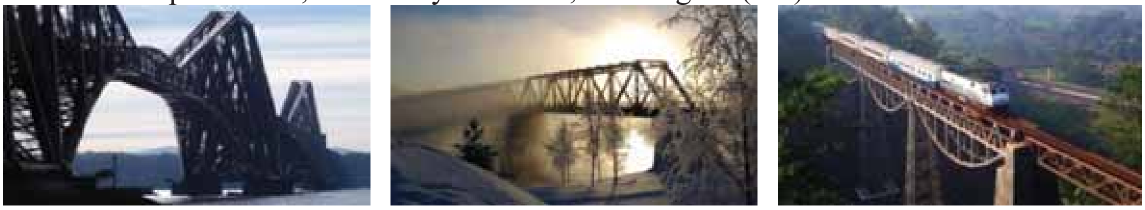
3-2-4- Utilities Bridges

These bridges used for crossing Gas, water or any Mechanical, electrical and plumbing pipes.

3-2-5- Multi-usage Bridges (Multi-Modal Transportation)

The development of transportation projects increasingly involves several modes of transportation including (light rail, transit facilities, bikeways, aircraft and water craft) The needs of each mode of transportation, present and future, should be anticipated and planned for in the project development. The users' visual comfort should be considered throughout the development of multi-modal projects.[1]

Multi-usage Bridges could be defined as the bridges who used for two or more functions like cars and pedestrian, or railway and cars, etc.[2] Figure (3-7)



Forth railway bridge, Scotland | Lorraine Viaduct, Switzerland | Cikurutug bridge, Indonesia

Hohenzoll ernbrucke Railway bridge, Germany | Land wasser viaduct, Switzerland | Orwood Road bridge crosses Indian Slough

Figure 3-6: Railway Bridges Examples[3]

Utilities bridge: Peace river bridge- Canada | Imbaba multi usage bridge - Egypt[4] | Railway bridge with a pedestrian path- Canada[5]

Schematic deign proposals for multiple layers bridges[6]

Figure 3-7: Utilities and Multi Usage (Multi-Modal Transportation) Bridges Examples.

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[1] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p3-1 to 3-4.

٢- هاني محمد ابو العلا: دراسة تحليليه لعناصر تصميم و تشكيل الكباري - حالة القاهره الكبري- رسالة ماجستير- قسم عماره- كلية الهندسه- جامعة القاهره- ٢٠٠٢-ص ٣٧-٤٠.

[3] - https://loco2.com/blog/10-cool-railway-bridges

[4] - http://www.marefa.org/images/thumb/a/ab/Ambababridgpic.jpg/270px-Ambababridgpic.jpg

[5] - http://webecoist.momtastic.com/2014/03/24/animal-bridges-15-life-saving-wildlife-crossings/

[6] - http://bridge183.rssing.com/chan-11488296/all_p16.html

3-2-6- Bridges Special Functions

3-2-6-1- Bridges as a Charity Work

In the middle ages, bridges played a major role in charity and as a community participation like monasteries.

volunteers efforts were directed to maintain and construct stone bridges. one of these bridges was the bridge crossing durance river at 1164 by monk benoit, later after this bridge a group of monks constructed some bridges named "Freres du pont " like "Freee masons" group who built churches at these times.

3-2-6-2- Bridges for Residential and Commercial Purposes

The Ponte Vecchio bridges is an example of residential and commercial bridge. It was a commercial capital at the middle ages. It connects south cities on Arno river.[1] Figure (3-8)

The Ponte Vecchio, or old bridge, was until 1218 the only bridge across the Arno in Florence. The current bridge was rebuilt after a flood in 1345. It contained some slaughter converted to jeweler at 16 century .[2]

Figure 3-8: Bridges for Residential and Commercial Purposes (The Ponte Vecchio)[3]

3-2-6-3- Bridges as a Memorial Icon.

Sometimes, bridges is designed to memorized an event or a date, For example Alamillo bridge is located in Seville- Spain. It was designed by the Spanish architect Santiego Calatrava. (figure 3-9)

Alamilo bridge (1992), In 1989 started the construction of the Alamillo bridge in Spain, it was finished to the world exhibition in the city in 1992. The bridge runs from center of town across the river Guadalquivir to La Cartuja where the Expo was.[4]

Figure 3-9: Bridges as a Memorial Icon (Alamilo bridge)

3-2-6-4- bridges as a Community Collaboration.

Bridges play a substantial rule to community. The community work may be during the bridge construction as Carroll creek park bridge in Maryland, Near Washington, USA is a good example of community collaboration. At 1993 many artists was invited to finish this art work also 173 thousand helped create a complex, richly layered artwork that drew more national attention with each passing month during its creation. share in this art work which attract thousands of tourists every year (Figure 3-10). Or it may be using the bridge for community and social activities after construction as Royal George bridge (Figure 3-11). [5]

3-2-6-5- bridges as a Defense Building

bridges represented a defense value in the middle ages to protect towns from invaders.[6] For example Skaliger bridge (Castel vecchio bridge)1356. figure (3-12).

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١ - حسام الدين محمد مجدي عبد القوي محمد: تحت الكوبري كفراغ عمراني عام في المدينة المصريه-رسالة ماجستير, قسم عمارة- كلية الهندسه- جامعة القاهره-٢٠١١- ص ١٦ - ١٩.

2 -http://www.visitflorence.com/florence-monuments/ponte-vecchio.html

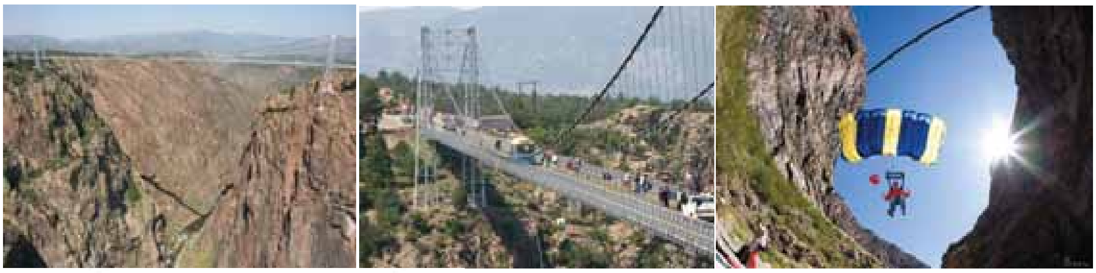
3 - David Brown: "bridges: Three Thousand Years of Defying Nature"- Mitchell Beazley- USA -2005-p 69.

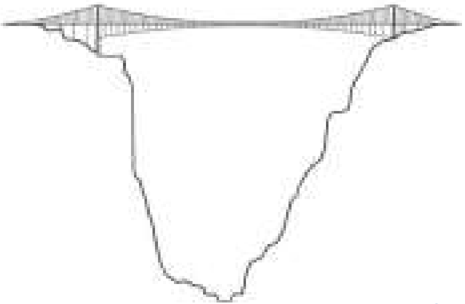
4 - http://www.bridge-info.org/bridge/index.php?ID=19

5 - http://bridge.skyline.net/history/

٦ -, هاني محمد ابو العلا: دراسة تحليليه لعناصر تصميم و تشكيل الكباري - حالة القاهره الكبري- رسالة ماجستير- قسم عماره- كلية الهندسه- جامعة القاهره- ٢٠٠٢- ص ٦٠.

Figure 3-10: Trompe l'oeil Painting on Carroll Creek Park Bridge [1]





Royal Gorge bridge Cañon City, Colorado, United States is the world's highest bridge (1929-2001). There are many social activities related to this bridge such as "Play Go" activity which is using parachutes and jumping from the bridge.[2]

Figure 3-11: Royal George Bridge[3]

It was built (1354-1356) by Cangrande II della Scala, to grant him a safe way of escape from the annexed eponymous castle in the event of a rebellion of the population against his tyrannical rule.

Figure 3-12: Castel Vecchio Bridge [4]

3-6-1-6- Wildlife Crossing bridges (Fauna bridges)

This kind of bridges used by animals, any other creatures to protect them from being killed by cars and to protect wildlife. These bridges have a different aesthetic to vehicular and pedestrian bridges. In general they have a strong connection to the landscape and need to emphasize this through their materials and earthworks. There is no need for parapet or typical pier forms but the elements need to be carefully considered so that a good aesthetic outcome is achieved. Figure (3-13)

3-2-6-7- Art and bridges

Well designed bridges and the more iconic structures are often seen as sculptural art effects in the landscape with artistic qualities in their own right. On occasion designers integrate art as an element into the design of bridges. For example piers can be designed with a texture or motif embedded into the structure. Painting can be used to provide an

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[1] - http://traveleering.com/this-bridge-isnt-exactly-what-you-think-it-is/

[2] - Wai-Fah Chen and Lian Duan: "Handbook of International bridge Engineering"- CRC press Taylor and francis group- USA-2014-p 1288

[3] - http://www.highestbridges.com/wiki/index.php?title=Royal_Gorge_bridge

[4] - http://www.italyguides.it/en/veneto/verona/castelvecchio/skaliger-bridge

artistic image or color a bridge element in a striking way. Safety screens can be designed with motifs and patterns layered into the mesh. Lighting can be used with the bridge to create an artistic effect.[1] Figure (3-14)

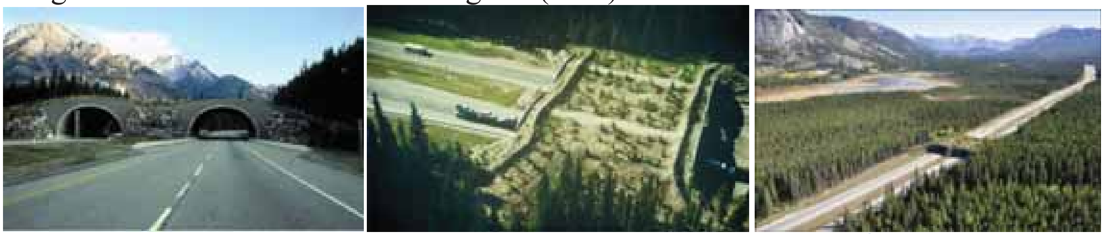

Figure 3-13: Fauna Bridge at Banff National Park Alberta, Canada[2]

The Aspire sculpture in Ultimo brightens up a dark, unattractive under bridge space. Australia

The integrated fallen tree motif on the pier of the Lizard tree bridge on the Hume Highway helps turn an elegant bridge into a memorable one. Australia[3]

6th of October pedestrian stair at Abdelmoneim Riad square colored by faculty of fine arts students[4], Egypt

Figure 3-14: Art and bridges Examples in Canada and Egypt

3-3- Conclusion

In this chapter, bridges different types were discussed either according to bridge's movement or according to bridge original function (Car, pedestrian railway, fauna, multi usage, etc..).

3-3-1- Concluded Prerequisites

AP: Bridge Main Function
AP: Bridge Expected Future Functions
AP: Bridge functions Achievement
AP: Taken Considerations to Achieve Functions
AP: Safety Codes

3-3-2- Concluded Credits

CR: Bridge Movement and Constancy
CR: Bridge Viability for Expansion

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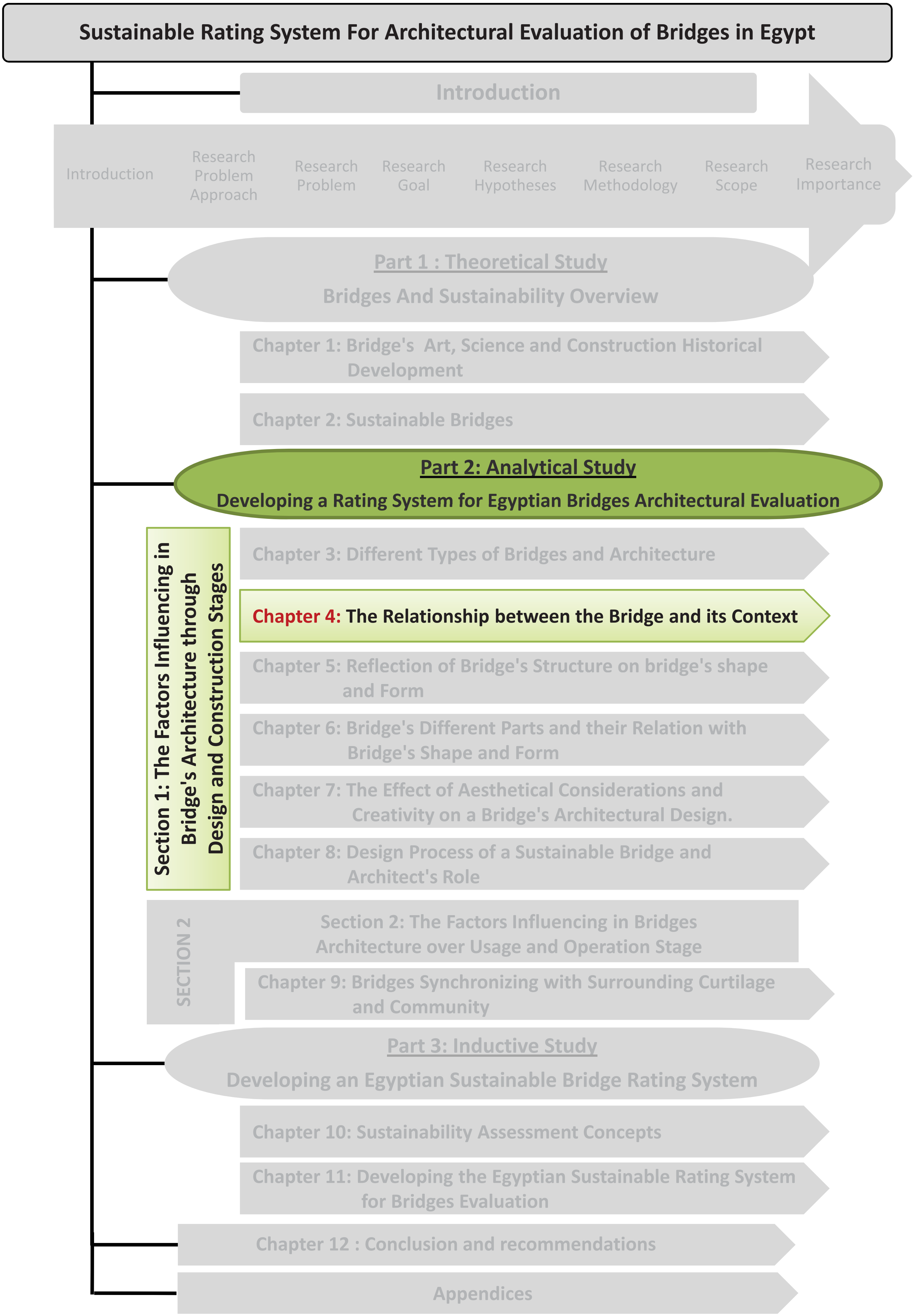
[1] "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p 110-111.

[2] http://twistedsifter.com/2012/07/animal-bridges-around-the-world/

[3] ("Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012.-p 111-112.

[4] http://aawsat.com/sites/default/files/styles/article_img_top/public/Last-211014-1.jpg?itok=aWesn3gE



Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

Introduction

Introduction | Research Problem Approach | Research Problem | Research Goal | Research Hypotheses | Research Methodology | Research Scope | Research Importance

Part 1 : Theoretical Study

Bridges And Sustainability Overview

Chapter 1: Bridge's Art, Science and Construction Historical Development

Chapter 2: Sustainable Bridges

Part 2: Analytical Study

Developing a Rating System for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages

Chapter 3: Different Types of Bridges and Architecture

Chapter 4: The Relationship between the Bridge and its Context

Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form

Chapter 6: Bridge's Different Parts and their Relation with Bridge's Shape and Form

Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design.

Chapter 8: Design Process of a Sustainable Bridge and Architect's Role

SECTION 2

Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community

Part 3: Inductive Study

Developing an Egyptian Sustainable Bridge Rating System

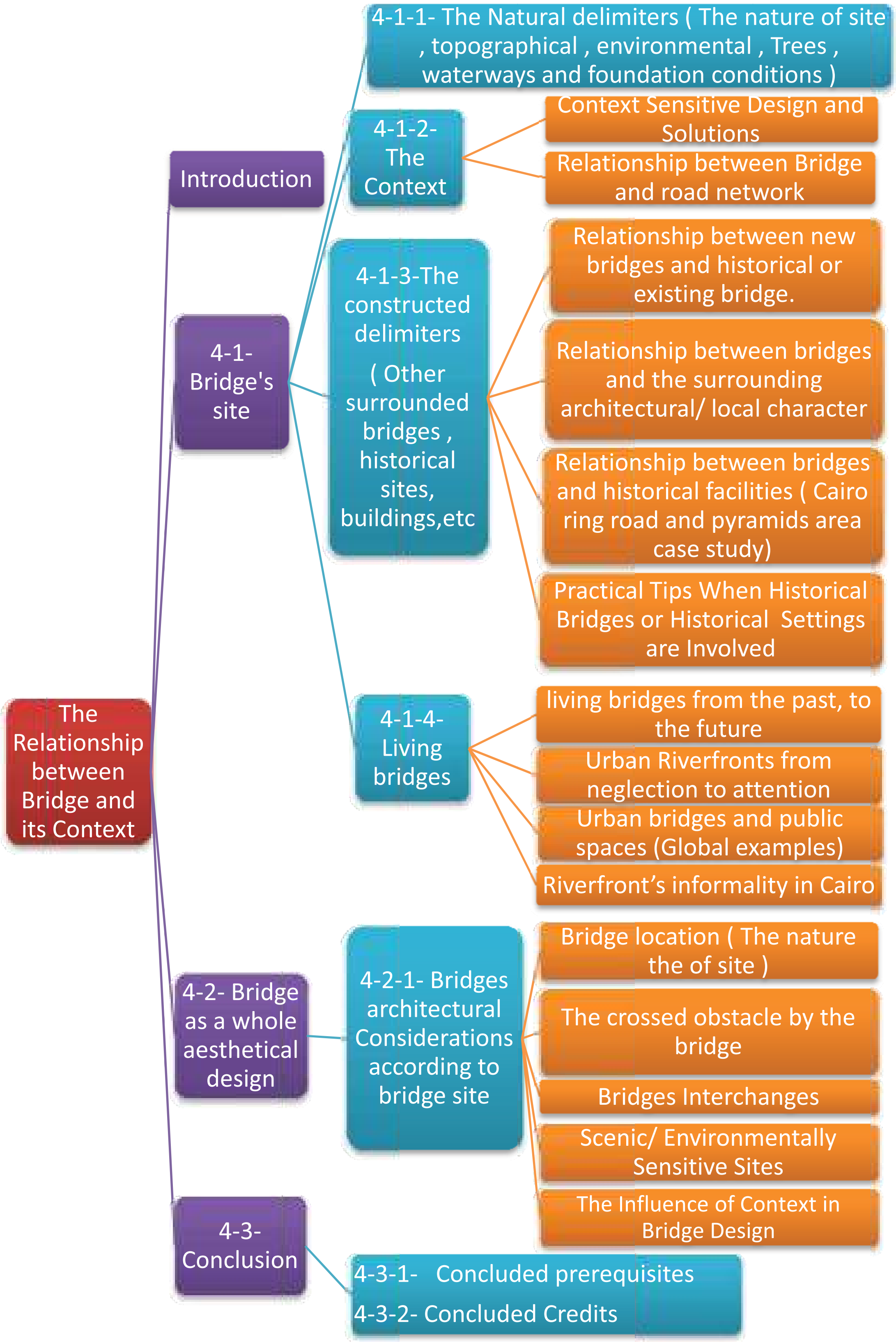
Chapter 10: Sustainability Assessment Concepts

Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Chapter 12 : Conclusion and recommendations

Appendices

Chapter 4 : The Relationship between Bridge and its context



Chapter 4 Structure: The Relationship between Bridge and its Context

Chapter 4: The Relationship between Bridge and its Context

Introduction

The bridge designer must understand what the bridge is expected to accomplish, functionally as part of a transportation system as well as socially, visually and symbolically as part of a living community and environment. The designer must understand the goals and the site and he has to have an idea of all of the criteria that the structure must meet.

4-1- The Bridge's Site

bridge's site is the most important feature that will influence the configuration and hence the aesthetical design of a bridge. Bridges designed to work with and complement a site will be both functionally and aesthetically successful. Designer should to go to the site at different times of day, at night and in as many different seasons as possible. There is no substitute for first-hand familiarity with the bridge site.

4-1-1-The Natural Delimiters (The Nature of Site, Topographical, Environmental, Trees, Waterways and Foundation Conditions).

A: selection and investigation of bridge's site.

Site selection: usually, the approximate site at which a bridge is to be build determined by considerations related to the overall planning of the highway, railway or pipeline route. But in other cases there are several areas to construct a bridge, and the bridge engineer has the responsibility of finding the best location within the area that the flexibility of the route planning allows.[1] Figure (4-1)

good Site selection at Sylvenstein Bridge in Upper Bavaria, Germany (selecting sites beside mountain to cross the bay reaching to the island)[2]

Bad site selection of Cairo ring road - Marriotya corridor, An agriculture site near Giza pyramids was selected, Informal housing and illegal towers were constructed which bad effected on pyramids view and curtilage (by researcher)

Figure 4-1: Bridge Site Selection Examples

Site Investigation: The extent and detail of the investigation of a bridge site depend largely on the class of bridge and the nature of the sites are available, the best way to investigate the site and the bridge is by determining the site's points of power and working on these points.[3] Figure (4-2)

The properties of the soil should be established to a degree of accuracy that is sufficient in terms of the design assumptions made in order to achieve that required reliability.

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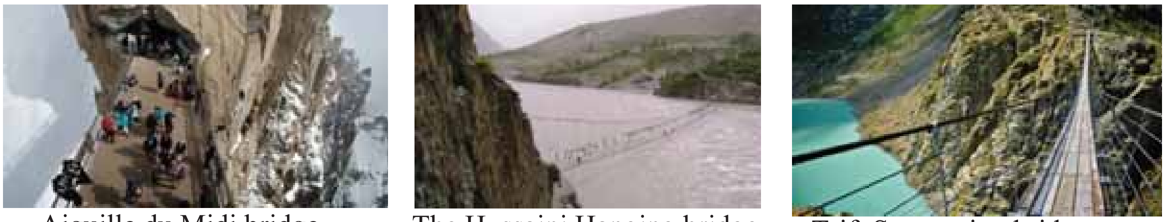
[1] -"Bridge aesthetics source book"- The American association of state highway and transportation officials - USA- 2010- p5.

[2] - http://www.earthporm.com/top-10-scenic-rides/

٣ - جورج صبحي راغب: "جماليات انشاء الكباري - رؤية خاصه من وجهة النظر المعمارية"- رسالة ماجستير- قسم عمارة- كلية الهندسة- جامعة القاهره- ١٩٩٨- ص٤٦٢-٤٦٦.



Aiguille du Midi bridge – France

The Hussaini Hanging bridge Northern Pakistan

Trift Suspension bridge – Switzerland

The Capilano Suspension bridge – Canada

The Canopy Walk – Ghana

Musou Tsuribashi bridge– Japan

Figure 4-2: Examples of Bridge Site Investigation[1]

It is essential that the bridge's substructure be designed to accommodate the subsoil and the type of structure, also the subsoil to be coordinated with geotechnical experts in order to optimize the expenditure in terms of risk.[2] Figure (4-3)

The Atlantic Ocean Road in Norway Dealing with natural determinates

Rhaetian Railway in Switzerland

Bixby Bridge in Big Sur, California, USA

Figure 4-3: Examples of Bridges Affected by Site Natural Delimiters[3]

4-1-2-The Context

A structure in an urban setting will have different requirements than one in more rural locations, especially if there will be pedestrians nearby or below. The bridge should fit into its surroundings. What is the nature of nearby land uses? Buildings? A bridge in an industrial area may warrant a different level of aesthetical design than a bridge located in a park or public place. Adjacent buildings and structures might lend existing architectural features that can be echoed in the bridge.[4]

4-1-2-1- Context Sensitive Design and Solutions:

Context Sensitive Design (CSD) is a process through which practitioners can apply techniques and considerations that will help shape a transportation project and yield design solutions which best serve the needs of the community.

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[1] - http://www.boxnewsbox.com/10-of-the-most-deadly-bridges-in-the-world/

[2] -"The appearance of bridges and other highway structures"- The highway agency -HMSO (Her Majesty's Stationery Office) - London- UK- 1996- p 20.

[3] - http://www.earthporm.com/top-10-scenic-rides/

[4] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook- Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA- 2009- p12.

Context Sensitive Solutions (CSS). Is any new or developed input from other sources than traditional local manuals to serve the needs of community.[1]

While many practitioners have been applying CSD/CSS principles for years, the topic was first formally described at the Thinking Beyond the Pavement Conference in Maryland in 1998. The purpose of CSD/CSS is to:

- Recognize that transportation projects have to be appropriate for the transportation need they are designed to address.
- Consider the context in which they will be constructed.
- Incorporate input from an interdisciplinary team comprised of project stakeholders.

In this way, the resulting project will be one of excellence and have the support of the community and project stakeholders.[2] Figure (4-4)

A bridge in Branch Brook Park, New Jersey accommodates multiple transportation needs- USA

El-mosher Tantawy Bridge- the Fifth settlement and resolving many traffic needs in different directions- Cairo

El-mosher Tantawy first design proposal (non constructed), resolving traffic and pedestrian needs- Cairo[3]

Figure 4-4: Context Sensitive Design and Solution Examples[4]

4-1-2-2-Relationship between Bridges and Road networks:

Roads Networks are considered one of the major factors affecting the urban planning because it affects land uses and connected neighborhoods. Bridges as a part of road networks components, have a big role to solve traffic conjunction problems and affect on land usage. As shown in table (4-1) the roads hierarchy AIA (American Institute of Architecture) Street Classification System, Bridges could be classified as a highway, boulevard or any other classification according to the bridge length, width, usage and speed. For example, Cairo Ring Road is supposed to be a highway, but because of informal surrounding buildings it became a boulevard.

4-1-3- The Constructed Delimiters (other Surrounded Bridges, Historical sites, Buildings, etc)

The bridge relates to surrounding constructed buildings and bridges, there are several relations between bridge and other constructed facilities:

- The bridge is under other constructed facility.
- The bridge comes through other constructed facility.
- The bridge is over other constructed facility.
- the bridge is beside other constructed facility.

Where a new bridge is adjacent to an existing one, it should be parallel and on an identical vertical alignment, but where this is impossible the difference should be constructed.[5] Figure (4-5)

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[1] - Susanna Massie: "Thinking beyond the pavement" -A National Workshop on Integrating Highway Development with Communities and the Environment while Maintaining Safety and Performance- 1998.

[2] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook- Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA- 2009- p29.

[3] - http://www.ahram.org.eg/Media/News/2015/3/9/2015-635615356496055762-605.jpg

[4] - http://www.nj.gov/state/njfilm/images/ess_Newark-Branch-Brook-Park-Essex-County-Parks-Park-Avenue-Bridge.jpg

[5]- "The appearance of bridges and other highway structures"- The highway agency -HMSO (Her Majesty's Stationery Office) - London- UK- 1996- p 16.

Table 4-1: AIA Street Classification System[1]

Classification	Description
Highway	A long-distance, medium speed vehicular corridor that traverses open country. A highway should be relatively free of intersections, driveways and adjacent buildings; otherwise it becomes a strip, which interferes with traffic flow.
Boulevard	A long-distance, medium speed vehicular corridor that traverses an urbanized area. It is usually lined by parallel parking, wide sidewalks, or side medians planted with trees. Buildings uniformly line the edges.
Avenue	A short-distance, medium speed connector that traverses an urban area. Unlike a boulevard, its axis is terminated by a civic building or monument. An avenue may be conceived as an extremely elongated square.
Drive	An edge between an urban and a natural corridor, usually along a waterfront, park or promontory. One side of the drive has the urban character of a boulevard, with sidewalk and buildings, while the other has the qualities of a parkway, with naturalistic planting and rural detailing.
Street	A small-scale, low speed connector. Streets provide frontage for higher density buildings such as offices, shops, apartment buildings, and roughhouses. A street is urban in character, with raised curbs, closed drainage, wide sidewalks, parallel parking, trees in individual planting areas, and buildings aligned on short setbacks.
Road	A small-scale, low speed connector. Roads provide frontage for low-density buildings such as houses. A road tends to be rural in character with open curbs, optional parking, continuous planting, narrow sidewalks, and buildings well set back. The rural road has no curbs and is lined with pathways, irregular tree planting and uncoordinated building setbacks.
Alley	A narrow access route servicing the rear of buildings on a street. Alleys have no sidewalks, landscaping, or building setbacks. Alleys are used by trucks and must accommodate dumpsters. Alleys are usually paved to their edges, with center drainage via an inverted crown.
Lane	A narrow access route behind houses on a road. Lanes are rural in character, with a narrow strip of paving at the center or no paving. While lanes may not be necessary with front loading garages, they are still useful for accommodating utility runs, enhancing the privacy of rear yards, and providing play areas for children.
Passage	A very narrow, pedestrian-only connector cutting between buildings. Passages provide shortcuts through long blocks or connect rear parking areas with street frontages. Passages may be roofed over and lined by shop fronts.
Path	A very narrow pedestrian and bicycle connector traversing a park or the open country. Paths should emerge from the sidewalk network. Bicycle paths are necessary along highways but are not required to supplement boulevards, streets, and roads, where slower traffic allows sharing of the vehicular lanes.

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1 - John Ray Hoke Jr: "Architectural Graphic Standards" 9th Edition-American Institute of Architects- USA -1996.

Saft Ellaban corridor - Egypt
New bridge near existing buildings[1]

Hakozaki bridge- Japan[2]
New extention of an existing bridge

Gate tower bridge A bridge is going through an Existing tower - Japan[3]

Figure 4-5: Constructed Delimiters Treatment Examples

4-1-3-1-Relationship between New bridges and Historical or Existing Bridge.

There are taken Considerations during Modification / Building new bridge near Existing bridge which should be followed by bridge's designer such as: Figure(4-6) and (4-7)

- The new bridge should be located so that the two bridges are seen as separate elements in the landscape and can be designed as separate entities, This can only be achieved through an appropriate horizontal separation.
- Distinguish New Work from Old in case of historical bridges or historical site: New work must be distinguishable from the old bridge. There are several means to achieve this by date stamping the new work so that it is identifiable, particularly where materials and form are carefully duplicated, by using new modern materials and forms to fit in sensitively, but differentiate from the old elements and forms of the existing bridge, by keeping a clear physical distance and sense of separation with the old bridge when building a bridge duplication, by avoiding pastiche (false imitation or mixture of styles) when designing a bridge duplication or connection to an old bridge.
- Respect the Setting bridges should respect their setting by: Preserving the curtilage, in this instance, the envelope around, below and above the bridge necessary to protect its heritage or cultural value.

  keep the curtilage as intact as possible and ensure that design changes of the bridge are sensitive to the character of that curtilage. Consider that the curtilage is also part of a wider setting.

  Respect the character of the heritage The character of the old bridge should always be respected whether duplicating, retrofitting or modifying a bridge of heritage

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[1] -By researcher

[2] -http://cob.cdcs.selu.edu/kwik-mind/U-anhly/Japantrafficsys/

[3] - http://www.amusingplanet.com/2012/01/gate-tower-building-with-highway.html

significance. <u>This can be achieved in different ways, depending on the scale of work to be carried out:</u>

- Respect the old bridge through adequate physical separation.
- Where possible, keep a sense of the scale of the old bridge, through protection of the major elements in its curtilage and the view points to the bridge.
- Where possible match the profile of the old bridge and keep the rhythm of the piers and uprights.
- Use form, materials and color that complement, but do not visually overpower, the character of the old bridge.
- Signage and interpretation signboards, in the agreed common style suitable for heritage bridges, should be used to support heritage bridge. Signage can also be used to explain changes to other culturally important bridges.
- Consider the relationship of modifications to the scale and character of the bridge, other elements and materials, the rhythm of existing uprights, and color.
- Carry out a visual analysis to ensure that the bridge modification fits into its built, natural and community context and provides a well designed solution which minimizes adverse visual impacts from all critical viewpoints.
- Keep painting up to date to prevent prolonged attack on the raw material, protect the bridge and its elements in the long term and maintain the aesthetic quality of the bridge.

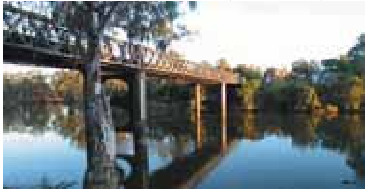
Where a new bridge is adjacent to an existing, it should be parallel and on an identical vertical alignment, but where this is impossible the difference should be contrasted.[1]


options to build a New bridges next to existing bridges in plan


In this adaptive re-use of an old bridge, the wrought iron lattice truss bridge was duplicated and incorporated into an adjacent cycle way


Modifications to Hinton Bridge over the Paterson River in Australia built in 1901


Distinguish new work from old Bridge, Australia


The bridge over the Murray River at Corowa has been carefully preserved


Preservation of bridges and Respecting the character of the heritage at Stonequarry Creek Bridge at Picton

Figure 4-6: Considerations during Modification / Building New Bridge Near an Existing Bridge

There are two cases when dealing with an existing bridge. As shown in table (4-2) the best concepts to deal with these historical or existing bridges are studied

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[1] -"The appearance of bridges and other highway structures"- The highway agency -HMSO (Her Majesty's Stationery Office) -London- UK- 1996- p.17.

The Iron bridge in England was built in the late 19th century and remodeled in 1991. It has a central bridge for pedestrians and a vehicular bridge on both sides

Figure 4-7: Adding a New Bridge Adjacent to an Existing One[1]

Table 4-2 Relationship between New Bridge and Historical/ Existing Bridge[2]

Build a New bridges next to existing bridges	Modifications and additions to heritage bridges and bridges of cultural value
• If accurate duplication is not possible an entirely different bridge design should be produced but very importantly, the designs should not compete but be complementary. • The bridges should either be parallel in vertical and horizontal alignment or curved in symmetry with the existing bridge. • Consideration should be given to matching the following elements: bridge height, pier spacing and pier alignment.  The Iron Cove Bridge  The proximity of the bridges over the Hawkesbury River at Brooklyn The two bridges are not separate but seen as one visual entity.[3]	This approach tends to be more applicable to modern bridges than older bridges, where technology and safety standards have changed and old design and construction skills lost or expensive to re-learn. The approach is basically to replicate the existing bridge design. It does not need to be exact but at least the following should be addressed: • Where possible the bridges should be parallel in vertical and horizontal alignment. • Spans and pier alignments should match. • Key aspects of the existing bridge such as pier dimensions, girder shapes, abutment locations, and lighting fixtures should be replicated. • In some cases details can be copied but this is not essential. If there are any concerns that the bridge cannot be closely duplicated then the new design approach should be considered.  On the Alfords Point Bridge, the duplication (right) adopted the bridge form in its entirety  Kobry Elquba bridge, Two different materials and structures leads to ugly shape - by researcher

A. The Impact of Historical Site on Bridge Design.

The bridges design is affected by designer's cultural back ground and the surrounding community heritage and own culture, Also bridge aesthetical items are taken from the

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[1] - https://rainprel.wordpress.com/2011/06/04/zaragoza-watching-time-go-by/

[2] -"Bridge Aesthetics Design guidelines to improve the appearance of bridges in NSW" - The Government Architects Office - RTA Operations Directorate- Bridge Section & RTA Road Network Infrastructure Directorate- Urban Design Section- New South Wales- Australia- 2003.- **P50-51.**

[3] - Judith Durpe and Frank O. Gehry: "Bridges: A History of the World's Most Famous and Important Spans"- Black Dog and Leventhal Publishers- New York- USA- 1997.-**p25.**

surrounding historical landmarks.

For example, Lambent bridge in UK affected by London heritage, England Also, Cairo university pedestrian bridge at Giza and adapted aesthetical items from Cairo university main dome.[1] As shown in figure (4-8)

Lambent Bridge- UK Cairo University bridge- Egypt

Figure 4-8: The Impact of Historical Site on Bridges design

4-1-3-2- Relationship between Bridges and the Surrounding Architectural/ Local Character:

A. The Local Culture and its Impact on bridge Design

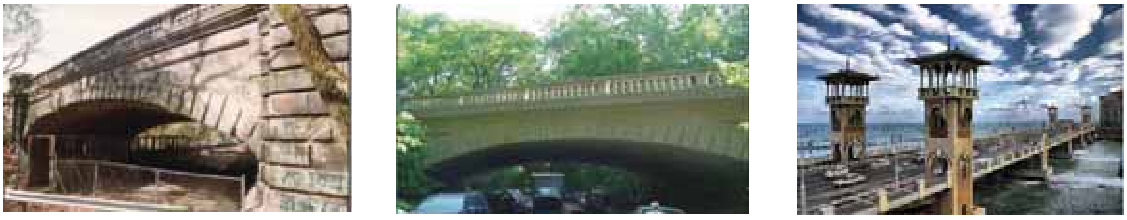
The local culture is considered one of the major factors affecting the bridge design. As an example of the effect of the surrounding local character on bridge is El-tunsi bridge.The impact of El-tunsi informal market on El-tunsi bridge. El-tunsi neighborhood is known as a big market of used furniture. When El-tunsi bridge was built, people constructed an informal slums under the bridge to show their goods. this market was burn twice on 2010 and 2013. Figure (4-9)

Figure 4-9: The Impact of El-tunsi Informal Market on El-tunsi Bridge- Egypt.[2]

As shown in figure (4-10) examples of bridges which followed the local architectural character are studied.

٢- حسام الدين محمد مجدي عبد القوي محمد: تحت الكوبري كفراغ عمراني عام في المدينة المصريه-رسالة ماجستير, قسم عمارة- كلية الهندسه- جامعة القاهره-٢٠١١- ص ١٦-١٩.

2 - http://mapio.net/s/66924761/, http://www.vetogate.com/874634 , http://www.youm7.com/story/0000/0/0/-/244191, http://www.vetogate.com/874634 and http://www.el-balad.com/1292915



This new bridge was designed to be a faithful reproduction of the handsome but severely deteriorated 1912 arch bridge Indianola Avenue over Iuka Ravine Historic District, Columbus, Ohio.USA.[1]

Stanly bridge at Alexandria - Egypt, which represent the Alexandria heritage but using modern materials[2]

Figure 4-10: Bridges Examples Followed the Local Culture.

B. The Surrounding Architecture Character

There are Two Ways to Deal with the Architectural Character: Either to design bridges that follow the local culture and use same materials, character and to be fully compatible with the surrounding culture Or to design bridges Completely contradictory to the local culture to be an optical attraction point In case of the inefficiency of using the traditional materials to construct a bridge.[3]

As shown in figure (4-11), the architect kisho kurokawa who designed the two offices buildings and connected them with La defense bridge which have a modern shape of the traditional Japanese arch bridge to carry pedestrians between two buildings. He also respected the surrounding architectural. Also, As shown in figure (4-12) characterThere are some examples of Chinese, Iranian and Japanese bridges. These bridges architectural character are followed surrounding architectural character to look as a one entity.[4]

La Defense Bridge Homogenization with the surroundings - by Kisho Kurokawa - Paris, France[5]

Figure 4-11: Examples of Bridges design according to surrounding architectural character

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[1] - http://homedesignlover.com/landscape-designs/japanese-inspired-garden-bridges/

[2] - http://safarinewseg.com/wpcontent/uploads

[3] - Frederick Gottemoller: "Bridgescape - the art of designing bridges"- john willey and son - New York, USA- 1998- p77-78.

[4]- David Bennett: "The architecture of bridge design"-1st edition- Thomas Telford house publications- London-UK-1997-p164,165.

[5] - https://www.flickr.com/photos/hdaparis/10942405644

Japanese traditional Garden pedestrian bridges

As shown in these examples, use Wood and surrounding materials to construct a traditional pedestrian bridge in different gardens in Japan.

Different examples from different Japanese parks.[1]

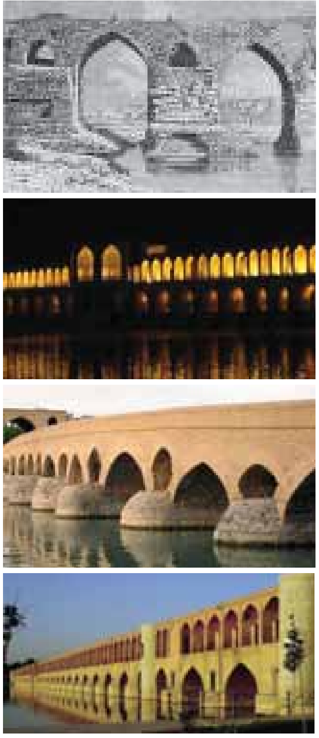
Chinese traditional wooden and arch bridges

As shown in these examples, Using local character and local materials to construct these different bridges.

Different examples from different Chinese parks.[2]

Iranian Old bridges

As shown in these examples, using same structure system, same materials in most of old Iranian bridges



Different examples of Iranian bridges [3]

Figure 4-12: The Impact of Architectural character on Bridge Design

4-1-3-3-Relationship between Bridges and Historical Facilities (Cairo Ring Road and the Pyramids Boundary):

On 5th of October 1994 the independent British newspaper published an article by Nicholas Schoon showing the dangers on pyramids by the ring road which was 3.5km far from pyramids. The bad effects of ring road passes near historical pyramids were:

- Bad visual effects on pyramids, because the Ring Road was considered as an optical barrier.
- The pollution from traffic which have bad effects on pyramids.
- Expected slums growing around ring road which already happened.
- Because of the pyramids plateau (20 km around Giza pyramids) is considered as natural reserve.

Many articles published in newspapers, UNICCO conferences and governmental meetings were held on 1994 - 1995 to discuss the problem and UNICCO proposed a solution which was refused by the government because its bad affect on Feisal and Elharam streets, Also another solution published on El-Akhbar newspaper on 16-4-

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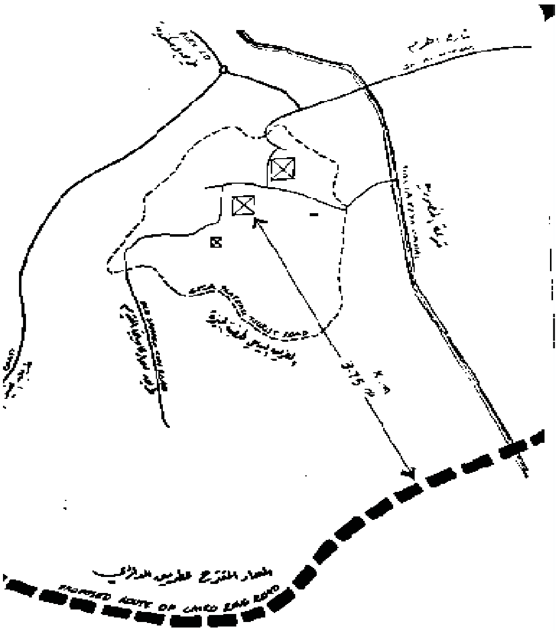
1 - http://lifeblog79.blogspot.com.eg/2012/03/wind-and-rain-bridge-china.html

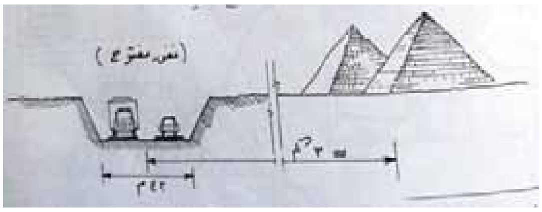
2 - http://www.123rf.com/photo_26794644_asia-china-xi-an-datang-lotus-park-lake-chinese-traditional-architectural-landscape-ancient-bridge-a.html

3 - https://bridgehunter.com/oh/franklin/2561433/

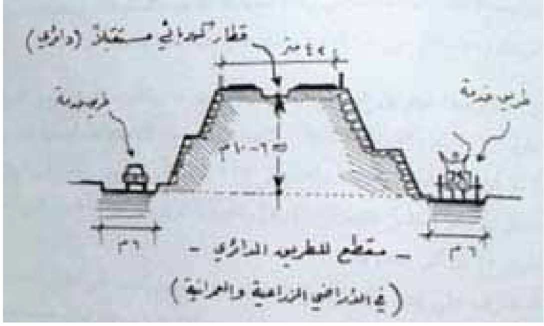
1995 to built an open tunnel. But all these solutions were refused because of the extra cost. The Ring Road was built as we see it these days with adding some rules to constrict the slums growth which were not enough, the expected slums were grown with bad view and pollution problem already have had with a bad effect on pyramids .[1]figure(4-13) and figure (4-14)

Figure 4-13: The Ring Road - Marryotia Corridor and Pyramids Boundary.[2]





The proposed solution instead of ring road which was published in Elakhbar 16-4-1995



Expected parallel road near ring road to serve the expected slums

Cairo ring road near Giza pyramids (preliminary drawings and proposed solutions)

Figure 4-14: Cairo ring road near Giza pyramids drawings.[3]

4-1-3-4-Practical Tips When Historic Bridges or Historic Settings are Involved:

The Standards call for the use of contemporary design that clearly differentiates new construction from the old. but new work has to mimic the old. As a conclusion, the main

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١ - مقال بعنوان (اوقفو هذه المهزله - الطريق الدائري خطر يهدد الاهرامات - ضجه في صحف و اذاعات العالم و اليونسكو تحذر)- الهام ابو الفتوح - جريدة الاخبار- اد عباس زعفراني - لقاء صحفي مع جريدة الاخبار ٦-١٢-١٩٩٤.

2 - by researcher and Google earth

٣ - عبد المنعم احمد شكري السعيد : "تاثسر شبكات الطرق علي استعمالات الاراضي" - دراسة تحليليه للطريق الدائري حول القاهره الكبري - رسالة ماجستير - قسم عماره - كلية الهندسه - جامعة القاهره- ١٩٩٥-ص ٢٠٢.

rule of replacing new bridge with historical one or constructing new bridge in a historical place is "changes that create a false sense of historical development shall not be undertaken and contemporary design for alterations and additions shall not be discouraged when such alterations and additions are compatible with the size, scale, color, material, and character of the property, neighborhood or environment." Unless the new design is going to be a faithful reproduction of what is being replaced, which is rarely the case, national preservation guidance for working with historic resources calls for using contemporary design that is compatible with the historic context, not modern bridges decorated to look like something old.[1]

4-1-4-Living Bridges

To discus living bridges we have to study living bridges development from the past to the future:

4-1-4-1-living Bridges from the Past to the Future

The term "Living Bridges" start to take place to confirm the hidden role of bridges to human activities and social life within its area and around [2]. Living bridges are multi-functional bridges that People can live, can Work, and enjoy quality landscape in one place. Occupation of a bridge makes it both a building and a bridge, which becomes another type of architecture. A precise English word for this type of bridge is called 'inhabited bridge', which can be broadly defined as a bridge that not only provides a link between two points for pedestrian and vehicular traffic but also supports a superstructure that can serve residential, commercial, industrial, religious or defensive purposes, thereby creating a continuity of the built-up area from one bank to another.[3]

Living on bridges is nothing new. In medieval times, the inhabited bridge sometimes could be described as a result of urban fabric extension. As a result, over time, the limited space in the city area became crowded. The river space, where the most central activities are found, enabled an inhabited bridge.

Living Bridges in Amsterdam were residential structure designed and built as social housing to accommodate 600 dwellings, also Ponte Vecchio in Florence, Italy was A bridge that connects Florence over the Arno river containing Shops and stalls cover the bridge.[4] Figure (4-15)

Figure 4-14: Medieval living bridges (Ponte Vecchio bridge - Florence)

Figure 4-15: Examples of Residential living bridges.[5]

The Hamburg Bridge represents a new dimension in bridge-building. This will be the first time that a truly urban, bustling pedestrian-friendly bridge of these dimensions including green areas has been established across water.

The scale of recent inhabited bridges has been increased many fold by comparison with the historical ones. However, they share the same features: the utilization of technology and the integration of construction and building.[1] such as Modern Living Bridge in

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[1] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook- Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA- 2009-p53.

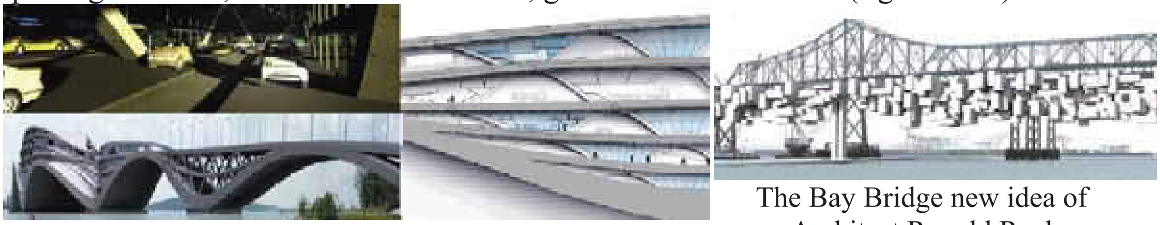
[2] - Marc Mimram: "Living bridges"- Paper- Lafarge publication-France- 2008 at http://www.lafarge.com/

[3] -Peter Murray: "Living bridges- The inhabited bridge, past, present and future"- Anne Stevens Prestel- New York- USA-1996-p53

[4] - Lloyd Alter, (2009). Bridges are for People: 7 Bridges that people live and work on. www.treehugger.com/sustainable-product-design.

[5] - www.livingbridge-hamburg.de

Singapore-Malaysia, and architect “Ronald Rael” proposal for the Bay Bridge that connects San Francisco to Oakland to create a linear park with bike and pedestrian access, housing and social activities, such as theaters, commerce and museums, plus sporting facilities, in addition to orchards, gardens and meadows.[2] (figure 4-16)



Modern Living Bridge in Singapore

The Bay Bridge new idea of Architect Ronald Rael

Hamburg Living Bridge Proposal

Figure 4-16: Examples of living bridges proposals.[3]

Some bridges now are subject to unplanned uses as well. The areas underneath some bridges have become makes shelters to homeless people, and the undersides of bridges all around the world are spots of prevalent graffiti. Living Bridges now in many developing countries which suffer from crowded and lack of open spaces can be named romance Bridge, family bridge, poor bridge, protesting bridge, and even suicide.

Today’s bridges do not contribute to urban life apart from traffic needs. Therefore, rethinking the role of urban bridges appears necessary. To achieve that kind of space features such as setting, spatial interaction between the bridge and the city and routes need more attention.[4]

4-1-4-2-Urban Riverfronts from Neglection to Attention

Many of the new world riverfronts try to make public access the overall goal of any regeneration process, to give the public the opportunity to return back and access their riverfronts. They provide extensive new areas of high-quality public open space, they also establish new linkages between existing inner-city areas, intensifying the interconnectedness of urban functions, making design guidelines address the treatment of existing functional barriers and create immediate physical, visual, and auditory access to the riverfront.

4-1-4-3-Bridges and Public spaces (Global Examples)

Some international examples will be reviewed to learn some lessons of how to create an memorable riverfront’s spaces on bridges. [5]

A: Galata Bridge, Istanbul (lower deck idea as restaurant and shops) with 3

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[1] - Daicai Lai: "Bridge the border-a border crossing complex across the Johor Strait"- Master thesis- Unitec Institute of Technology-2011-p80.

[2] -Lloyd Alter : "Bridges are for People-7 Bridges that people live and work on"- Article-2009- at www.treehugger.com/sustainable-product design.

[3] - http://www.treehugger.com/sustainable-product-design/bridges-are-for-people-7-bridges-that-people-live-and-work-on.html

[4] - Stephan E.& Stefania C: "The Neglected Aspect of Urban Bridges as Public Spaces"- IABSE Congress Report- 16th Congress of IABSE- International Association for Bridge and Structural Engineering-Lucerne- USA-2000-p64- 72.

[5] - George Andrew: "Take Me to the River- Designing the Intimate Waterfront"- Master thesis- MSC of Landscape architecture-Virginia polytechnic institute and state university -USA-2006-p50.

vehicular lanes, tram line and a sidewalk in each direction, the bridge is a place for fishing and socializing, for eating and drinking. The lower deck of the bridge has a lot of restaurants, while the top deck is a popular spot for fishing from. Figure(4-17)

Figure 4-17: International Example of Living Bridge (Galata Bridge)[1]

B: The Banpo Bridge: (Idea of double deck bridge, lower as pedestrian and fountain show on the upper) is a significant bridge in downtown Seoul over the Han River, South Korea, the concept of this bridge is a "double deck bridge", the lower deck located close to the waterline. This deck incorporates pedestrian and bike paths that provide easy access to the Banpo Hangang Park. The fountain is programmed to play several shows during the day and night. Also Banpo bridge is the longest fountain in the world.[2] (figure 4-18)

Figure 4-18: Examples of river front bridge (The Banpo Bridge)[3]

C: Helix-bridge (idea of parallel pedestrian bridge): The world's first double helix curved bridge in Marina Bay pedestrian bridge, it is set to transform Singapore's city landscape form, lighting feature is an important of this bridge. programmed to play several shows during the day and night.[4] Figure (4-19)

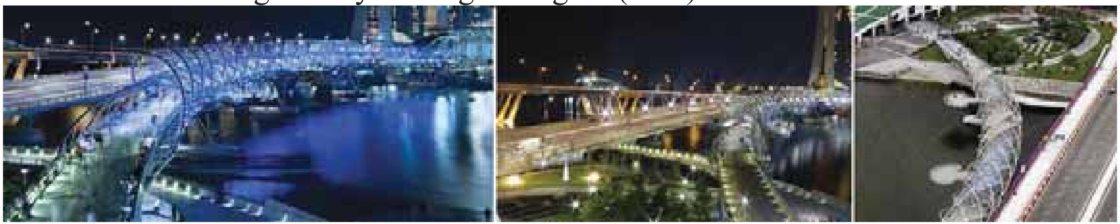

Figure 4-19: Example of pedestrian river front bridge (Helix bridge)[5]

D: High Main Street Bridge (viewers terraces idea) over Miami River Hamilton, Ohio maintained traditional structure and added concrete curved terraces. figure (4-120)

Figure 4-20: Pedestrian river front bridge (Bridge over Miami River Hamilton, Ohio)[6]

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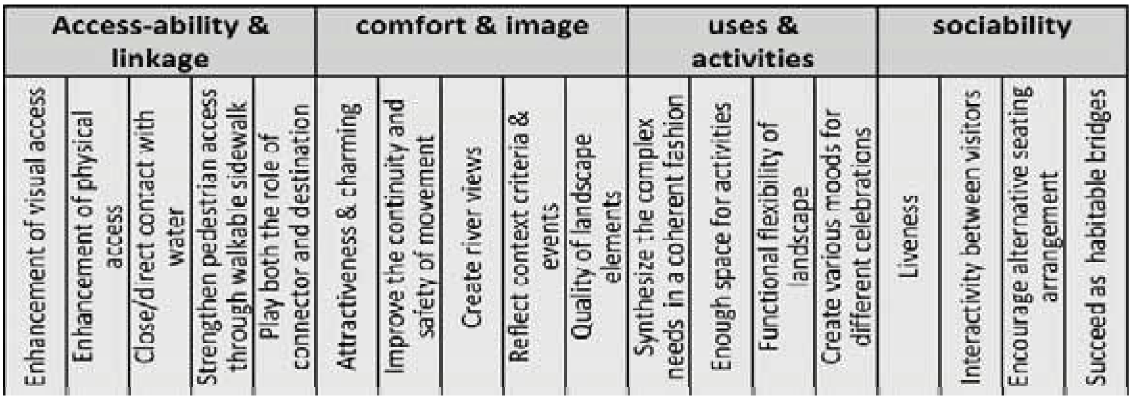
[1] - www.urbanwaterfront.blogspot. com/2011/05/thicken
[2] - http://www.theseoulguide.com/sights/bridges/banpo-bridge/
[3] - ww.en.wikipedia.org/wiki/Banpo_Bridge
[4] - www.livingpod.com/lifestyle/architecture/double-helix-curved
[5] - www.livingpod.com/lifestyle/architecture/double-helix-curved
[6] - http://bridgescape.net/web/bridges/imgs/hamilton4.jpg

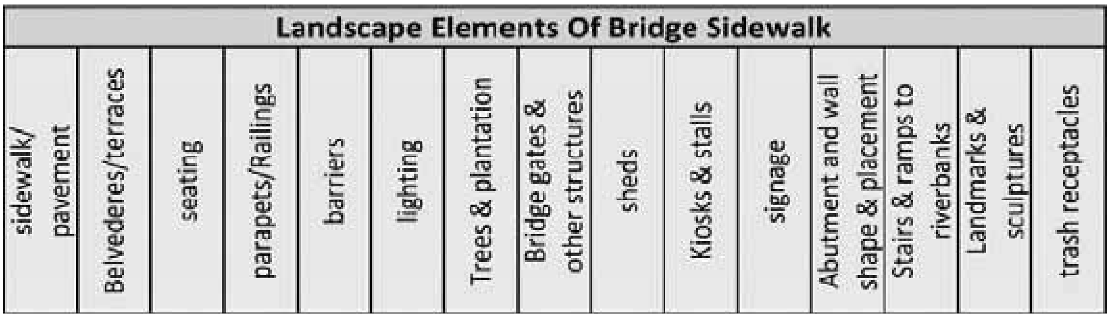
From the previous examples and many others we can suggest evaluation criteria of riverfront’s bridge-scape, also suggest Bridge-scape elements to help when creating or redesigning riverfront’s bridge-scape. Tables (4-3) and (4-4).

Table 4-3: Proposed evaluation criteria of riverfront’s bridge-scape.[1]



Access-ability & linkage					comfort & image					uses & activities				sociability			
Enhancement of visual access	Enhancement of physical access	Close/direct contact with water	Strengthen pedestrian access through walkable sidewalk	Play both the role of connector and destination	Attractiveness & charming	Improve the continuity and safety of movement	Create river views	Reflect context criteria & events	Quality of landscape elements	Synthesize the complex needs in a coherent fashion	Enough space for activities	Functional flexibility of landscape	Create various moods for different celebrations	Liveness	Interactivity between visitors	Encourage alternative seating arrangement	Succeed as habitable bridges

Table 4-4: Elements of riverfront’s bridge-scape. [2]



Landscape Elements Of Bridge Sidewalk														
sidewalk/ pavement	Belvederes/terraces	seating	parapets/Railings	barriers	lighting	Trees & plantation	Bridge gates & other structures	sheds	Kiosks & stalls	signage	Abutment and wall shape & placement	Stairs & ramps to riverbanks	Landmarks & sculptures	trash receptacles

4-1-4-4-Riverfront’s Informality in Cairo

Over the past few decades, many of the Nile's riverfront has been systematically occupied by an assortment of private projects. Co-operatives or syndicates of many kinds, private owners and some governmental companies have occupied parts of the riverbank and built private clubs, cafeterias, restaurants or the like, where only members of the co-operatives or companies, or people who can afford private locations are allowed inside. This unplanned privatization of the riverfront has physically, visually and symbolically separated the Nile from the general public.[3]

However, in recent years the Nile riverfront in the city of Cairo has experienced numerous changes in the form of designed projects to take advantage of the river's potential for attracting visitors and users by accommodating their various leisure and recreational, to reconnect its people with the river and to freely access the riverbanks.[4] still physical and visual blockage made by insensitive design of structures blocking the view of the Nile from the main street and sidewalk.[5] Figure (4-21)

As an example the most famous Nile River bridges over in Cairo are Kasr Elnile bridge (1875),6th of October bridge (1980), Abbas bridge (1908) and University bridge (1957) . Figure (4-22)

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[1] - Usama Nassar, Ahmed Fathy and Ahmed Saleh: "living bridges on the river Nile-a vision to enhance urban space informality and usage Paper- 2012.

[2] - Same previous reference..

[3] - Hesham.Gabr: "Use and misuse of public open space along the Nile- Waterfront in Coastal Management"- Paper-2004.

[4] - Hesham. Gabr: "Perception of urban waterfront aesthetics along the Nile in Cairo- Egypt- Coastal Management"- Paper-2004.

[5] - Usama Nassar, Ahmed Fathy and Ahmed Saleh: "living bridges on the river Nile-a vision to enhance urban space informality and usage Paper- 2012.

Figure 4-21: Current situation of Nile riverfront[1]

1- 6th of October bridge 2- Qasr-Elnile bridge 3- University bridge 4- Abbas bridge

Figure 4-22: River bridges in Egypt.[2]

- **Activities and events on bridges**

The crowd on sidewalks became uncomfortable and to raise concern for public safety. Activities on Nile bridges varies from walking, exercising, sitting in front of the river, having popularity lower-class Food and Drink, fishing, cycling and celebrations like weddings. But, unfortunately most of these activities are informally uses on Nile river bridges, unlike most of universal bridges with view as Galata bridge, turkey. The Turkish government built under Bridge floor for using it as a restaurants, cafe shops and other public activities locations.[3] (figure 4-23)

4-2-Bridge as a Whole Aesthetical Design

The aesthetic impact of a bridge is not merely the impression created by a bridge's surface features, such as color, materials, ornamentation, etc. Rather, it is the effect made on the public by every aspect of the bridge its individual parts as well as its whole. Every decision made about the structure's overall design has an aesthetic consequence. [4]

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[1] - By researcher

[2] - Google earth

[3] - Usama Nassar, Ahmed Fathy and Ahmed Saleh: "living bridges on the river Nile-a vision to enhance urban space informality and usage Paper- 2012.

[4] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 32.

Figure 4-23: Different Informal Uses of Riverfront Bridges (Celebrations, Wedding Ceremonials, Fishing, Walking and other Social Activities) in Abbas and Elgamaa Bridges.[1]

Bridge as a Whole Aesthetical Considerations:

The influence of the bridge project on the natural, manmade environment , on the adjacent communities, urban and rural surroundings, existing bridges within the transportation corridor or immediate vicinity.

- Bridge structure type should be based on location compatibility, design suitability, safety, and economics Recommendation of an architectural design direction to establish aesthetic and visual suitability for corridors or site locations.
- Bridge design details such as railings, medians, abutment types, pedestrian protection, lighting, walkways, bridge heads, signing attachments, etc should be compatible with bridge site.

Public Visibility and Community Involvement

- The visibility of a highway bridge, from both the structure itself and the roadway, must be considered during design. This includes assessing the primary and secondary viewpoints, the numbers of individuals viewing the structure and the duration of view. Structures that have a high visibility or are located in an area of visual, historic, and cultural significance, warrant more attention to aesthetics than do their less celebrated counterparts.
- Bridges may also function as local or regional landmarks, gateways to cities, or symbols for communities. People want to be proud of where they live and they take an interest in the appearance of property they own, Bridges form an important part of an area's public environment, the prominence of landmark structures can have an enormous impact on the impressions created of an area or community. [2] Figure (4-24)

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[1] - By researcher

[2] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p 32

Manhattan bridge- 1901 George Washington bridge-1931 Verrazano-Narrows bridge-1969

Queens Boro bridg-1909[1] Brooklyn bridge -1883 Hell Gate bridge - 1916

Figure 4-24: New York bridges as a city's landmark[2]

4-2-1- Bridges Aesthetical Considerations According to Bridge Site

Here are most important factors affecting on bridges design (according to bridge's site)

4-2-1-1-Bridge Location (The Nature the of the Site)

A bridge built in an urban area is different than a bridge built in a rural area, Here are some guidelines for Bridge aesthetical considerations according to the selected bridge site (bridge in landscape and bridge in urban site)

A. Bridge in the landscape

- Hiding the bridge in the landscape, by reducing its size and screening it. this approach while suited to smaller bridges, does not work on larger more visible ones.
- Making the bridge as distinctive as possible to contrast and stand out in the landscape. this approach can be expensive and is perhaps better suited to urban situations.
- Making the bridge as simple and elegant as possible to complement the natural landscape or urban setting. this approach is a practical, cost effective objective for overpasses and larger bridges and can lead to good looking bridge solutions.
- The complexity of a bridge should be minimized in a rural setting.
- Complexity tends to attract the eye and compete with views of the landscape. A simple structure frames the landscape and provides an aesthetically pleasing contrast
- with the natural textures of the backdrop.
- Bridges with a horizontal form are generally preferable to bridges on a grade over flood plains and significant expanses of water.
- Natural vegetation should be protected and augmented The aesthetic value of a bridge will be greatly enhanced if the natural bush land around the bridge is protected and recovered.
- By the careful sitting and design of the bridge and approaches, so that significant stands of existing vegetation are retained.
- By minimizing the footprint of the bridge (pile caps, abutments) so that the retention of local vegetation is maximized.
- By minimizing the presence and extent of intermediate structures and hard surfaces between the bridge and landscape.
- By recovering local habitat, in the landscape around the bridge, through careful

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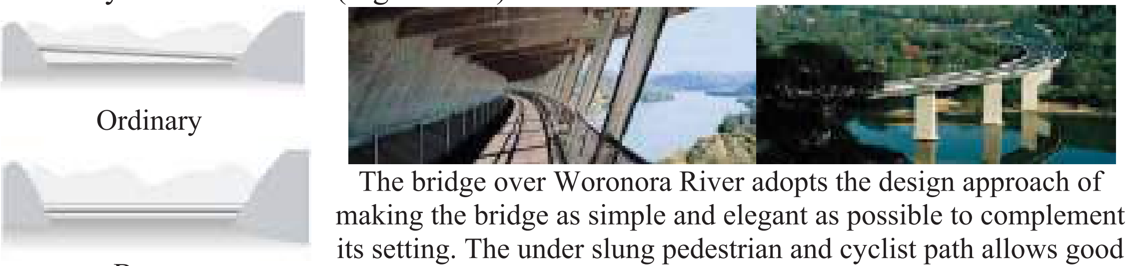
[1] - http://www.nyhabitat.com/blog/2013/08/19/top-5-bridges-new-york/

[2] - http://nyc-architecture.com/TEN/TEN-Bridges.htm

- design of earthworks and planting and the selection of endemic species grown from locally collected seed.[1] (Figure 4-25)



Ordinary

Better

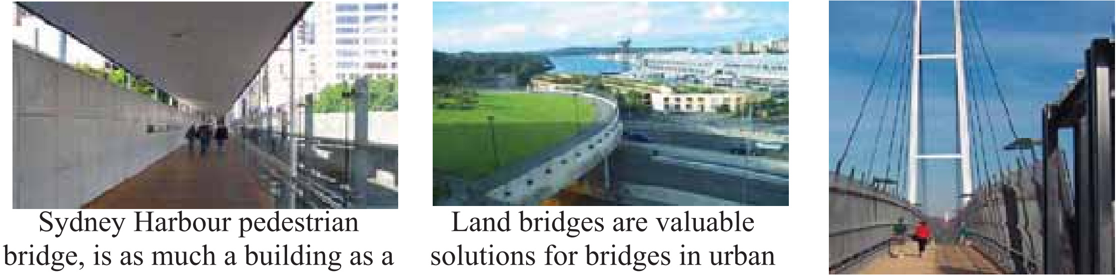
The bridge over Woronora River adopts the design approach of making the bridge as simple and elegant as possible to complement its setting. The under slung pedestrian and cyclist path allows good views out over the landscape.

Figure 4-25: Bridge design to advantage from the Surrounding View[2]

B. Bridges in Urban Settings

Whatever the size and function of the bridge in an urban setting, it needs to be considered as a piece of the built environment as well as a bridge structure. Some design considerations which could help to deliver benefits to the local communities are:

- Creating a landmark structure which complements or contrasts with its visual catchment.
- Maximizing views from and throughout the bridge to the local urban setting.
- Designing a well proportioned, neat and pleasing structure.
- Respecting locally valued structures, their cartilages, local styles and materials.
- Ensuring the spaces under the bridge are not dark, degraded and unsafe. Figure (4-26)



Sydney Harbour pedestrian bridge, is as much a building as a bridge. With glazed views south and windows to the north. (Australia)[3]

Land bridges are valuable solutions for bridges in urban areas (Australia)[4]

Dean Street pedestrian bridge in Albury.It forms one focal point of the Dean Street axis, the other being the memorial[5]

Figure 4-26: The Affect of Urban Settings on Bridge Design

4-2-1-2-The Crossed Obstacle by the Bridge

General Aesthetical and Structural Guidelines according to Crossed Obstacles.

Bridges are organized into groups based on the types of situations which occur frequently. The designer should find the guidelines given in each category consistent enough with the others that they can be combined. As shown in tables:

- Table (4-5): Bridge aesthetical considerations according to the selected site (Vehicle/ Highway bridge Over Highway)
- Table (4-6): Bridge aesthetical considerations according to the selected site (Bridges over Valleys or Deep Highway Cuts)
- Table (4-7): Bridge aesthetical considerations according to the selected site

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[1] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 36-40.

[2] - http://www.rms.nsw.gov.au/projects/planning-principles/centre-for-urban-design/achievements/creative-solutions.html

[3] - http://www.topentity.com/woronora-river-bridge/

[4] - http://www.cmnzl.co.nz/assets/sm/3630/61/0099-E26Hughes.pdf

[5] - http://www.visitsydneyaustralia.com.au/domain.html

(Bridges over Waterways)
- Table (4-8): Bridge aesthetical considerations according to the selected site (Viaducts and Long Interchange Ramps)
- Table (4-9): Bridge aesthetical considerations according to the selected site (Highway bridge over Railroad and Railroad Bridge over Highways)
- Table (4-10): General Bridge aesthetical considerations at any site

4-2-1-3- Bridges Interchanges

Interchanges need special design considerations since several structures may be visible at one time. They may even be physically linked together with retaining walls and/or noise walls. Increased functional complexity tends to create visual confusion and disorder.

General Aesthetical Considerations for Bridges Interchanges.

- Various structures having different requirements can be visually integrated by using uniform details and uniform structural systems that will provide unity and harmony. This requires close coordination between the designers of the individual structures, along with the application of a comprehensive design theme utilizing common elements. These consistent features serve to improve the drivers' psychological comfort.
- Interstate segments and major interchanges offer opportunities for economy through repetition. Repetitive use of architectural treatments for bridge columns, piers, abutments, and architectural detail allows contractors to reuse formwork, thus reducing the project cost. Figure (4-27)

Retaining walls and bridge elements share common visual design elements, interchange Minnesota

Uniform details minimize confusion of complex interchange, Duluth, Minnesota

6th of October bridge - Abdelmenem Riad square - Bridge dealing with roads and building[1]

Figure 4-27: Example on bridge interchanges

4-2-1-4- Scenic/Environmentally Sensitive Sites

Sites having outstanding natural beauty or spectacular viewpoints demand a structure that responds to the site either by blending in with the surroundings or by dramatically contrasting with the surroundings.

Designers should be aware of the viewers' sensitivity to visual details, character, and quality of the structure. On a pedestrian bridge, for example, viewers are more aware of scale and detail than they would be on an interchange bridge. The designer also needs to consider the viewers' expectations of the setting. For example, the viewer expects a bridge crossing a large body of water, or deep ravine, to reflect the unusual requirements of the site. The built and natural environment should be made as visible as possible through the bridge. Minimize the profile of a bridge to allow the landscape setting to dominate the view and be appreciated from all viewpoints.[2] (figure 4-28)

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1 - http://www.cairoportal.com/Content/Upload/large/320151223534.jpg

2 - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 32.

Natural beauty of site reflected in bridge type and materials, Black Hills National Forest, South Dakota

On the pedestrian bridge over The Boulevard in Strath field the placement of the girder to the side of the piers/ lift shafts allows for good district views out from the ends of the bridge.

The sweeping form of the Sea Cliff Bridge, north of Wollongong, with two-rail parapet provides panoramic views

Rock foundations permit arch bridges. Reichenau Bridge, Switzerland.

Having pedestrians on a bridge suggests the addition of overlooks. Upper Middle Road over 16 Mile Creek, Ontario.

Figure 4-28: Example on Scenic/Environmentally Sensitive Sites.[1]

4-3-1-5-The Influence of Context in Bridge Design

The choice of bridge structure is affected by many contextual factors that include the following:

- Influence of span required and the alignment of the bridge as part of route option.
- Topography and geology.
- The Context and bridge function
- The visual presence of the structure and the character of the area.[2]

1 2 3

1- Short to medium span bridges generally use pre stressed concrete girders Karuah Bypass,2- medium span bridges generally use post tensioned box or incrementally launched girders (Robinvale, Muray River) and medium to long span bridges generally use balanced cantilevered girders 3.Nearby land uses must be considered 4- Clearwater Memorial Causeway, Clearwater, Florida.[3]

4

Figure 4-29: Influence of Context on Bridge's Design

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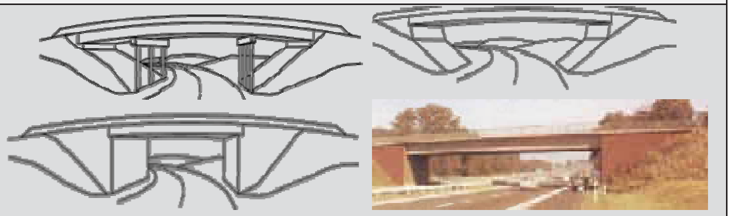
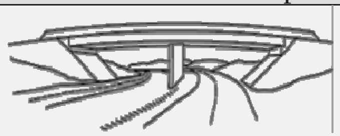
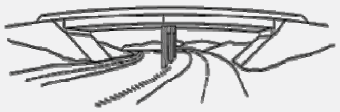
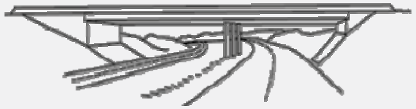
[1] - https://www.theguardian.com/artanddesign/australia-culture-blog/gallery/2014/oct/02/twelve-beautiful-australian-bridges-in-pictures

[2] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p31-32.

[3] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook- Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA- 2009- p12.

Table 4-5: Bridge aesthetical considerations according to the selected site (Vehicle/Highway bridge Over Highway).[1]

<table>
<tr><td colspan="3">Determinants of Appearance: Bridge should be kept simple, with simple lines and shapes, few different materials, and with all parts in clear relationship to one another. These bridges seen by people during their speed movement, At 100to 150 meters the only parts clearly visible are the features of the elevation view. The following elevation features will determine the visual impression created by the structure: The parapet and girder fascias, the wing walls of the abutments, the end elevation of the pier (height and shape), the number of spans and their proportion and the bearings and bearing pads, when dominant.</td></tr>
<tr><td rowspan="2">Determinants of appearance</td><td>Single span structure</td><td><u>There are two proposals to deal with bridge abutments:</u>
1: Eliminate the side piers and move the abutments back down the slope to a point set by safety clearances, structural economy, and appearance. and it will make the bridge appear shorter.
2: Build a vertical abutment on the road limits, Minimal clearance, high abutments from the early days of highway bridge building. (worst proposal)

<u>Design considerations</u> The principles of abutment placement are the same as for the single-span structure. •Pier placement is generally determined by the centerline of the under-roadway median. That leaves pier shape and superstructure shape as additional elements to deal with. •Sloping abutments outward may make the bridge appear longer and also serve to deemphasize the abutment height.</td></tr>
<tr><td>Double and treble span structure</td><td>• Minimize the end elevation of the pier cap by keeping the vertical dimension significantly smaller than the horizontal, by using a keystone shape, The effect is to make the cap seem more a part of the girder
• Maximize the overhang (the amount of slab cantilevered beyond the fascia girder), which should reduce the overall length of the piers.
• Maximize the girder spacing, which may reduce the number of columns, (the girder spacing should be evaluated for maintenance of traffic for future deck replacement).
• use one column per girder or girder pair, which may eliminate the pier cap as an element. Move the abutment down the side slope if this allows the elimination of the side pier altogether.

A simple wall pier, a good solution

Pier cap recessed behind front column

Using one pier column for each girder and placing the wing walls parallel to the upper roadway are good techniques

This bridge illustrates the unbalancing effects of two different abutment heights
•Integrate the pier cap in the superstructure, which eliminates the pier cap as a visual element as well as all but two of the columns. an aesthetic viewpoint, to keep them parallel to the upper roadway Straight walls which simply bisect the angle between upper and lower roadway, although the most economical solution, should be avoided, if possible, because they create a major object unrelated to either roadway and they create triangular areas of landscaping top and bottom which are hard to plant and maintain.</td></tr>
</table>

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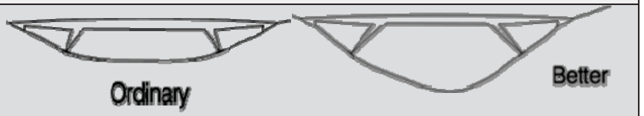
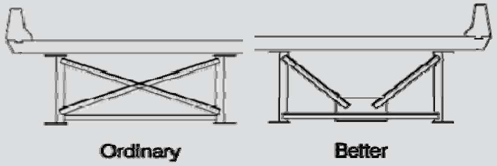
[1] -" Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p,VII-1

Table 4-6: Bridge aesthetical considerations according to the selected site (Bridges over Valleys or Deep Highway Cuts).[2]

Determinants of appearance	**Consider the possible points of observation:** • Roadways, trails, dwellings, etc. provide viewing locations underneath • The overall layout of the approach roadways shall be carefully considered. • Important viewpoints may be miles away. **The following major features of the bridge are likely to determine the visual impression:** •The shape of the basic horizontal and vertical geometry Keep the bridge on vertical and horizontal tangents, or on long continuous curves if possible •Decisions concerning the type of superstructure should always have economics and maintenance as prime considerations. An economic bridge can still be visually exciting • Pier placement, which relates also to the number and shape of the span openings • Parapet shape, superstructure depth and abutments are generally not as important due to the height and length of this type of bridge. • Dynamic visual impressions of arches and frames at prominent locations may offset additional economic costs Sufficient height is required to develop these bridge types visually and structurally.
Arches and frames	**For arches:** At the crown, the arch rib should just touch the floor system. Keep deck supports similar over the whole length of the bridge. Try to keep symmetry. **For frames:** Get enough slant on the legs to take full advantage of the visual (and structural) potential of this form. Carefully study the proportions of the frame legs versus horizontal and ratio of span lengths to ensure a pleasing shape. **For both arches and rigid frames:** Try to find natural locations on the valley walls (such as a rock outcropping) or cut side walls (as on a bench) to place the springing. Keep sway bracing and floor system to a minimum number of members that are simply arranged and in a clear and consistent relationship to the main members. Take advantage of structural needs (stiffeners, bearing plates, etc.) to develop attractive details which accentuate the points of stress concentration and transfer.  The dynamism of an arch or rigid frame in these situations are elegant  The importance of height to a rigid frame  Proportions are critical to the design of a rigid frame
Multigirde	Use hunched girders where possible. Transition to different girder depths using tapered webs Steel girder superstructures are frequently used for bridges over valley and highway cuts. Since the spans will often vary in length over the bridge, it may be necessary to change girder depth, provide haunches, or both .  superstructure rests on piers & flows as a continuous ribbon.
View	Consider view from the underside if appropriate. Paint steel a light color to help reflect light to the bridge underside. Keep bracing to a minimum using fewer, larger members rather than many smaller Members Simplify bracing elements. Make use of vertical stiffeners as connection plates for cross bracing, etc  Keep bracing to a minimum and at a consistent angle to the girders

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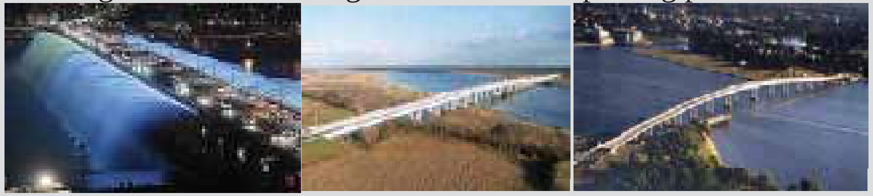
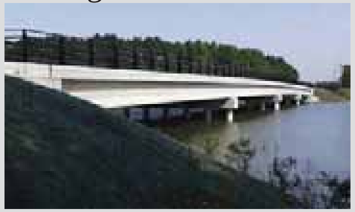
[2] - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005.-p VIII-1

Table 4-7: Bridge aesthetical considerations according to the selected site (Bridges over Waterways)[3]

<table>
<tr><td colspan="2">

Determinants of appearance: The visual goal of bridges of this type should be to display the basic geometry of the bridge as a sweep of structural ribbon from shore to shore. The bridge should be the same form and material throughout its length; variations in depth to accommodate span changes, such as haunches, should be accomplished gradually with smooth curves or slight tapers.
These features determine the visual impression:
• The shape of the basic horizontal and vertical geometry
• Superstructure type or types
• Pier shape, number and spacing of piers, Parapet and railing design.
• These bridges should provide sufficient detail and interest based upon its location. and should follow the guidelines described in vehicle Bridges over Highways.
•In the case of the bridge located in a park and viewed closely by park users, care should be taken to make the bridge fit into its surroundings to encourage its use •The designer should avoid placing piers in the waterway, as they become debris collectors during flood stage.

These bridges blends in with the area and considered as good examples of bridges over waterways. From the left: Bridge in, bridge in Chicago, Rainbow fountain Seoul bridge Japan,

The structure has been modified to accommodate equestrian trails (Lift) to provide safe access under the highway. The stone-like finish on the walls (Right) fits well into the park setting.

The stone work on the parapets and the pier matches the nearby mill.
</td></tr>
<tr><td>Pier configuration</td><td>

•If bridges are relatively narrow and high above the water, carefully shaped single shaft piers can be very effective. •Avoid mixing battered columns and vertical columns. Do not batter the outside columns on piers with three or more columns unless structurally necessary The pier cap is a prominent element in the oblique view and will interrupt the visual lines of the structure unless it is minimized.
•Adapt changes in height in ways which preserve the main lines of the basic pier.
•Keep visible lines, overhangs and colors as consistent and continuous as possible when the structural type changes.

Minimum use of columns makes this a more attractive structure. and This a good example of the use of single shaft piers. Australia

Too many columns and piers give the appearance of a forest of columns.
</td></tr>
</table>

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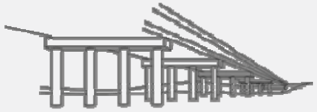
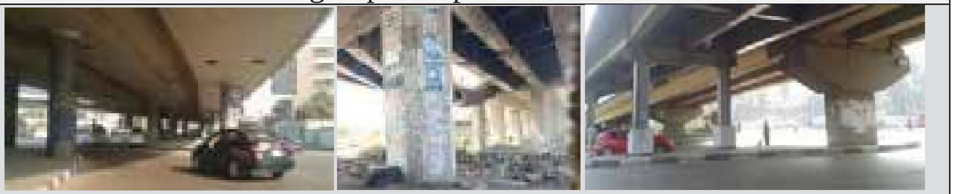
[3] 3 - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005 -p IX-1

Table 4-8: Bridge aesthetical considerations according to the selected site (Viaducts and Long Interchange Ramps).[4]

	Determinants of appearance: Viaducts, particularly in urban areas, may have an almost infinite number of viewpoints, many of which may involve pedestrian traffic in close proximity to the bridge. With this range of possibilities, it is hard to identify specific features of the bridge as being more important. Any and all features could be important depending on the circumstances. However, the following features will probably be most important: • The shape of the basic horizontal and vertical geometry • Pier placement and shape • Structure type • The appearance of the underside of the superstructure	
Superstructure	• Keep the horizontal and vertical geometry as smooth as possible. • Use horizontal and vertical curves of generous length. • Use long continuous spans and curved girders (if roadway is curved). • Keep the form and depth of the structure as continuous as possible. • Make girder depth transitions with smooth curves and/or long tapers Use large overhangs to emphasize horizontal continuity and minimize pier width.	 Smooth horizontal curve with generous radius  Interchanges at 6th of October bridge
Substructure	• Because there will be so many piers, and they will be visible from so many different viewpoints, it is important to minimize the number of elements, and keep the shape simple. • Single shafts are better than paired columns, and paired columns are better than multicolumn piers. • Where different lengths of piers occur, make an effort to have their shapes compatible. • Evaluate a pier shape for all heights of piers to be used • Use as few piers and columns per pier as possible. • Keep all piers the same material and consistent in shape, where possible. • Chamfered pier tops attenuate the substructure/superstructure joint and emphasize superstructure continuity and lightness Place piers so that they are radial to bridge curvature. • Where radial piers are not possible, try to keep adjacent piers or series of piers as close to parallel as possible to avoid having an oddly placed pier. In complex situations consider integral pier caps.	 Ordinary  Better
Underside Design	• Consider whether significant pedestrian or vehicular traffic will be able to view the underside of the bridge for sustained periods. • Simplify and organize the bracing, lighting, drainage details, etc. into clear patterns. • Painting the steel a light color will tend to brighten the underside.	 Several examples of bad appearance bridges from below in Egypt (Ring road, Elquba bridge and 6th of October bridge - by researcher)

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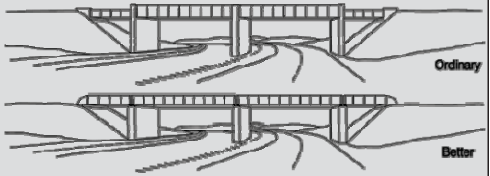
[4] -"Bridge aesthetics around the world"- Committee on General structures, subcommittee on bridge aesthetics- Transportation research board- National research council- Washington- USA-1991--.p108-111

Table 4-9: Bridge aesthetical considerations according to the selected site(Highway bridge over Railroad and Railroad Bridge over Highways)[5]

<table>
<tr>
<td>Highway bridge over railroad</td>
<td colspan="2">Determinants of appearance •Bridges carrying highways over railroads are similar in many respects to highway overcrossings. •The only people likely to see the bridge are occasional railroad employees, or those in trains moving at high speed, then less emphasis need be made.
•Multiple short spans should be avoided. The multiple spans will usually provide a cluttered view.
•Piers located adjacent to tracks should be avoided.
•Piers should be located as far from the tracks as possible or eliminated entirely.
•This will result in a two-fold benefit. First, from an operational standpoint, the pier will not be a safety hazard and will not require a railroad crash wall. Second, from an aesthetic standpoint, the tunnel-like effect of the pier closing in on the tracks will be eliminated.</td>
<td colspan="2">
The designer did a great job of matching the architectural details of the bridge to the architecture of the locale.

Single-span crossing with slender superstructure</td>
</tr>
<tr>
<td rowspan="4">Railroad bridge over highways</td>
<td colspan="2">Design Suggestions:
• Taper protective barriers at the end of the wing wall to visually increase the bridge's length and give a finished appearance. If the railroad only makes up a portion of the crossing, then taper down or round the barrier at the ends to give a finished appearance.</td>
<td colspan="2">• The protective barrier or pedestrian screen should be tapered down at the end posts.
• Tapered endings emphasize the length of the structure.
• Place wing walls parallel to roadway to emphasize the length of the structure.</td>
</tr>
<tr>
<td colspan="4">Determinants of appearance • There are limitations on what the designer can do to improve its appearance. • The heavy concentration of loads that these bridges are required to carry result in deep girders and massive substructure elements.</td>
</tr>
<tr>
<td>superstructure</td>
<td>• The visual goal is to display the strength of the superstructure while maximizing its apparent length.
• Where possible, keep the fascia girder depths in all spans the same.
• Superstructure depth-to-span ratio should be kept as small as possible.</td>
<td>• Eliminating at-grade crossings in flat terrain presents its own special challenge.
• Superstructure details such as bearings should be exposed, as they will complement the structure appearance.
• Use stiffener details to emphasize the horizontal nature of the girder, if possible.</td>
<td>

Avoid girders of different depths</td>
</tr>
<tr>
<td>Subst</td>
<td>• Pier and abutment design should work to emphasize the slenderness of the superstructure. • Use large simple shapes for the pier and abutments.• Use Skew wing walls with abutment.</td>
<td colspan="2">• Abutment wing walls placed parallel to the railroad alignment is good to the appearance.• A pronounced chamfer at the top of the pier will highlight the substructure/superstructure interface.</td>
</tr>
</table>

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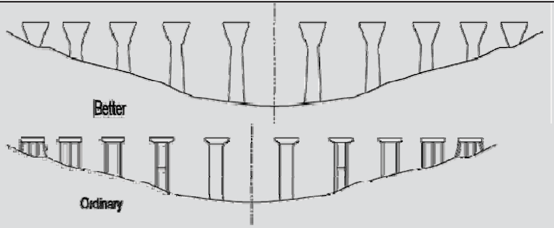
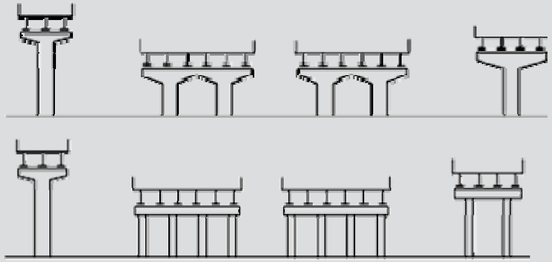
[5] - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005 -p XI-1

Table 4-10: General Bridge aesthetical considerations at any site.[6]

<table>
<tr><td rowspan="2">steel rigid frame</td><td rowspan="2">With steel rigid frames, give the legs enough slant to maximize their length and to give full play to the visual illusion of an additional span and an open feeling</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2">This rigid frame highway overcrossing is very appealing, though the legs might have been slanted a little more.</td><td colspan="2">Note the importance of proportions in rigid frames. The legs are light and graceful.</td><td>The legs are heavier and strongly delineate the triangular void the effect is a little too massive.</td></tr>
<tr><td rowspan="2">Ending the parapet</td><td colspan="6">There are four basic alternatives are shown of parapet ending</td></tr>
<tr><td>
Alternate 1: Ending the superstructure features at the abutment will make the bridge seem shorter and deeper.</td><td colspan="2">
Alternate 2: Extending the superstructure features over the abutment will make the bridge seem longer and will emphasize the horizontal continuity of the bridge.</td><td colspan="2">
Alternate 3: If the parapet is solid and of the same material as the abutment, the abutment can be made to appear continuous with the parapet by keeping the abutment side wall and parapet face in one plane</td><td>
Alternate 4: A variation of this approach is to form the parapet features into the corners of the abutment, emphasizing the portal effect. This works well for medium to high abutments.</td></tr>
<tr><td>Pier placement</td><td colspan="2">Pier placement can make or break the appearance. The proportions of each opening (ratio of height to span length) should be roughly similar. Piers should not be placed at the deepest part of the ravine. Consider oblique views and varying pier heights in developing a family of piers. Piers must look pleasing when viewed as a group or individually.</td><td colspan="2">

Piers families proposals
</td><td colspan="2">
Keep bracing to a minimum and at a consistent angle to the girders</td></tr>
<tr><td>Bridge overall</td><td colspan="6">• Give the bridge an overall appearance of unity, choose shapes from the same family. rounded pier designs with rounded parapets. •use a minimum number of different materials, different colors, and different textures also, always use a given material, color or texture the same way within a structure.
•Most importantly, proportion the span lengths and abutment heights to achieve the most aesthetic balance in the structure.</td></tr>
</table>

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[6] - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005 -p Vi-1

4-3- Conclusion

In this chapter, the effects of bridge context on bridge architecture was studied, the bridge context is consisted of Natural and constructed delimiters, the surrounding context, existing or historical bridge or building and the effect of surrounded architectural character or local culture on the bridge architecture. Also living bridges was studied going through and history, global treatment of living bridges informality of riverfronts in Egypt.

At the end of the chapter, main consideration affecting the bridge design as a whole according to its location, interchanges, sensitive site and a crossed obstacle.

Site Selection and its Impact on Bridge Design could Be Concluded as Shown below:

A. **The Nature of the Site,**

- The proper investigation of the subsoil conditions is essential, the nature and extent of such investigation will depend on the nature of the sub soil and the type of structures and its foundations and should preferably be planned in stages in conjunction with geotechnical experts in order to optimize the expenditure in terms of risk.

B. Selection of Bridge's Sites.

In order to evaluate a probable bridge site, many aspects have to be considered before proceeding with the investigation, it is advisable to obtain all available information on aspects which will affect the eventual design including design criteria.

- Site data and Rout location maps should be well studied.
- Topographical maps, including any available aerial and terrestrial surveys and river cross-sections.
- Local geological or soil maps and any relevant geological and geotechnical information available from neighboring works.
- Weather and flood records or oceanographic and tidal information where applicable.
- Location of existing bridges over relevant river or in same area of the designed bridge.
- The surrounding historical places and surrounding buildings.
- Land values, land use, expropriation plans and wildlife habitats and vegetations maps.

C. **Investigation of Bridge Site .**

The extent and detail of investigation of bridge site depend largely on the class of bridge and the nature of the sites that available. the investigation may comprise various stages starting with a study of topographical maps, surveys, photographs and other resources of information and by a process of elimination selecting the most promising sites to be investigated.

a detailed checklist could be drawn up and should cover the following:

- Topography: nature of the approaches to the site the space to be spanned, suitable abutment and foundation positions, accessibility.
- River and flood characteristics: Recorded flood levels, flood marks, scour damage and direction of flow.

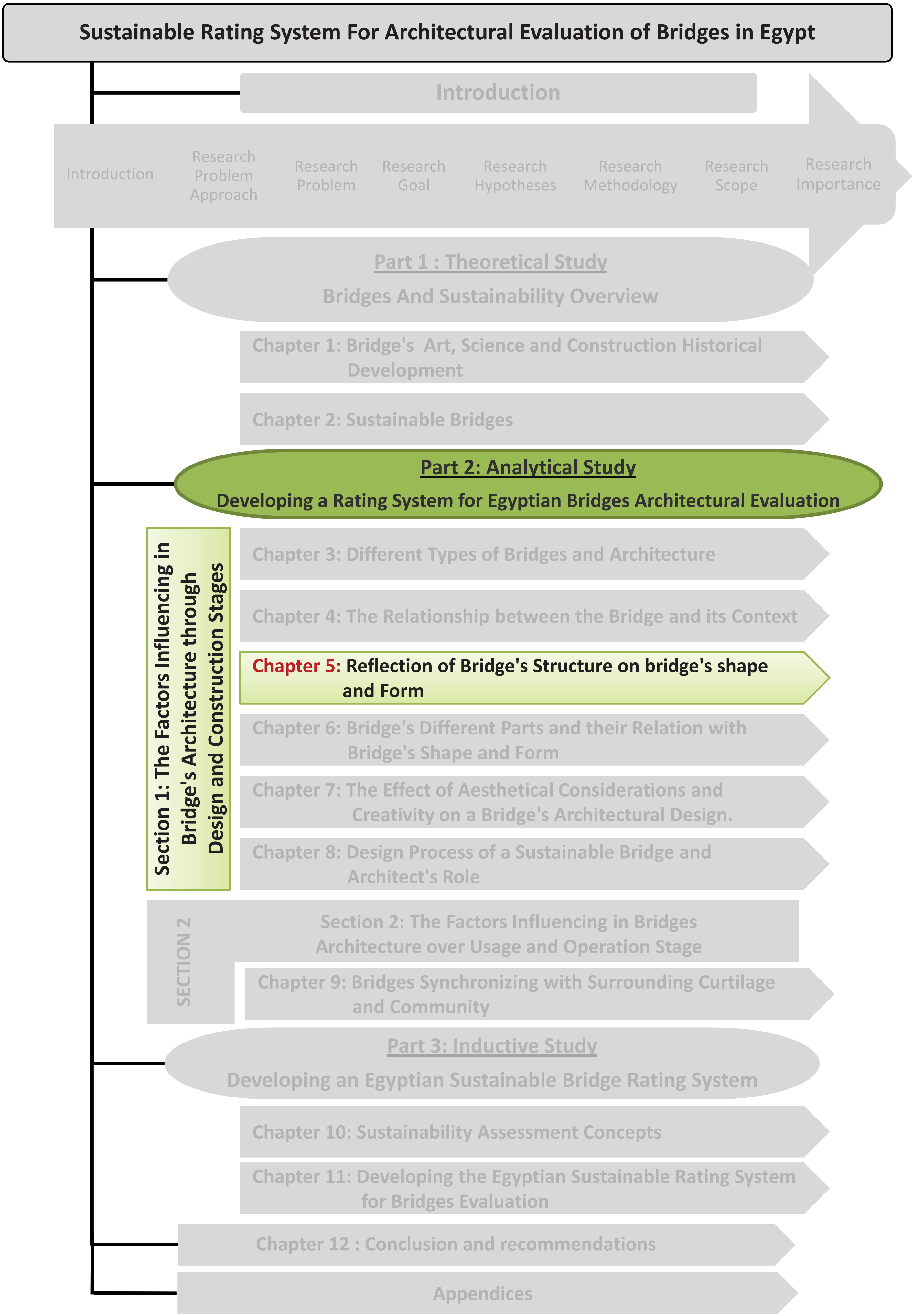
4-3-1- Concluded Prerequisites

AP: Bridge Goals Analysis
AP: Relationship between Bridges and Road Networks
AP: Site Natural Delimiters

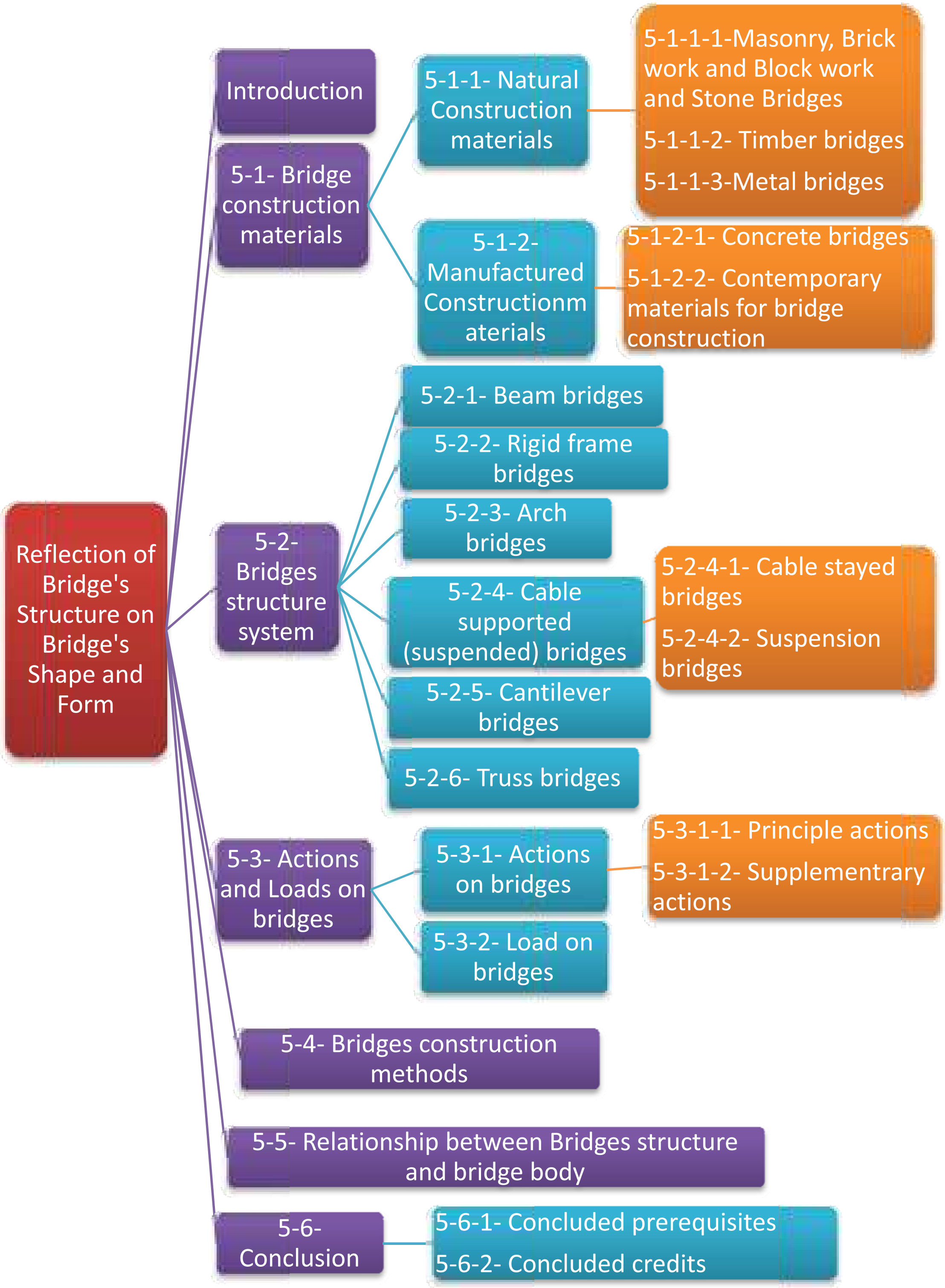
AP: Site Constructed Delimiters
AP: Context Sensitive Design and Solutions
AP: Historical Sites/Bridge Treatment
AP: Bridge Surroundings Character
AP: Expected Bridge Effect on the Curtilage

4-3-1- Concluded Credits

CR: Site Investigation
CR: A Living Bridge Plan
CR: Bridge as a Whole Aesthetical Design


Sustainable Rating System For Architectural Evaluation of Bridges in Egypt
Introduction
Introduction
Research Problem Approach
Research Problem
Research Goal
Research Hypotheses
Research Methodology
Research Scope
Research Importance
Part 1 : Theoretical Study
Bridges And Sustainability Overview
Chapter 1: Bridge's Art, Science and Construction Historical Development
Chapter 2: Sustainable Bridges
Part 2: Analytical Study
Developing a Rating System for Egyptian Bridges Architectural Evaluation
Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages
Chapter 3: Different Types of Bridges and Architecture
Chapter 4: The Relationship between the Bridge and its Context
Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form
Chapter 6: Bridge's Different Parts and their Relation with Bridge's Shape and Form
Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design.
Chapter 8: Design Process of a Sustainable Bridge and Architect's Role
SECTION 2
Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage
Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community
Part 3: Inductive Study
Developing an Egyptian Sustainable Bridge Rating System
Chapter 10: Sustainability Assessment Concepts
Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation
Chapter 12 : Conclusion and recommendations
Appendices

Chapter 5 : Reflection of Bridge's Structure on Bridge's Shape and Form



Chapter 5 structure: Reflection of Bridge's Structure on Bridge's Shape and Form

Chapter 5 : Reflection of Bridge's Structure on Bridge's Shape and Form

Introduction

The necessity of classifying bridges in Various ways has grown as bridges have involved from simple beam bridge to modern suspension bridges and Cable-Stayed bridges. Bridges are always classified according to the following Characteristics: (Material of Construction, span lengths, structural form, span types, load path characteristics, usage, position 'for movable bridges', deck type)
Experience has shown that certain configuration, are most suitable under specific circumstances that can be related to the functional requirements, the site conditions, the magnitude of span required and the materials and the methods of construction used. These factors are all interrelated so that there are usually several alternative solutions that may be competitive. The objective of the designer is therefore to find the combination that gives an optimum solution in terms of the functional requirements and cost. Also, there are another factors determine the choice of the materials of construction, Apart from the structural properties, must be made to durability.
In the particular circumstances of exposure such as the possibility of weathering. Corrosion of steel, deterioration, discoloration, cracking of which factors may not only have a significant effect on maintenance costs.[1]

5-1- Bridge's Construction Materials

As shown in figure (5-1) types of bridge construction natural and manufactured materials are introduced.

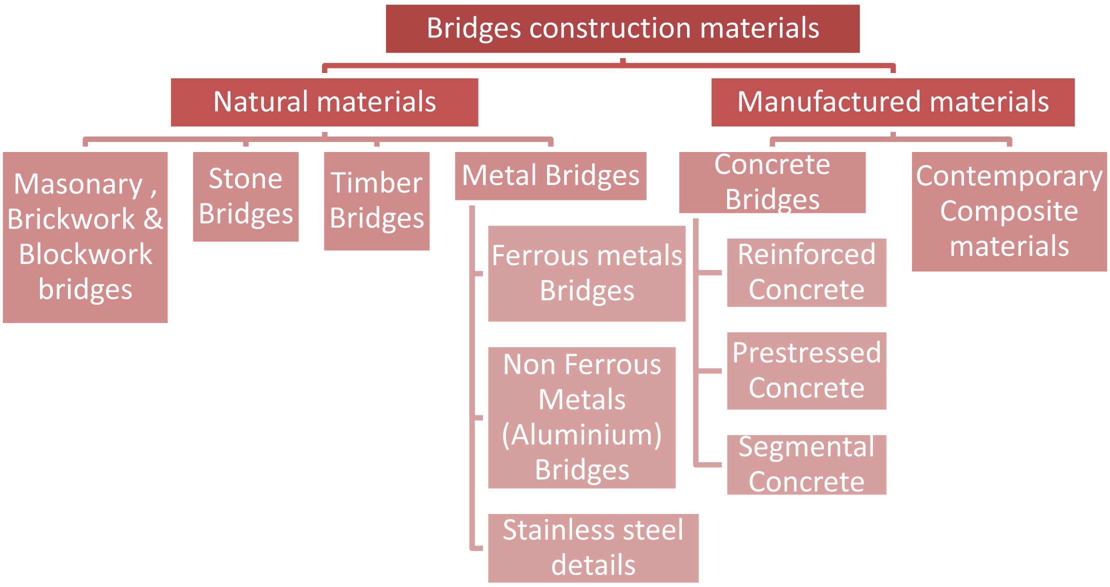


Figure 5-1: Bridge Construction Materials .[2]

5-1-1- Natural Construction Materials

5-1-1-1- Masonry, Brick Work, Block Work and Stone

Over the last three decades the term ‘masonry’ has been widened from its traditional meaning of structures built of natural stone to encompass all structures produced by stacking, piling or bonding together discrete chunks of rock, fired clay, concrete,

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١ - جورج صبحي راغب: "جماليات انشاء الكباري - رؤية خاصه من وجهة النظر المعمارية"- رسالة ماجستير - قسم عمارة- كلية الهندسة- جامعة القاهره- ١٩٩٨. - ص٢٦٥-٢٧١.

[2] - by researcher

etc. to form the whole.

Stone has been defined as the natural, hard substance formed from minerals and earth material which are present in rocks. **Rock** is defined as the portion of the earth's crust having no definite shape and structure. [1]

In contemporary construction most masonry in the world is built from man-made materials such as bricks and blocks. Stone, because of its relatively high cost and the environmental disadvantages of quarrying, is mainly used as thin veneer cladding or in conservation work on listed buildings and monuments.

Second to wood, masonry is probably the oldest building material used by man; it certainly dates from the ancient civilizations of the Middle East and was used widely by the Greeks and Romans. Early cultures used mud building bricks, and very little of their work has survived, but stone structures such as the Egyptian pyramids, Greek temples and many structures made from fired clay bricks have survived for thousands of years. The Romans used both fired clay bricks and hydraulic (lime) mortar and spread this technology over most of Europe. As shown in figure (5-2) masonry bridges parts are illustrated.

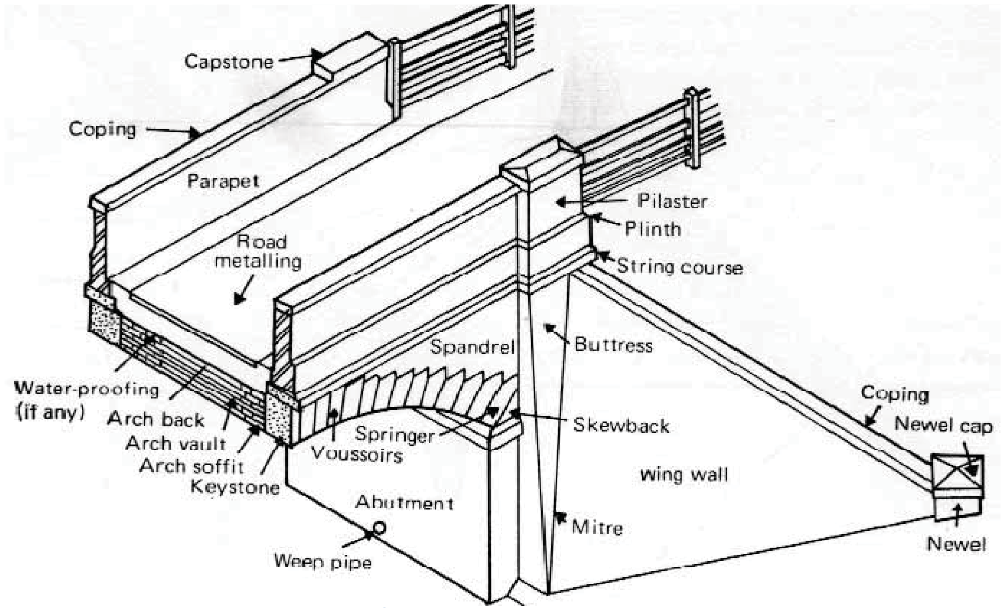
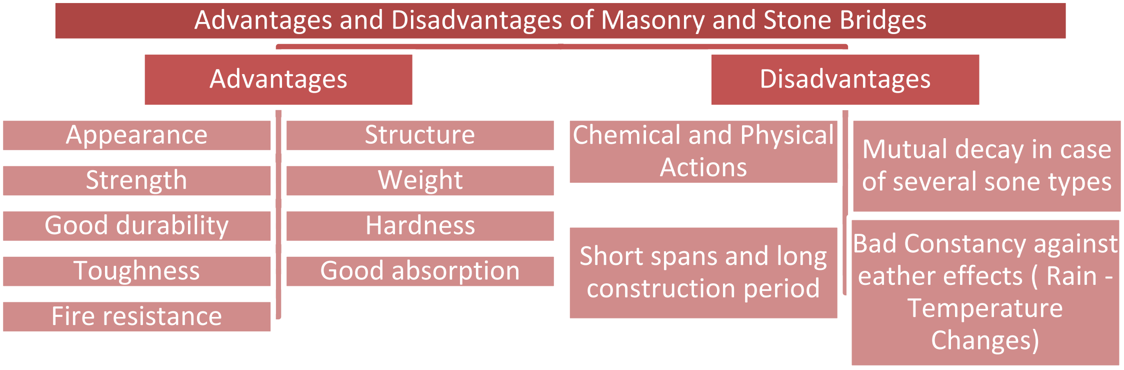


Figure 5-2: Masonry Bridges Parts[2]

In figure (5-3) advantage and disadvantages of masonry bridges are discussed.



Advantages and Disadvantages of Masonry and Stone Bridges

Advantages

- Appearance
- Strength
- Good durability
- Toughness
- Fire resistance
- Structure
- Weight
- Hardness
- Good absorption

Disadvantages

- Chemical and Physical Actions
- Short spans and long construction period
- Mutual decay in case of several sone types
- Bad Constancy against eather effects (Rain - Temperature Changes)

Figure 5-3: Advantages and Disadvantages of Masonry and Stone Bridges[1]

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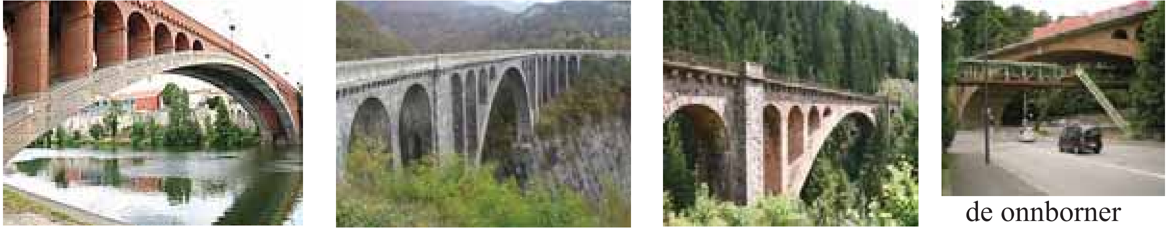
[1] - S.K. Duggal: "Building materials-3rd revised edition"- New age international limited publishers- New Delhi- USA-2008-p 67-80.

[2] -Mckibbins L, Melbourne C, Sawar N and Sicilia Gaillard C: "Masonry arch bridges: condition appraisal and remedial treatment Report"- Published by CIRIA- Classic House-2006.- p 15

Also as shown in figure (5-4) and figure (5-5) some Examples of longest masonry and stone bridges examples are shown.



Pont de la Libération - France -96m

Viaduc de la Roizonne - France 79m

Gutach Bridge- Germany - 64m

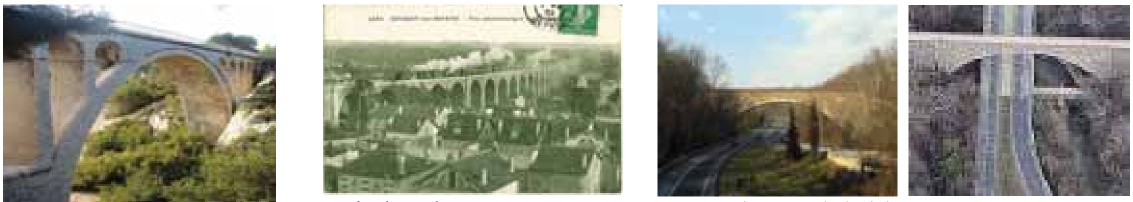
de onnborner Eisenbahnbrücke - Germany 66m[2]

Grosvenor Bridge - UK 61m

Stone Arch Bridge- USA-60 m

Wiesen Viaduct - Switzerland - 55m

Wiesen Viaduct - Norway[3] - 54m



Viaduc des Eaux-salées - France - 50m

Viaduc de Nogent-sur-Marne - Drance - 50m

Union arch bridge - USA - 67m

Figure 5-4: Longest Masonry /Stone Bridges Examples in the World[4]

Puente Nuevo, Ronda, Spain

Bastei Bridge,, Germany

Charles Bridge, Czech Republic

Pont Neuf, Paris, France

Stari Most, Mostar, Bosnia and Herzegovina

Puente de Piedra, Zaragoza, Spain

Figure 5-5: Stone Bridges Examples[5]

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1 -S.K. Duggal: "Building materials-3rd revised edition"- New age international limited publishers- New Delhi- USA-2008-p 67-80.

2 - http://www.eccenet.org/News/tech/ARCHBRIDGES.doc

3 - Statens Vegvesen: "Masonry Arch Bridges- Håndbok"-2002- p88.

4 - http://edition.cnn.com/2014/04/15/travel/worlds-longest-bridges/

5 - http://10mosttoday.com/10-most-beautiful-stone-bridges-in-the-world/

- **Artificial Stone**

Where durable natural stone is not available at reasonable cost, artificial stone, also known as cast stone becomes the choice. Artificial stone is made with cement and natural aggregates of the crushed stone and sand with desired surface finish. Suitable coloring pigments may be added. However, coloring should not exceed 15% by volume. Cement and aggregates are mixed in proportion of 1:3.[1]

5-1-1-2-Timber Bridges (Wooden Bridges):

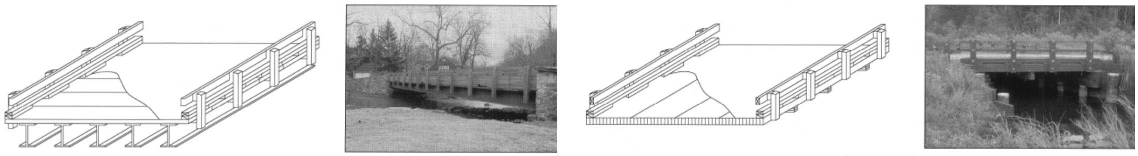
Wood is considered the oldest material used in bridges construction. Wood is still used in bridges construction till now either in its original shape or as a manufactured composite materials.[2]

Using timber for bridges construction as any other material is depends on the balance between timber advantages and disadvantages as a construction material.

Some Advantages of Using Timber in bridge construction are strength, resistance, constructability, Durability, Light weight material and it considered Economical material in small span bridges. [3]

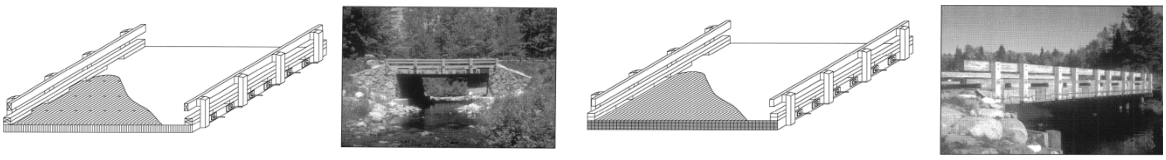
But the Main Disadvantages of Timber are Decay by the atmosphere moisture, Insect attack and combustibility, So timber or wooden bridges need continuous maintenance .[4]

As shown In Figure (5 - 6) Standard plans For timber bridge substructure are shown.



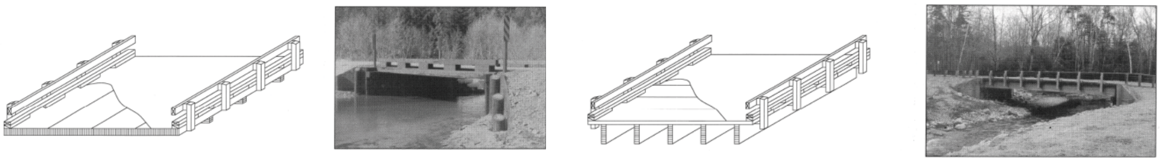
Transverse Glulam Decks for steel Beam

Spike-Laminated Decks



Stress-Laminated Sawn lumber Decks

Stress-Laminated Glulam Decks



Longitudinal Glulam panel Decks

Glulam Stringer and transverse Glulam Deck

Figure 5-6: Standard Plans For Timber Bridge Substructure.[5]

As shown in figure (5-7) some examples on Timber bridges all over the world.

5-1-1-3- Metal Bridges:

Metals are aiming the most useful building materials. They exist in nature as compounds like oxides, carbonates, sulphides and phosphates and are known as ores. Metals are derived from ores by removing the impurities. Those used for engineering purposes are classified as ferrous metals, with iron as the main constituent, cast iron,

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1 - Odhiambo Odera, Paul Chepkuto and OchiengOkaka: "An investigation into the durability, weathering and strength properties of coral stone"- Bachelor thesis- Department of civil and construction engineering- University of Nairobi-Kenya-2012.-p50.

2 - Wai-Fah Chen & Lian Duan: " Bridge engineering handbook"- 2nd edition- USA- 1999-p 20.2.

3 - Michael A. Ritter: "Timber Bridges: Design, Construction, Inspection, and Maintenance"-Washington- USA-1990- p.3-19 to 3-22.

٤- فيصل محمود ابو العزم: "الكباري بين التصميم المعماري و الانشاء" - دراسة تحليليه - رسالة ماجستير - قسم عمارة - كلية الفنون الجميله - جامعة حلوان -٢٠٠٣- ص ٥١-٦٥.

5 - Wacker, James P Smith & Matthew S: "Standard plans for timber bridge superstructures"- General Technology Report- Madison-U.S. Department of Agriculture- Forest Service- Forest products Laboratory-USA-2001.p4-46.


The Eagle River Timber Bridge -Michigan - USA[1]


Wooden bridge at Kannur, India[2]


Accademia Bridge, Grand Canal, Venice[3]

Nature Bridges employs environmentally friendly construction methods to build timber sand dune walkways for any type of coastal landscape without damaging nature's delicate balance.[4]

Figure 5-7: Timber Bridges Examples

wrought iron and steel and others like aluminum, copper, zinc, lead and tin in which the main constituent is not iron as non ferrous metals.[5]

- **Advantages of Metal bridges**[6]

Steel offers many advantages to the bridge builder, not only from the material itself, but also from its broad architectural possibilities. The following are some of the advantages that steel can offer.

- High strength to weight ratio
- High quality material
- Speed of construction
- Versatility
- Modification and repair
- Recycling
- Durability
- Aesthetics

As shown in figure (5-8) examples of steel pedestrian bridges are discussed.

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[1] - http://www.wheeler-con.com/timber-recreation-bridges/pratt-truss/

[2] - http://www.michiganhighways.org/indepth/M-26_timberbridge.html

[3] - http://www.telegraph.co.uk/news/worldnews/europe/italy/11633333/How-Venices-only-timber-bridge-is-to-be-restored-thanks-to-the-private-sector.html

[4] - http://www.naturebridges.com/gallery_new/dune.php#prettyPhoto

[5] -S.K. Duggal: "Building materials-3rd revised edition"- New age international limited publishers- New Delhi- USA-2008-p 365-378.

[6] - http://www.tatasteelconstruction.com/en/design-guidance/steel-bridges/advantages-of-steel-bridges

Truss girder footbridge
Praha - Prague

Cable stayed footbridge
Pasarela Atirantada La Rosa
Spain[1]

Cable stayed footbridge
Miller's Crossing Bridge,
England

Ijburg Bridge, Netherland

Rostock Bridge- Germany

Gelsenkirchen Bridge- Germany

Boudry bridge, Suisse

Emmeloord bridge, Netherland

Figure 5-8: Examples of Steel Pedestrian Bridges.[2]

A. Types of Metal Materials :[3]

Ferrous Metal Material: Ferrous (iron-based) metals have widespread use throughout all branches of engineering but are particularly important in construction. Iron and carbon-based alloys, cast iron and steel, are used in structural use in their own right or in the form of reinforcing or pre-stressing steel for concrete construction.[4]

Iron is a pure element occurring in four different allotropic structures as alpha, beta, delta, and gamma iron. The delta form is commercially unimportant. Gamma iron containing carbon, is called austenitic and alpha iron containing carbon, is called ferritic. The other steel alloys having same gamma structures are also called austenitic. Similarly alloys having alpha structure are called ferritic. [5]

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[1] - Hirt.Manfred and Lebet.Jean-Paul: "Steel Bridges-Conceptual and Structural Design of Steel and Steel-Concrete Composite Bridges" 1st Edition- EPFL Press publications- Germany- 2013- p 43-1 to 43-8.

[2] - Rangachari Narayanan: "Steel Bridges-Version 2"-Teaching materials of Institute for Steel Development and Growth- India- 2015http://www.steel-insdag.org/index.html- p 43-1 to 43-8

٣- فيصل محمود ابو العزم: "الكباري بين التصميم المعماري و الانشاء" - دراسة تحليلية - رسالة ماجستير - قسم عمارة - كلية الفنون الجميله - جامعة حلوان -٢٠٠٣- ص٥١-٦٠.

[4] - Peter Domone & John Illston : "Construction Materials- Their nature and behavior" 4th edition- Spon Press publication-UK- 2010-P 68.

٥- فيصل محمود ابو العزم: " الابداع في تصميم المنشات المدنية العمرانية" رسالة دكتوراة-قسم عمارة- كلية الفنون الجميلة- جامعة حلوان- ٢٠٠٩-ص٥٥-٦٠.

Non-Ferrous Metal Materials: Although the production of individual non-ferrous metals is small in comparison to the iron, the former play an important part in many engineering structure and industrial processes. The non-ferrous metals and their alloys are used despite their high cost because they provide a wide variety of properties. Some of the more commonly used non-ferrous metals are aluminum, copper, tin, zinc, and manganese.[1]

5-1-2- Manufactured Construction Materials

There are many manufactured materials used in bridge construction, such as concrete, fiber composite, polymer etc..)

5-1-2-1- Concrete Bridges:

Concrete is to be the most predominantly used material for highway bridge construction. There is hardly any bridge in Which concrete is not used in some form. With the exception of orthotropic plate bridges, where an asphaltic wearing surface is used on the deck, concrete (or reinforced concrete) exclusively is used for decks, overlays, curbs, Sidewalks (pedestrian walkways), parapets, and substructures(abutments, wing walls, piers and bents).[2]

Concrete Has many advantages:[3]

- Ability to be cast in almost any shape
- Low cost
- Durability
- Fire resistance
- Energy efficiency
- On-site fabrication
- Aesthetic properties

A. Types of Concrete Bridges

In figure (5-9), table (5-1) types of concrete bridges (cast in place and pre stressed concrete bridges), table (5-2) types of concrete bridges (Precast Segmental Concrete Bridges and Precast Cast in Situ Concrete Bridges) and table (5-3) types of concrete bridges (Steel-Concrete Composite I-Girder Bridges and Steel-Concrete Composite Box Girder Bridges) are reviewed and discussed.

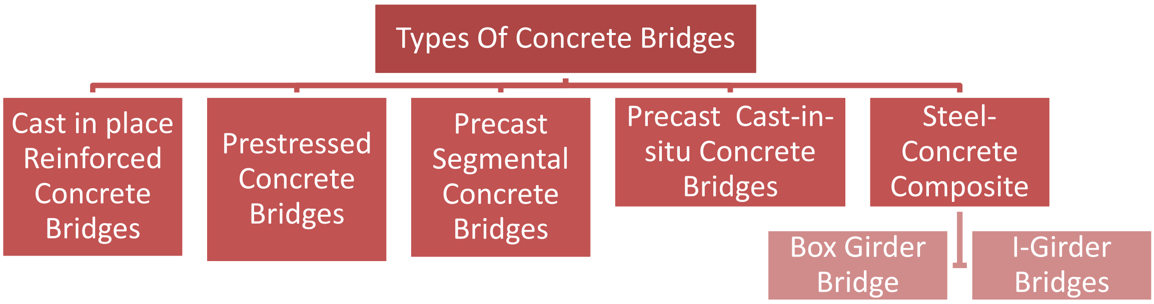

Figure 5-9: Types of Concrete Bridges .[4]

Concrete Components:

Portland Cement: It is a cementing material resembling a natural stone quarried from Portland in U.K. Portland cement may be defined as a product obtained by finely pulverizing clinker produced by claiming to incipient fusion, an intimate and properly proportioned mixture of argillaceous and calcareous materials.[5]

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1 - S S.K. Duggal: "Building materials (third revised edition)"- New age international limited publishers- New Delhi- USA-2008-p 380-400

2 - Narendra Taly : "Design of Modern Highway Bridges"-The Mcgraw-Hill companies publication- Columbus-USA- 1998-p 122-123

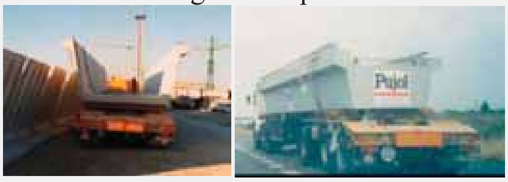
3 "Bridge Design practice"- CALTRANS (The California Department of Transportation)-Chapter 5 (Concrete Design Theory Reference guide)- USA-2015- p5-1.

4- By researcher

5 - S.K. Duggal: "Building materials (third revised edition)"- New age international limited publishers- New Delhi- USA-2008-p 144 -147.

Admixture: Admixtures are chemicals that are added to concrete during mixing and significantly change its fresh, early age or hardened state to economic or physical advantage. They are usually defined as being added at rates of less than 5% by weight of the cement, but the typical range for most types is only 0.3– 1.5%. They are normally supplied as aqueous solutions of the chemical for convenience of dispensing and dispersion through the concrete during mixing. Their popularity and use have increased considerably in recent years.[1]

Table 5-1: Types of concrete bridges (Cast-in-place Reinforced Concrete Bridges and Pre stressed Concrete Bridges)

	Cast-in-place Reinforced Concrete Bridges	Pre stressed Concrete Bridges
Introduction and definition	Cast-in-place concrete is formed and cast directly in its setting location. Cast-in-place concrete structure are often constructed monolithically and continuously. They usually provide a relatively Low maintenance cost and better earthquake resistance performance. It may not be a good choice when the project is on a fast-track construction schedule or when the available false work opening clearance is limited.	Pre-Stressed Concrete structures are using High strength materials to improve serviceability and durability, are an attractive alternative for long span bridges, and have been used Worldwide since the 1950s. In this part we are only discussing Conventional pre-stressed Concrete Bridge.
Materials	1- Concrete (Considering Compressive strength, Tensile strength, Creep and shrinkage) 2- Steel reinforcement (Considering Bar shape and size and Stress-strain Curve)	1- Concrete. 2- Steel for pre-stressing 3- Advance Composite for Pre-stressing 4- Grout
Structure	• Slab Bridge • T-Beam Bridge • Box-Girder Bridge	Section Types: • Void slabs • I-Girder • Box Girder
Examples	 Cast-in-place Bridge - USA  Richmond Hill Bridge	 Pre-stressed bridges examples - at Australia  Pre-stressed concrete U-shaped beam
	References: Wai-Fah Chen & Lian Duan: " Bridge engineering handbook"- 2nd edition- USA.. Walter podolny, JR: "Recommended Practice for Precast Post-Tensioned Segmental Construction Reported by Joint PCI-PTI Committee on Segmental Construction"- Paper-1982-p 31-33. Michel Virlogeux: "Comparison between cast-in-situ and precast segmental construction"- Article-IABSE reports- 1991-p841.	

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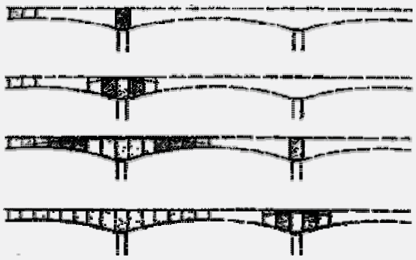
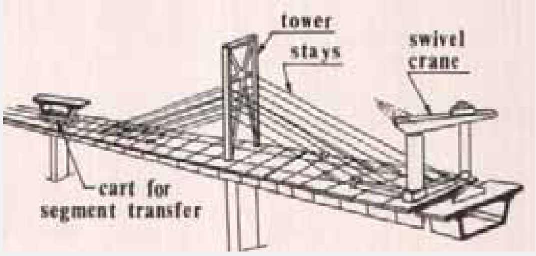
[1] - Peter Domone & John Illston : "Construction Materials- Their nature and behavior" 4th edition- Spon Press publication-UK-2010-p99.

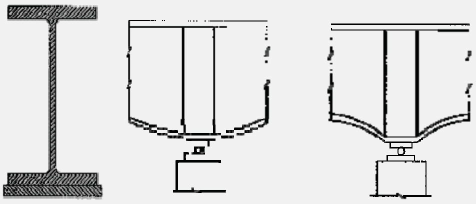
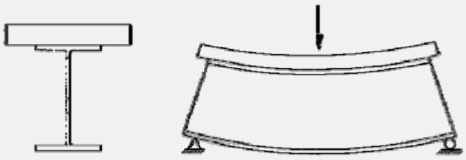
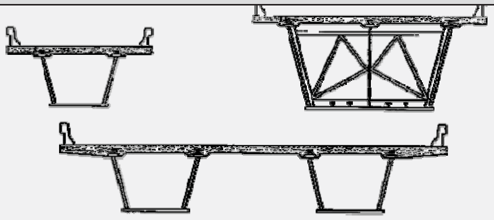
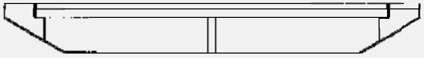
Table 5-2: Types of concrete bridges (Precast Segmental Concrete Bridges and Precast Cast in Situ Concrete Bridges)

<table>
<tr><th colspan="2">Precast Segmental Concrete Bridges</th><th>Precast Cast in Situ Concrete Bridges</th></tr>
<tr><td rowspan="2">Introduction and definition</td><td colspan="2">Precast refers to the process of construction in which a concrete element is cast somewhere other than where it is to be used. The other place may be somewhere else on the building site or away from the site, probably in a casting yard or factory. The precast element may be pre-stressed, may be of ordinary reinforced concrete, or may be without reinforcement.
The single precast elements may be component of a general precastconcrete system, or may serve as singular purpose in a construction system of mixed materials or types of elements.</td></tr>
<tr><td>Pre-cast Segmental concretes are manufactured in a pre-cast plant or on site (tilted-up construction). Cast in steel moulds with precise dimension. Very good quality control. Delivered and erected on site.</td><td>Cast in-situ are constructed on site using fresh concrete from trucks and placed by workers. Quality Control is the responsibility of the site manager.</td></tr>
<tr><td>Adds.</td><td colspan="2"><u>Regular Reinforced Concrete components Considering:</u>
1- Required chemical additions.
2- Seismic Considerations. 3-Casting and Erecting consideration</td></tr>
<tr><td>Structure Type</td><td>A-Balanced Cantilever Girder Bridges
B- Progressive and span-by-span Bridges
C- Incrementally Launched Bridges

Balanced Cantilever construction</td><td>D- Arches Bridges
E-Rigid Frame Bridges F- Trusses bridges
G -Segmental Cable-Stayed Bridges

Schematic of progressive placing technique</td></tr>
<tr><td>Examples</td><td>
Auction road bridge - Lancaster

Balanced cantilever construction employing a launching girder in Denmark.

Span-by-span technique using movable steel truss (Long Key Bridge).</td><td>
St. Croix bridge is cast piece by (giant) piece</td></tr>
<tr><td colspan="3">References: http://www.answers.com/Q/What_is_the_difference_between_cast_in_situ_and_precast_concrete
Robert Schmidt and Ayertey: "comparing the use of precast and cast in-situ concretes in construction industry"- Lecture- 2010-p 5.</td></tr>
</table>

Table 5-3: Types of concrete bridges (Steel-Concrete Composite I-Girder Bridges and Steel-Concrete Composite Box Girder Bridges)

	Steel-Concrete Composite I-Girder Bridges	Steel-Concrete Composite Box Girder Bridges
definition	An I-section is the most simplest and most effective solid section of resisting and shear, it consists of Regular Reinforced concrete components in addition to Steel I section plate.	Box Girders are Used in Urban highway, Horizontally Curved and Long-span bridges. They have higher flexural capacity and tensional rigidity and the closed shape reduces the exposed surface making them less susceptible to corrosion. Also they provide smooth, aesthetically pleasing structures
Types	I girder bridges and steel box girder with orthotropic decks are often used for longer span bridges	There are two types of steel box girders: Steel-Concrete composite box girder (Steel box with concrete deck) and Steel box girders with orthotropic decks.
Examples	 Typical section  Composite and non-composite section  Three-Spans continuous plate Girder Bridge  South park bridge-Seattle-USA	 Typical cross section of composite box girder  Two span continuous box-girder bridge  Span-by-span technique using false work at Pennsylvania Transportation Research Facility.  Virtual Reality Image of Pre-stressed Concrete bridge construction
https://www.dywidag-systems.com/emea/projects/project-details/article/lower-screwtail-bridge-beeline-highway-az-usa.html http://www.whatsontheare.com/2012/05/02/primary-uses-of-cast-in-place-reinforced-concrete/ http://www.crsi.org/projects-responsive http://www.pci.org/project_resources/project_profiles/profile_pages/auction_road_bridge/ http://www.yourclassical.org/story/2015/03/18/photos-st-croix-bridge-is-cast-piece-by-giant-piece http://sdotblog.seattle.gov/2012/06/27/south-park-bridge-construction-continues-and-businesses-are-open/ http://www.yourclassical.org/story/2015/03/18/photos-st-croix-bridge-is-cast-piece-by-giant-piece http://bridges.transportation.org/Pages/Minnesota.aspx http://www.archiexpo.com/prod/pujol/product-89366-915930.html http://www.fcp.at/en/projects/p19-lavant-bridge		

Reinforcing Steel: Steel reinforcing bars are manufactured as plain or deformed bars.

Aggregate: There are three general types or groups of aggregate depending on their source:

- primary, which are specifically produced for use in concrete.

- secondary, which are by-products of other industrial processes not previously used in construction.
- recycled, from previously used construction materials e.g. from demolition.[1]

Lime: Until the invention of Portland cement, lime was used as the chief cementing material in the building construction both for mortar and plasters. Most of the ancient palaces, forts, temples, monuments, etc., have been built with lime. Though Portland cement has almost replaced lime, but still at places, where lime is available locally and during the period of shortage of ordinary Portland cement lime provides a cheap and alternative to cement. Usually, lime in free state is not found in nature.[2]

5-1-2-2- Contemporary Materials for Bridges Construction:

In figure (5-10) miscellaneous materials for bridges construction are shown.

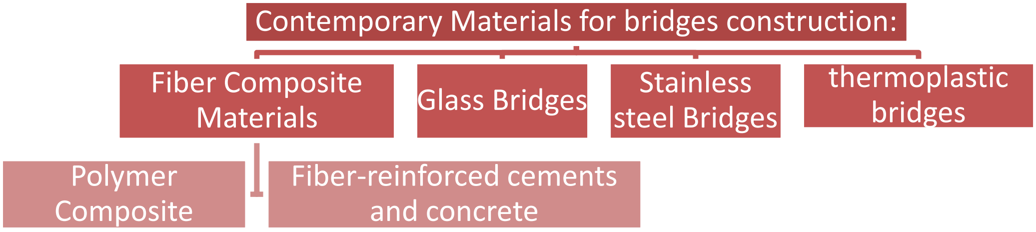


Figure 5-10: Contemporary Materials for bridges construction.[3]

- **Fiber Composite Materials:**

The history of fiber-reinforced composites as construction materials is more than 3000 years old. Well-known examples are the use of straw in clay bricks, mentioned in Exodus, and horsehair in plaster.

Other natural fibers have been used over the ages to reinforce mud walls and give added toughness to rather brittle building materials.

This part is divided into two sections to reflect the difference in the mechanics of the reinforcing process between fiber-reinforced polymers and cementations materials. The first, on fiber-reinforced polymers, is mostly concerned with pre-cracking behavior, and the second, on fiber-reinforced cement and concrete, is mainly concerned with post-cracking performance.[4]

Polymer Composite: When a load is applied to a fiber-reinforced composite consisting of a low-modulus matrix reinforced with high-strength, high-modulus fibers, the viscoelastic flow of the matrix under stress transfers the load to the fiber; this results in a high-strength, high-modulus material that determines the stiffness and strength of the composite and is in the form of particles of high aspect ratio (i.e. fibers), is well dispersed and bonded by a weak secondary phase (i.e. matrix).

Many amorphous and crystalline fibers can be used, including glass, and fibers produced from synthetic polymers, such as carbon fiber (made by elongating poly-acrylonitrile and then placing its elongated form in various inert gases). Making a fiber involves aligning the molecules of the material, and the high tensile strength is associated with improved intermolecular attraction resulting from this alignment. Polymeric fibers are made from those polymers whose chemical composition and geometry are basically crystalline and whose intermolecular forces are strong. As the extensibility of the material has already been utilized in the process of manufacture,

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1 - Peter Domone & John Illston : "Construction Materials- Their nature and behavior" 4th edition- Spon Press publication-UK-2010- p114.

2 - "Bridge Design practice"- CALTRANS (The California Department of Transportation)-Chapter 5 (Concrete Design Theory Reference guide)- USA-2015.p5-2.

3 - By researcher

4 -"Stainless Steel in Bridges and Footbridges Catalogue" -ArcelorMittal Stainless- Europe-2002-p2.

such fibers have a low elongation.[1] figure (5-11)

Fiber-reinforced cements and concrete: In the wider literature, one finds references to both fiber-reinforced cement and fiber-reinforced concrete. The first normally refers to thin-sheet material with high fiber content, no coarse aggregate and a matrix with markedly higher cement content than

normal concrete. The fibers are intended to provide primary reinforcement, i.e. The second normally refers to more traditional concrete to which fibers are added either to provide post-failure integrity in the event of accidental overload (secondary FRC), or to provide control of shrinkage-related cracking (tertiary FRC).[2]

The Lego bridge in Wuppertal, Germany[3]

Fiberglass-polymer composites form the core of a renovated bridge deck in Springfield, USA[4]

Test bridge using the fiber-reinforced cement composite, Virginia, USA[5]

Figure 5-11:Fiber Composite Materials Bridges

Glass Bridges:

Recently, There are some steel structure bridges with Glass flooring, handrails, Details, etc.. Examples: figure (5-19)World longest Walkway in China which stretching a quarter-of-a-mile above a 980ft canyon Construction of the world's longest and highest glass-bottomed bridge has now been completed in Zhangjiajie, central China's Hunan province.

Daredevil workers today joined the last set of steel decks linking the 1,230-foot-long skywalk that hangs 984 feet above the ground, The bridge at Tianmenshan National Forest Park, which cost approximately one year and 26 million Yuan (£2.6 million) to build, beats the walkway above the Grand Canyon in Arizona, which sits at a mere 720ft high. Figure (5-12)

Stainless Steel Bridges:

Stainless steel is an alloy of steel, chromium and eventually other elements such as nickel or molybdenum. It is the chromium that renders the steel stainless. In fact, by virtue of the chromium's reaction with oxygen, the surface of stainless steel consists of a self-protecting passive layer that automatically regenerates itself if damaged. The other alloying elements (molybdenum in particular) further enhance this corrosion resistance. According to its constituent elements and their relative percentages, stainless steel breaks down into more than a hundred grades grouped into several major categories that are found in European standard EN 10088. Thus, stainless steel may be ferritic, austenitic, duplex or martens tic. Each category has specific mechanical properties such as hardness, yield strength, tensile strength, elongation, etc.

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1 - Peter Domone & John Illston : "Construction Materials- Their nature and behavior" 4th edition- Spon Press publication-UK-2010- p305,317.

2 - Peter Domone & John Illston : "Construction Materials- Their nature and behavior" 4th edition- Spon Press publication-UK-2010- p365-367.

3 - https://www.polymersolutions.com/blog/plastic-bridging-gap/

4 - https://www.nsf.gov/news/news_summ.jsp?cntn_id=106729

5 - http://www.canadianconsultingengineer.com/features/new-road-materials/

China Longest Walkway on the world[1]

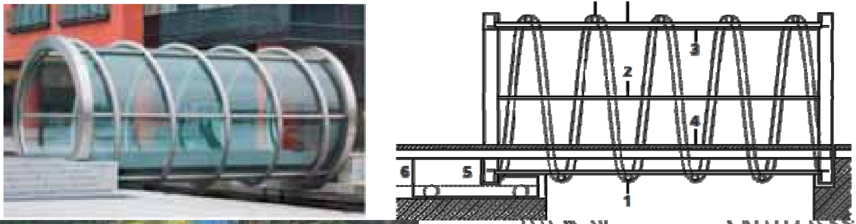
Whittle Arch and Glass Bridge, Coventry 2003[2]

Figure 5-12: Examples of Glass Bridges

These properties are decisive in the choice of a grade for one application or another.Austenitic stainless steels are the most widely used category and today still account for almost 70% of stainless production. However, with the fluctuating cost of nickel in particular, but also of molybdenum, use of the austeno- ferritic duplex category, with a lower content of alloying elements, is increasing. Today, it offers equivalent or even superior quality in terms of corrosion resistance and its superiority in terms of mechanical performance makes it a particularly competitive material in the bridges and footbridges market.[3] Figure (5-13)

Girder bridge in Stockholm, Sweden

Helical Bridge in London, England



Stress-ribbon Bridge in Switzerland

Figure 5-13: Examples of Stainless Steel Bridges[4]

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1 - http://www.dailymail.co.uk/news/peoplesdaily/article-3344133/Is-terrifying-bridge-China-completes-world-s-longest-glass-walkway-stretching-quarter-mile-980ft-canyon.html

2- http://www.ramboll.com/projects/ruk/whittle%20arch%20and%20glass%20bridge

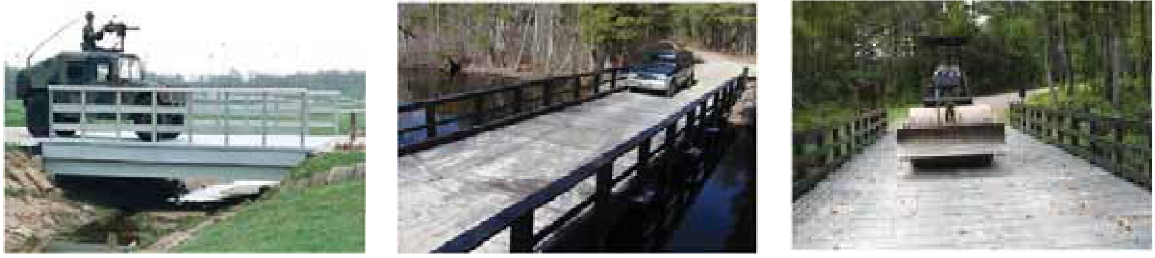
3 -" Pedestrian bridge in stainless steel catalogue"- 1st edition- Building series- Vol.7- Euro inox publications-Germany-2004.

4 -" Pedestrian bridge in stainless steel catalogue"- 1st edition- Building series- Vol.7- Euro inox publications-Germany-2004.

- **Thermoplastic bridges:**

The first vehicular bridge composed of an immiscible polymer blend of polystyrene/high density polyethylene-reinforced thermoplastic with rectangular cross section was built at Fort Leonard Wood, Missouri in 1998, with a high initial cost as compared to traditional materials. The bridge used steel girders to support the thermoplastic sections and to this day has not required any maintenance and still looks new. When viewed on a life-cycle cost basis, the bridge paid for its high initial cost in less than eight years. [1]

Next, in 2002, came a vehicular bridge utilizing the same composite used at Fort Leonard Wood, located in Wharton State Forest in New Jersey with a load capacity of 36 tons and an initial cost close to a chemically treated wood bridge. This was the first bridge to take advantage of the fact that I beams can be molded from the plastics, which is much more efficient in bending than rectangular cross sections. An additional advantage is the possibility of nesting sections to distribute loads and shorten construction time.[2] Figure (5-14)


Vehicular bridge at Fort Leonard Wood, Missouri built in 1998 with a maximum load capacity of 12.5 tons.

Vehicular bridge in Wharton State Forest, New Jersey built in 2002 with an I-beam substructure and a maximum load capacity of 36 tons.

A successful crossing of a 30-ton steamroller over Bridge at Fort Bragg, North Carolina.

Figure 5-14: Thermoplastic Bridges Examples. [3]

5-2- Bridges structure systems

Different bridges structure systems will be discussed as grouped at figure (5-15)

The architect rule in structure system is to choose the most beautiful structure system within the specific budget which facilitates the bridge original function not to calculate the bridge loads or study loads transferring methods.

5-2-1- Beam bridges

They can be mentioned as the simplest and the oldest among the other types. When the need of a bridge first arose in history, beam type solutions were the first to be formed across the creeks. Primitive solutions such as placing woods across the gap were put into effect. There was no complex design or an extraordinary idea of loads transfer. [4]

The applied forces are transferred through the structure in a very simple way in beam bridges. The loads are transferred vertically to the supports. The structure is designed to carry both tension and compression; because in this configuration, the upper part works in compression and the lower part works in tension. Therefore, during the history of bridges, steel type beam bridges have been very widespread types since steel can carry

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[1] - T. Nosker, R. Lampo: "Innovative Structural Concepts for Plastic Lumber Materials- Society of Plastic Engineers ANTEC Conference- Indianapolis-USA- May 1996.

[2] - Vijay Chandra, John S. Kim, Thomas J. Nosker, and George J. Nagle: "world's first thermoplastic bridges"- paper- Department of Defense Corrosion Conference- Washington-USA -2009

[3] - Same previous reference

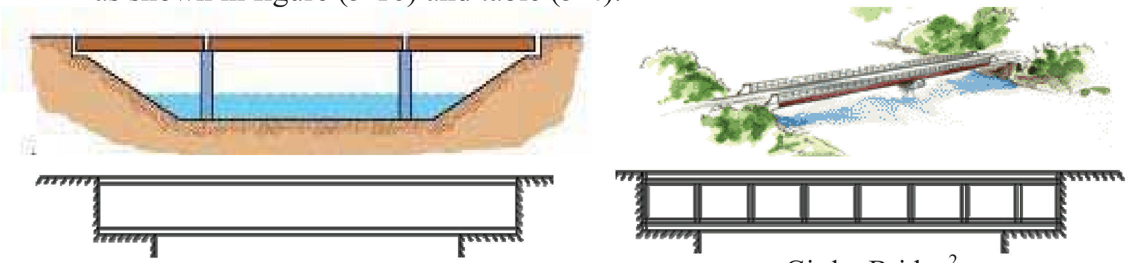
[4] - Aysu Berk: "Geometrical analysis of bridge forms and their feasibility in structural design"- Master thesis- The graduate school of natural and applied sciences of middle East technical university- Turkey- 2005-p27.

both tension and compression. Concrete beam bridges have also been very common in beam bridges. However, as the materials used in beam bridges should be strong in both tension and compression and concrete is weak in tension, steel bars are used in the tension parts in order to strengthen the element.

- **Definition:** Beam Bridges also known as “Girder Bridge” a Deck supported by two pillars at its' ends.

The simplest beam bridge could be a slab of stone, or a plank of wood laid across a stream. Bridges designed for modern infrastructure will usually be constructed of steel or reinforced concrete or a combination of both. The concrete used can either be reinforced, pre stressed or post-tensioned.[1]

- **Different Types Of Beam bridges:** There are different types of Beam bridges as shown in figure (5-16) and table (5-4).



Beam Bridge

Girder Bridge[2]

Figure 5-16: Types of Beam Bridges[3]

The advantages of using beam structure in bridges is their simplicity and economy The design and calculations are more straightforward than other different types of bridges.

5-2-2- Rigid-frame (Rahmen) bridges

Rigid-frame (Ramen) bridge is a bridge type made up of groups of rigidly connected members on which bending moment, axial force, and shear force work at the same time. Rigid-frame bridges are grouped into Vierendeel bridges, which are considered superstructure girder bridges, and bridges of superstructure-substructure integral structure. figure (5-17)

Bridges of superstructure-substructure integral structure include braced rigid-frame bridges, V-leg rigid-frame bridges, and viaducts in urban areas. The applied spans of rigid-frame bridges are about 40 to 80 meters in general.[4]

Rigid frame bridges are sometimes also known as Rahmen bridges. In a standard girder bridge, the girder and the piers are separate structures. However, a rigid frame bridge is one in which the piers and girder are one solid structure.

The cross sections of the beams in a rigid frame bridge are usually I shaped or box shaped. Design calculations for rigid frame bridges are more difficult than those of simple girder bridges. The junction of the pier and the girder can be difficult to fabricate and requires accuracy and attention to detail.

Though there are many possible shapes, the styles used almost exclusively these days are the pi-shaped frame, the batter post frame and the V shaped frame.[5]

- **The construction Materials for Rigid frame Bridges:**

Mainly Concrete and Steel are the material used for Rigid-frame (Ramen) bridges.

---

[1] - http://www.innovateus.net/science/what-beam-bridge

[2] - P. C. Vasani and Bhumika B. Mehta: "Different types of bridges and its suitability"- Paper submitted to Applied Mechanics Department- College of Engineering- Ahmedabad- India -2015.

[3] - http://www.britannica.com/technology/bridge-engineering

[4] - http://www.jfe-eng.co.jp/en/products/infrastructure/bridge/br06.html

[5] - http://www.eng-forum.com/articles/articles/Rigid.htm

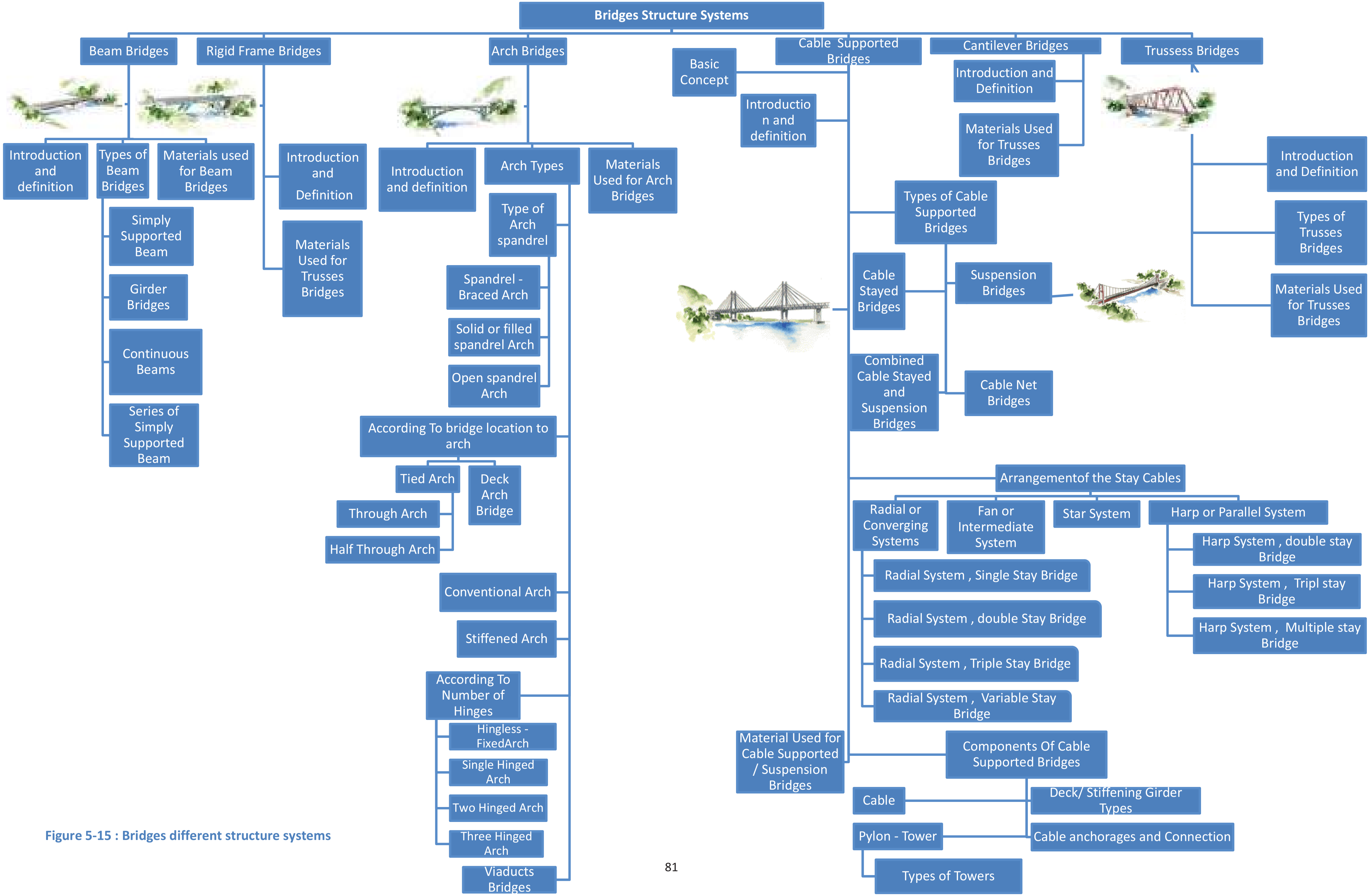
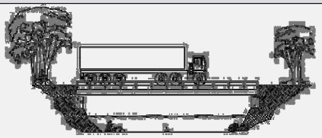
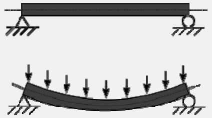
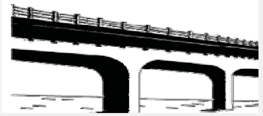
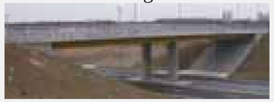
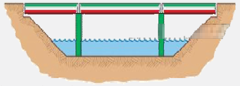
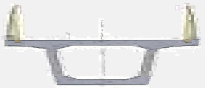
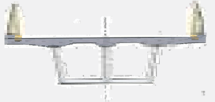
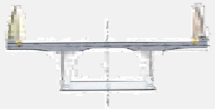
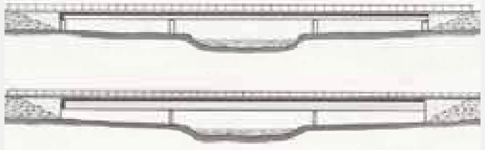
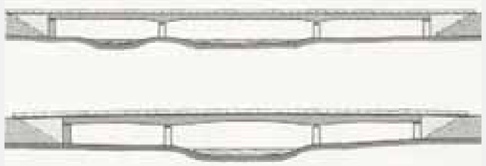
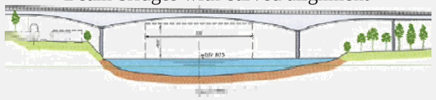
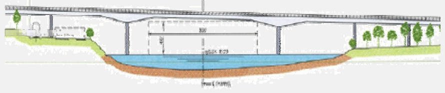
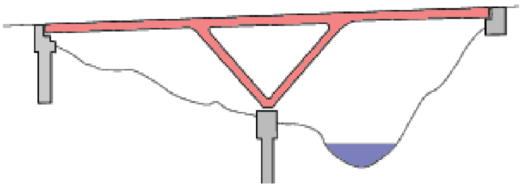


Figure 5-15 : Bridges different structure systems

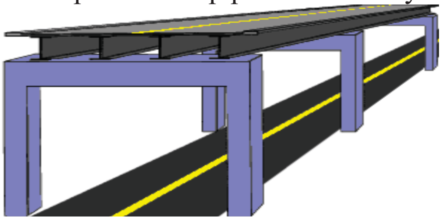
Table 5-4 : Different Types of Beam bridges

	Simply Supported Beam	Continuous Beam Bridges	Series of Simply Supported Beam	Girder Bridges		
				Concrete Section Girders	Steel Section Girders	Hunched Box Girder
Definition	When a bridge is made up of one beam spanning between only two supports, it is called a simply supported beam bridge. The design of the beam bridge is suitable to span a range of 10m to 20m - up to 30m.	If two or more beams are joined rigidly together over supports, the bridge becomes continuous.	When a bridge is made up of several equal beams spanning between series of supports, it is called a series of simply supported beam bridge. Disadvantage of this type of bridges, Several joints and bearings.	Typical concrete sections include the following: A concrete box girder, probably a single cell that would be post-tensioned in order to attain adequate strength Edge girder system with transverse floor beams and a longitudinal slab system. This would be particularly suitable for a cable-stayed structure and other types of structures involving hangers, such as the arch structure.	Structural Steel alternatives include: -A two cell box -A single-cell box girder The single cell box has certain issues with fatigue and redundancy requirements . Cable stressing is a means of gaining the required redundancy when having only two webs.	A box girder bridge is a bridge in which the main beams comprise girders in the shape of a hollow box. The box girder normally comprises either pre-stressed concrete, structural steel, or a composite of steel and reinforced concrete. The box is typically rectangular or trapezoidal in cross-section. Box girder bridges are commonly used for highway flyovers and for modern elevated structures of light rail transport. Although normally the box girder bridge is a form of beam bridge, box girders may also be used on cable-stayed bridges and other forms.
Example	 Standard steel composite beam bridges for roads and highways  Gun Lane bridge carries the Chatham line at Strood and is a typical simply supported beam bridge, in this case with plate girders, photographed on 10th April 2009.  Sketch showing Simply supported Beam Bridge as a dick supported on Two pillars and the deflection forces on it.	 Bridge of State Route 36 over Lake Belton in Belton, Texas USA  Typical Continuous-Span Bridge  Trinity Over bridge on the A120- USA  The Lake Ponchartrain Causeway in Louisiana	 Example of Series of Simply Supported Beam  The end product is shipped to a building site.  A sketch showing series of simply supported beam bridge	 Concrete Box Girder  Edge Girder System  Bridge in Richmond, British Columbia, Canada  Inside Box girder	 Two-Cell Steel Box Girder  Single-Cell Steel Box Girder  Multi-girder bridge using variable depth girders Westgate bridge, Gloucester	 Beam bridges with straight haunches  Beam bridges with curved alignment  Hanched Box Girder  Lewiston – Clarkston Bridge  Box Girder, with a Straight Tapered Haunch
References	Eugene J.Obrien and Damien L.Keogh: "Bridge Deck Analysis"- E and FN Spon publications- London- UK- 1999-p9-13. http://www.britannica.com/technology/simply-supported-beam-bridge http://www.semgonline.com/structures/struct_03.html http://www.steel-bridges.com/highway-bridge-composite-beam.html https://www.fhwa.dot.gov/bridge/prefab/if09010/appd.cfm http://www.globalsecurity.org/military/library/policy/army/fm/3-34-343/chap3.htm			http://www.steelconstruction.info/Modelling_and_analysis_of_beam_bridges http://www.slideshare.net/aziziabdulla/bridges-collection-by-dr-aziz-i-abdulla Smith, D. A.& Hendy, C. R: "Strengthening of Irwell Valley Bridge"-UK" -Bridge Engineering (Institution of Civil Engineers) - UK- 2002-p33-43 F. Leonhardt: " Brücken: Ästhetik und Gestaltung". (In German and English, translated title: Bridges: Aesthetics and Design.) The MIT Press- Cambridge- UK-1984. Lawrie Associates: "Pedestrian / Bicycle Bridge Conceptual Design Phase Knoxville South Waterfront Redevelopment area"- report to city of Knoxville draft design program executive report-USA-2011.		

Concrete Batter-Post Bridge, Finland
The batter post rigid frame bridge is particularly well suited for river and valley crossings because piers tilted at an angle can straddle the crossing more effectively without requiring the construction of foundations in the middle of the river or piers in deep parts of a valley



V shape bridge: Each V-shaped pier provides two supports to the girder, creating a less cluttered profile



Pi shaped frame: The frame supports the raised highway and at the same time allows traffic to run directly under the bridge

Pont du Languedoc, France

Saft El-laban Corridor/ Giza by researcher

Grand Canal Bridge at Le Havre- France[1]

São João Bridge - Portugal[2]

Grand Duchess Charlotte Bridge- Luxemburg

Figure 5-17: Examples of Rigid Frame Bridges[3]

5-2-3- Arch Bridges

After girders, arches are the second oldest bridge type and a classic structure. Arches are good choices for crossing valleys and rivers since the arch does not require piers in the center. Arches can be one of the more beautiful bridge types. Arches use a curved structure which provides a high resistance to bending forces. Unlike girder and truss bridges, both ends of an arch are fixed in the horizontal direction (no horizontal

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[1] - http://www.eng-forum.com/articles/articles/Basic%20types.htm
[2] - https://structurae.net/structures/bridges-and-viaducts/rigid-frame-bridges
[3] - Antónia Királyföld, Gábor Pál: "concrete structures frame bridges on v-shaped supports"-Article-2012

movement is allowed in the bearing). Thus when a load is placed on the bridge horizontal forces occur in the bearings of the arch. These horizontal forces are unique to the arch and as a result arches can only be used where the ground or foundation is solid and stable.[1] Figure (5-18)

- **Definition of Arch :** As a structural Unit, an arch is defined as a member shaped and supported in such a manner that intermediate transverse loads are transmitted to the supports primarily by axial compressive thrusts in the arch.[2]

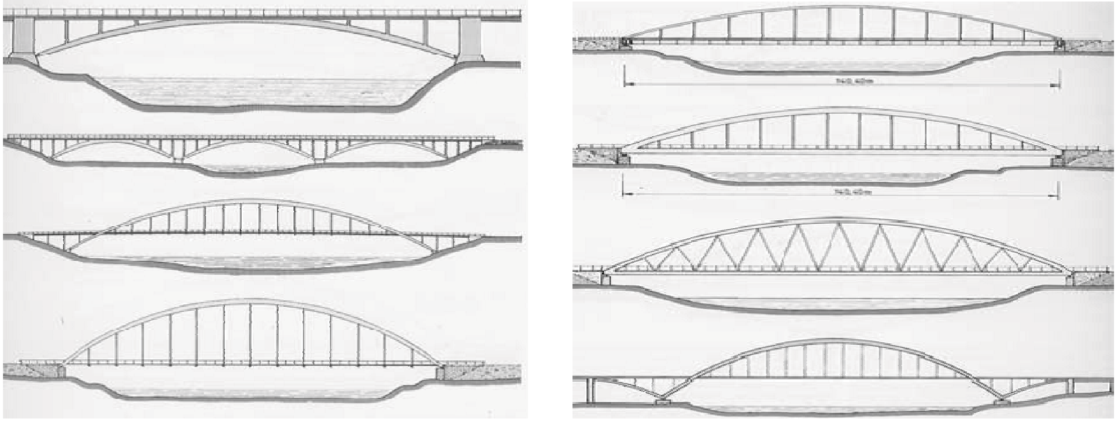


Figure 5-18: Different Alignment of Arch Bridges[3]

- **Types of Arch bridges according to spandrel Type:**

Spandrel definition, an area between the extradoses of two adjoining arches, or between the extrados of an arch and a perpendicular through the extrados at the Springing line.[4]

There are three Types of Spandrel figure (5-19)

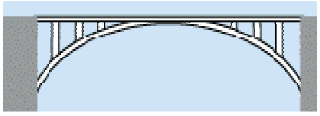
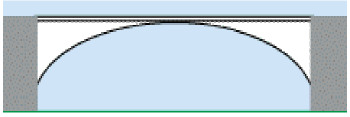
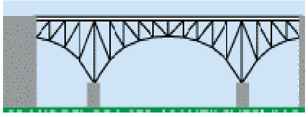
	Spandrel Arch- Braced	**Solid or filled spandrel Arch**	**Open spandrel Arch**[5]
Definition	A spandrel-braced arch or open spandrel deck arch carries the deck on top of the arch.	A closed spandrel is usually filled with rubble and faced with dressed stone or concrete. Occasionally, reinforced concrete is used in building pony arch types	
Sketch			
Example	 Arch bridge Bixby Creek Bridge, Monterey, California[6]	 The Pont du Gard aqueduct- France- layers of filled spandrel arch[7]	 Robert macafee Bridge- Pennsylvania[8]

Figure 5-19: Types of Spandrel Arch Bridges

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1 - http://mary08.pbworks.com/w/page/20434749/Bridges

2 - Liebenberg. A.C and F. K. Kong: "Concrete Bridges: Design and Construction (Concrete Design and Construction Series)"-John Wiley and Sons Inc publications- London- UK-1993-p38.

3- F. Leonhardt: " Brücken: Ästhetik und Gestaltung". (In German and English, translated title: Bridges: Aesthetics and Design.) The MIT Press- Cambridge- UK-1984- p86.

4 - http://www.dictionary.com/browse/spandrel

5 - http://pghbridges.com/basics.htm

6 - :http://pghbridges.com/basics.htm

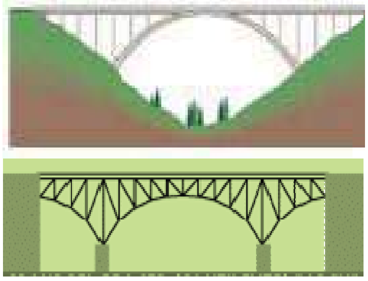
7 - http://www.pbs.org/wgbh/nova/tech/build-bridge-p3.html

8 - http://www.bridgemapper.com/bridge_detail.php?ID=3511

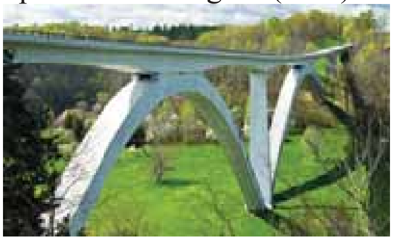
• Types of Arch bridges according to bridge location to arch:

Deck- Arch Bridges:

A Deck-Arch bridge is one where the Bridge deck which includes the structure that directly supports the traffic loads is located above the crown of the arch. The deck arch is Also known as a true arch or perfect arch. figure (5-20)



Deck-Arch Bridge Sketches[1]



The Natchez Trace Parkway Bridge- USA

The New River Gorge Bridge (The longest Arch Bridge in the world)- USA

Deck-Arch Bridge examples

Figure 5-20: Examples of Deck- Arch Bridges[2]

Tied Arch Bridge:

A tied Arch is one where reactive horizontal forces acting on the arch ribs are supplied by a tension tie at deck level of a through or half-Through arch. The tension tie is usually a steel plate girder or a steel Box girder.

The tied arch is a variation on the arch which allows construction even if the ground is not solid enough to deal with the horizontal forces. Rather than relying on the foundation to restrain the horizontal forces, the girder itself "ties" both ends of the arch together. The tied arch (bowstring) type is commonly used for suspension bridges, the arch may be trussed or solid. The trusses which comprise the arch will vary in configuration, but commonly use Pratt or Warren webbing. While a typical arch bridge passes its load to bearings at its abutment; a tied arch resists spreading (drift) at its bearings by using the deck as a tie piece. Also we can describe Tied arch bridges by carrying the thrust through a tie, a tension member between the ends of the span.[3]

There are two types of tied arch bridges: Through arch bridge and Half-Through arch bridge.

A Through Arch: Is one where the bridge deck is located at the spring line of the arch.

A Half-Through arch is where the bridge deck is located at an elevation between deck arch and a through arch.[4] figure (5-21)

Conventional Arch Bridge (Masonry, Brick-Work and Stone Arch bridges): Masonry bridges, constructed in stone and concrete, may have open or closed spandrels A closed spandrel is usually filled with rubble and faced with dressed stone or concrete. Occasionally, reinforced concrete is used in building pony arch types.[5] figure (5-22)

• Stiffened Arch

A structure Engineer Called Millar developed bridges calculations to reach the new bridge form called Deck-Stiffened Arch which neither Hinged arch nor a hollow box bridge. Maillart made the arch relatively heavy with the deck relatively light and the

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[1] - http://karinarodriguezcoronado.pbworks.com/w/page/12678894/Bridges

[2] - http://www.pbs.org/wgbh/nova/tech/build-bridge-p3.html

[3] - Roger L. Brockenbrough & Frederick S. Merritt: "Structural Steel Designer's Handbook"- Section 15 Arch bridges- AISC, AASHTO, AISI, ASTM, AREMA, and ASCE-07 Design Standards- Fourth Edition- Mcgraw-Hill publications- USA- 2000-p115.

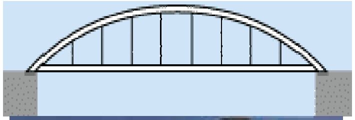
[4]- Wai-Fah Chen and lian Duan: "Bridge engineering handbook"-2nd edition- Taylor & Francis Group- USA-2000-p 17.3.

[5] - Ceng. David Cox: "Brick Work Arch Bridges"- The Brick Development Association- USA- 1996-P 4-13.

connecting columns very light.[1] figure (5-23)

Tied Arch

Sketc

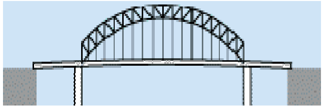


Examples

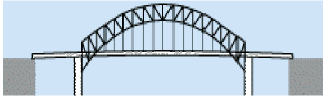
Single arch member Barquetta, Seville[2]

Independent arches Toome Bypass, Northern Ireland

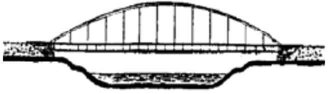
Inclined arches Košická Bridge, Bratislava



Trussed Through Bridge



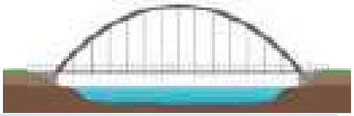
Trussed Half-Through Bridge[3]



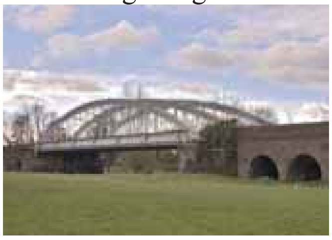
Steel Tied Arch bridge

Arch with Diagonal Hangers[4]

Through Arch

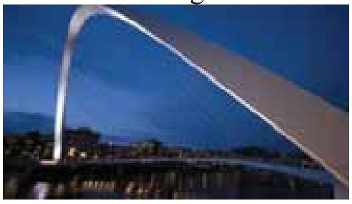


Stanley Ferry Aqueduct Bridge-England



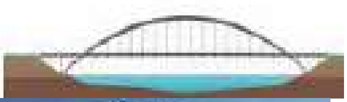
Brunel Windsor Bridge-Yorkshire[5]

Fort Pitt Bridge- USA[6]



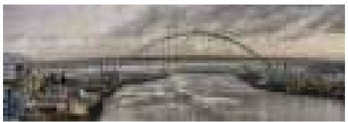
Gateshead Millennium Bridge-England[7]

Half Through Arch



The Bayonne Bridge-New-York- USA[8]

Roosevelt lake BRIDGE-Arizona[9]



Fremont bridge- Portland[10]

Sydney Harbor Bridge-Australia

Fairmont Bridge-Portland[11]

Figure 5-21: Types of Tied Arch Bridge

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[1] -"Bridge aesthetics around the world"- Committee on General structures, subcommittee on bridge aesthetics- Transportation research board- National research council- Washington- USA-1991-P 74.

[2] - http://www.steelconstruction.info/Tied-arch_bridges

[3] - http://www.eng-forum.com/articles/articles/arch.htm

[4] - http://karinarodriguezcoronado.pbworks.com/w/page/12678894/Bridges

[5] - Wai-Fah Chen and lian Duan: "Bridge engineering handbook"-2nd edition- Taylor & Francis Group- USA-2000-p 17.4.

[6] - http://karinarodriguezcoronado.pbworks.com/w/page/12678894/Bridges

[7] - http://www.gateshead.gov.uk/Leisure%20and%20Culture/attractions/bridge/Home.aspx

[8] - http://www.panynj.gov/bridges-tunnels/bayonne-bridge.html

[9] - https://bridgehunter.com/az/gila/roosevelt-lake/

[10] - http://www.lightthebridges.org/bridges/fremont/

[11] - http://pghbridges.com/basics.htm

Semi-Circular Arch: Bridge of Arta in Arta, Greece

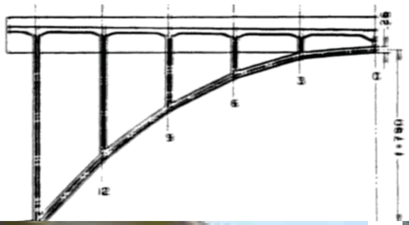
Segmental Arch: Segmental Arch Bridges- at China

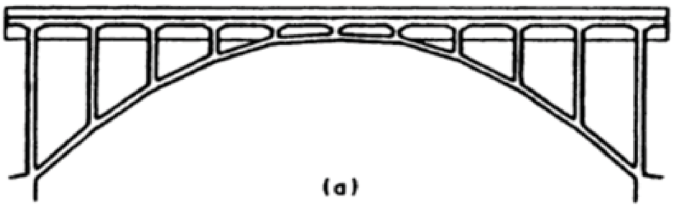
Semi-Elliptical Arch :Midhurst Road bridge, Lip hook[1]

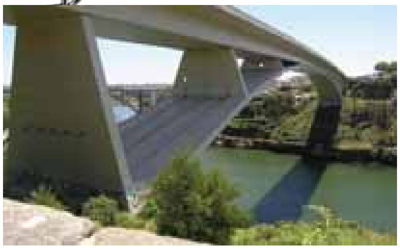
Gothic arch: Puente del Diablo bridge- Spain[2]

Skew Bridge : Rainhill Skew Bridge[3]

Figure 5-22: Types of Conventional Arch Bridge







Infante D.Henrique bridge, Portugal

Reichenau bridge- Switzerland

Gueroz bridge- Switzerland[4]

Figure 5-23: Examples of Stiffened Arch[5]

- **Arch Types according To Number of Hinges:**

A further classification refers to the articulation of the arch. A fixed arch As shown in Figure (5-33) is depicted in and implies no rotation possible at the supports, A and B. The hinge-less arch uses no hinges and allows no rotation at the foundations. As a result a great deal of force is generated at the foundation (horizontal, vertical, and bending forces) and the hinge-less arch can only be built where the ground is very stable. However, the hinge-less arch is a very stiff structure and suffers less deflection than other arches.

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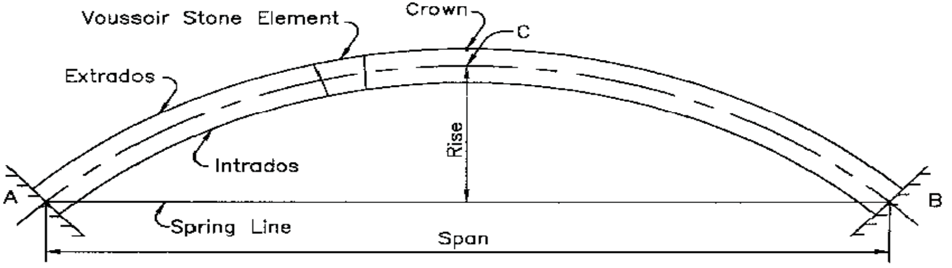
[1] - https://en.wikipedia.org/wiki/Arch_bridge
[2] - http://kaleidoscope.cultural-china.com/en/10Kaleidoscope3071.html
[3] - http://www.semgonline.com/structures/struct_07.html
[4] - https://structurae.net/structures/bridges-and-viaducts/deck-stiffened-arch-bridges
[5] - Xanthakos. Petros P: "Theory and Design Of Bridges"- A wiley- Inter science Publications-USA-1994-p 991

Three-Hinged arch that allow rotation at A,B and C:The three-hinged arch adds an additional hinge at the top or crown of the arch. The three-hinged arch suffers very little if there is movement in either foundation (due to earthquakes, sinking, etc.) However, the three-hinged arch experiences much more deflection and the hinges are complex and can be difficult to fabricate. The three-hinged arch is rarely used anymore.

A two hinged arch that allow rotation at A and B.[1]:The two hinged arch uses hinged bearings which allow rotation. The only forces generated at the bearings are horizontal and vertical forces. This is perhaps the most commonly used variation for steel arches and is generally a very economical design.

A One hinged arch that allow rotation only at point C.[2] figure (5-24)



Hinge-less Arch **A One Hinged Arch** **A two Hinged Arch** **A Three Hinged Arch**

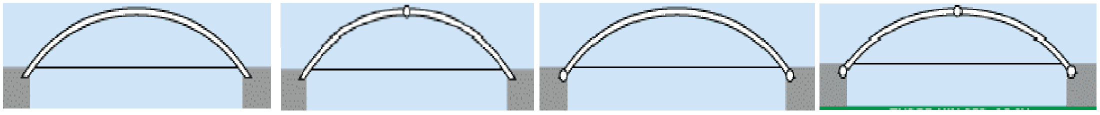


Figure 5-24: Arch Types According to Number of Hinges[3]

- Viaduct Bridges:

A long elevated roadway usually consisting of a series of short spans supported on arches, piers, or columns.[4] figure (5-25)

Knaresborough Viaduct, North Yorkshire[5]

Glenfinnan Viaduct- Skotland[6]

The Ronaco Bridge- Italy[7]

Figure 5-25: Examples of viaduct bridges

- **Arch Bridges Construction Materials**

Brick-Work, Stone, masonry, concrete, wrought iron, cast iron, timber and structural steel.

5-2-4-Cable Supported (Suspended) Bridges

Early cable-suspended bridges were footbridges consisting of cables formed from twisted vines or hide drawn tightly to reduce sag. The cable ends were attached to trees or other permanent objects located on the banks of rivers or at the edges of gorges or

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1 - Wai-Fah Chen and lian Duan: "Bridge engineering handbook"-2nd edition- Taylor & Francis Group- USA-2000-p 17.5.

2 - http://www.eng-forum.com/articles/articles/arch.htm

3 - http://pghbridges.com/basics.htm

4 - http://www.merriam-webster.com/dictionary/viaduct

5 http://www.trekearth.com/gallery/Europe/United_Kingdom/England/North_Yorkshire/Knaresborough/photo204095.htm

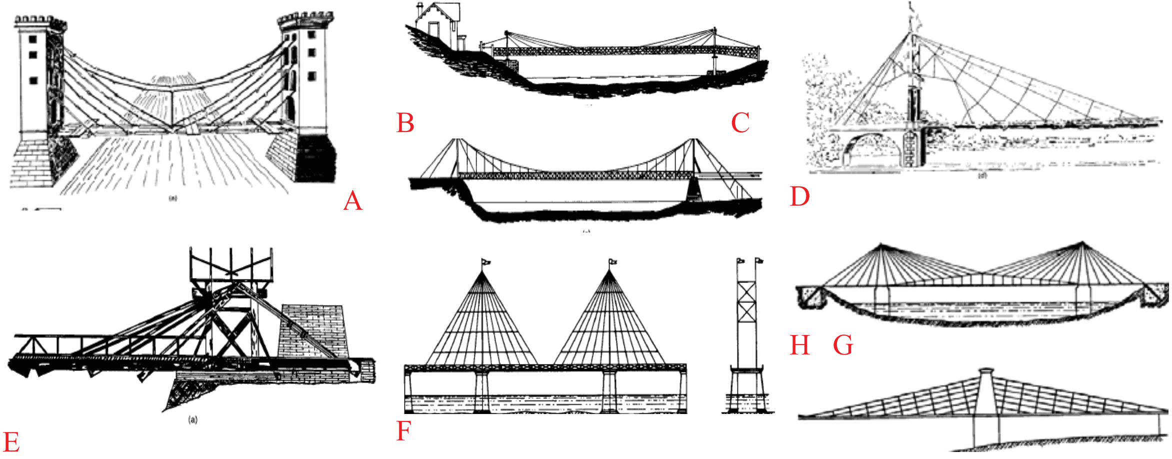
6 - http://photorator.com/photo/52396/the-glenfinnan-viaduct-amp-railway-lochaber-scotland-

7 - Sinopoli: "Arch Bridges (History, Analysis, Assessment, Maintenance and Repair)"- proceeding of the second international arch bridge conference- A.A. Balkema publications- Venice- Italy-1998- p 343-344.

other natural obstructions to travel. The deck, probably of rough-hewn plank, was laid directly on the cable. This type of construction was used in remote ages in China, Japan, India, and Tibet. It was used by the Aztecs of Mexico, the Incas of Peru, and by natives in other parts of South America. It can still be found in remote areas of the world.

From the sixteenth to nineteenth centuries, military engineers made effective use of rope suspension bridges. In 1734, the Saxon army built an iron-chain bridge over the Oder River at Glorywitz, reportedly the first use in Europe of a bridge with a metal suspension system.

However, iron chains were used much earlier in China. The first metal suspension bridge in North America was the Jacob's Creek Bridge in Pennsylvania, designed and erected by James Finley in 1801. Supported by two suspended chains of wrought-iron links, its 70-ft span was stiffened by substantial trussed railing and timber planks.[1] Figure (5-26)



(a) Chain bridge by Faustus Verantius, 1607. (b) King's Meadow Footbridge. (c) Dryburgh-Abbey Bridge. (d) Nienburg Bridge (e)Lo¨scher-type timber bridge. (f) Poyet-type bridge. (G) Gischlard-Arnodin-type sloping-cable bridge. (H) Hatley chain bridge.

Figure 5-26: History of Cable supported (suspended) Bridges[2]

- **Types of Cable Supported Bridges.**

There are two types of cable supported bridges. These types are cable stayed bridges and suspension bridges. In some cases, cable stayed bridges and suspension bridges could be combined. Table (5-5)

5-2-4-1-Cable-Stayed Bridges

Cable stayed bridge are similar to suspension bridges. The visual perception and some geometry of the structures have similarities; however, the load transfer mechanism is different. In cable-stayed bridges, the cables are connected to the towers. The cables carry the deck and they transfer the load directly to the towers. There are many straight cables as the opposite of the swaying main cable. The cables transfer the load from the deck, through the towers, to the ground. Extra abutments are not compulsory in these types of bridges. There are sometimes twin systems of cables and towers whereas there are also bridges with one system in the middle. But when the cables and towers are placed in the middle, the deck is essential to be box girder, in order to achieve tensional stability.[3]

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1 - Roger L. Brockenbrough & Frederick S. Merritt: "Structural Steel Designer's Handbook"- Section 15 Arch bridges- AISC, AASHTO, AISI, ASTM, AREMA, and ASCE-07 Design Standards- Fourth Edition- Mcgraw-Hill publications- USA- 2000. 15.1

2 -Same Previous reference

3 - Aysu Berk: "Geometrical analysis of bridge forms and their feasibility in structural design"- Master thesis- The graduate school of natural and applied sciences of middle East technical university- Turkey- 2005-p32.

- **Cable Net bridges:**

It is a developed system from Combined cable stayed and suspension bridge system. The most favorable structural system for a cable net bridge seems to be as shown in The cables of Net cable system might be divided into the following groups indicated into same figure:

- Main span top cable.
- Side span top cable.
- Side span stay cable.
- Self-anchored main span stay cables.

5-2-4-2- Suspension Bridges:

The longest bridges in the world are suspension bridges or their cousins, the cable-stayed bridge.[1]

A suspension bridge is one where cables are put across the obstacle and the deck is suspended from these cables. Suspension bridges have tall towers or pylons through which the cables are strung. So, the towers are supporting the majority of the roadway's weight. [2]

Suspension bridge is the structure system which the deck is carried by the main cable and its many supporting cables. The shape of the main cable can be thought as the opposite version of the shape of the arch bridge, swaying between the towers. As far as this contrast is concerned; cables are all working in tension, opposite to arch bridges, in this case. However, this time the towers, which carry the entire load, are working in compression.

Suspension bridges are advantageous and very successful for crossing long spans especially when an intermediate pier is not appropriate to construct.

However, they are not suitable when the span is smaller but the loading is heavy, since the system would not work efficiently and the great amount of load In suspension bridges, the tower is a support for the main cables when they carry the load to the abutments. As loads are finally transferred to the ground, the conditions of the soil are important. The cables used might either be a compacted bundle of parallel high tensile steel strands or may be made up of a group of wire ropes.[3] Figure (5-27)

- **Combined Cable stayed and suspension bridge:**

The idea of combining the suspension and cable stayed system has occurred at different occasions during the modern history of cable supported bridges, although the system has not been chosen for actual construction since the days of the Brooklyn bridge.

- **The Cable stayed systems are only possible under these Conditions:**

The correct Analysis of structural system, The use of tension members having under dead load a considerable degree of stiffness due to high pre-stress and beyond this still sufficient capacity to accommodate the live load and The use of erection methods which ensure that the design assumptions are realized in all economic manner.

- **Material Used for Cable Supported / Suspension Bridges:**

Most Common Materials used for Suspension / Cable stayed bridges is reinforced concrete or Steel Trusses for pylon and girders and for cables and anchors Steel is the perfect material for usage. [4]

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1 - http://pghbridges.com/basics.htm

2 - http://karinarodriguezcoronado.pbworks.com/w/page/12678894/Bridges

3 - Walther. Rene: "Cable Stayed Bridges" 2nd edition- Cromwell Press publications-Great Britain-UK-2003-p 6-7.

٤- جورج صبحي راغب: "جماليات انشاء الكباري - رؤية خاصه من وجهة النظر المعمارية"- رسالة ماجستير- قسم عمارة- كلية الهندسة- جامعة القاهره- ١٩٩٨, ص١٤١-١٤٣.

Pedestrian Bridge- San Diego1 | The Millau V cable-stayed bridge | Mexico Inaugurates World's Tallest Suspension Bridge[2]

Sky Bridge Langkawi- Malaysia[3]

Infinity Bridge- Stockholm[4] | 6th of October Bridge, Egypt by researcher

Brooklyn Bridge- New York- USA[5]

Figure 5-27:Different Shapes of Cable Supported (Suspension & cable stayed) Bridges

- **Structural Components of Cable stayed / Suspension Bridge:**

The basic structural components of a suspension bridge system as shown in figure (5-37) are discussed.

- Stiffening Girder/ Trusses longitudinal Structures which support and distribute moving vehicle loads.
- Main cables: A group of parallel-Wire bundled cables which support stiffening
- girders/ trusses by hanger ropes and transfer loads to towers.

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1 - http://www.welcometosandiego.com/2010/02/downtown-san-diego-harbor-drive-pedestrian-bridge-update/

2 - http://vacation-island.blogspot.com.eg/2014_02_23_archive.html

3 - http://undesign.rssing.com/chan-2608804/all_p13.html

4 - www.pinterest.com

5 - http://www.history.com/topics/brooklyn-bridge

- Main Towers: Intermediate vertical structures which support main cables and transfer bridge loads to foundations.
- Anchorages: Massive concrete blocks which anchor main cables and act as end supports of a bridge. As shown in figure (5-28) Interface to every structural Component. Also in table (5-5), Types and Components of cable suspended bridges are discussed to be considered during bridge architectural design stage.

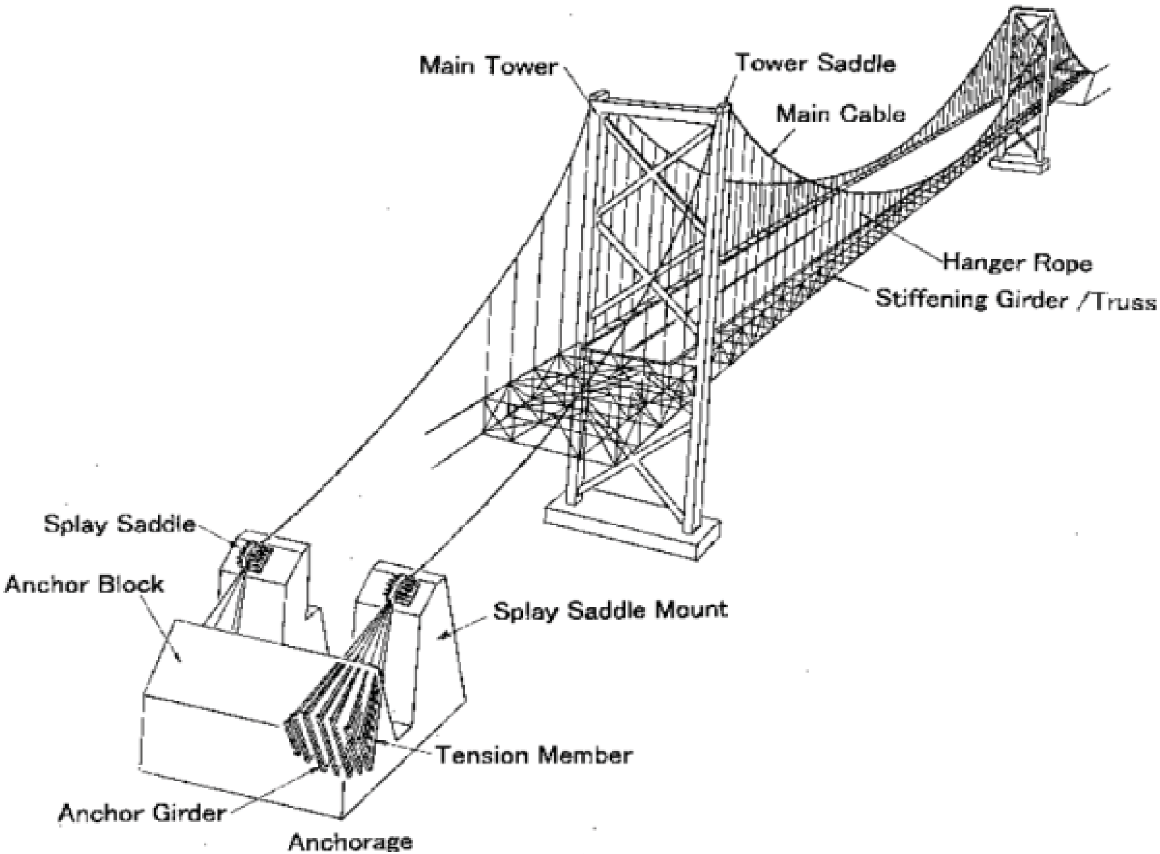

Figure 5-28: Suspended Bridge Components.[1]

- **Arrangement of Stay Cables:**

According to the various longitudinal arrangements. Cable-stayed bridge could be divided following four basic systems as shown in tables (5-6) Radial or converging system, Fan or intermediate system, star system and harp system.

5-2-5-Cantilever Bridges

Engineers in the nineteenth century understood that a bridge that was cantilevered across multiple supports would distribute the loads among them. This would result in lower stresses in the girder or truss and meant that longer spans could be built. Several nineteenth century engineers patented continuous bridges with hinge points mid-span. The use of a hinge in the multi-span system presented the advantages of astatically determinate system and of a bridge that could handle differential settlement of the foundations.[2]

- **Definition:** A cantilever bridge is a bridge built using cantilevers, structures that project horizontally into space, supported on only one end.

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[1] - Wai-Fah Chen and lian Duan: "Bridge engineering handbook"-2nd edition- Taylor & Francis Group- USA-2000-p 18.2

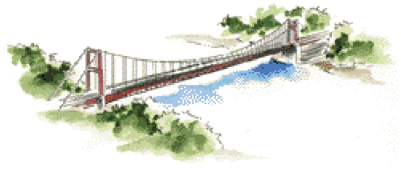
[2] - Same Previous reference

Table 5-5: Different Types and Components of Cable Supported Bridges

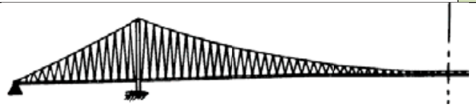
Types of Cable Supported Bridges

Cable stayed bridge

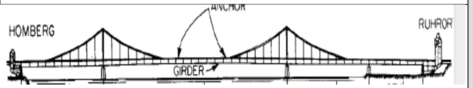
Suspension Bridge



Combined cable stayed and suspension bridges



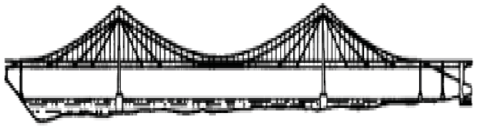
Suspension system with inclined suspenders



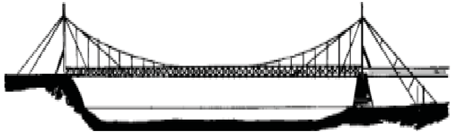
Suspension bridge with vertical suspenders

Bridge system proposed by Dischinger

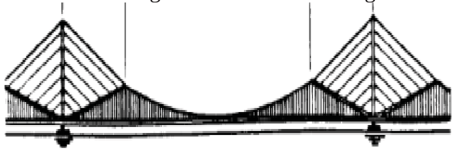
Hybrid bridge proposals for Gibraltar Straits Crossing



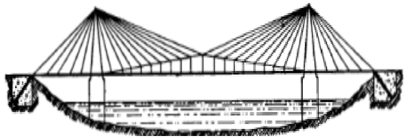
The Salazar Bridge. elevation of the bridge in 1993



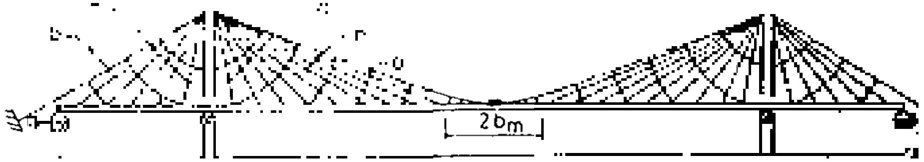
Dryburgh-Abbey Bridge



Hybrid bridge proposals for Gibraltar Straits Crossing



Gischlard-Arnodin-type



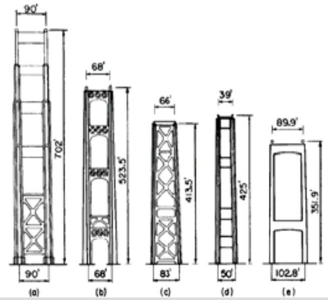
Cable net bridges bridge

References

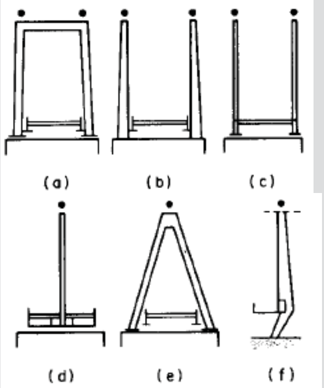
Walther. Rene: "Cable Stayed Bridges" 2nd edition- Cromwell Press publications-Great Britain-UK-2003-p6-7.
Roger L. Brockenbrough & Frederick S. Merritt: "Structural Steel Designer's Handbook"- Section 15 Arch bridges- AISC, AASHTO, AISI, ASTM, AREMA, and ASCE-07 Design Standards- Fourth Edition- Mcgraw-Hill publications- USA- 2000-p15.1 to 15.6
Khaled M.Mahmoud:"Modern techniques in bridge engineering"- BTC Bridge Technology Consulting- CRC Press Taylor and Francis group- A Balkema book-New York-USA-2011-p 6-9.
Edward Allen & Waclaw Zalewski" "Form and Forces- Designing Efficient, Expressive Structures"-1st edition, John Wiley & Sons publications- New York- USA-2010-p 352-355.
Khaing. Mayee Mon: "Study on Variation of Joint forces in stiffening truss of Cable-Stayed bridges" Lecture- Yangon technological university- Department of civil engineering-2012.

Components of Cable Supported Bridges

Pylon - Tower: Typical pylon configurations are portal frames. For economy, pylons should have the minimum width in the direction of the span consistent with stability but sufficient width at the top to take the cable saddle.



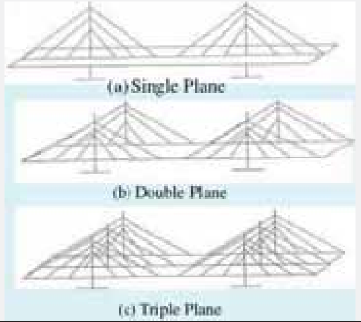
Suspension-bridge pylons: (a) Golden Gate, (b) Mackinac, (c) San Francisco-Oakland Bay, (d) First Tacoma Narrows, (e) Walt Whitman

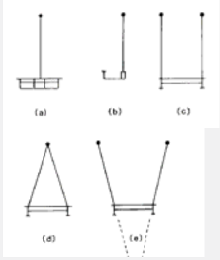


Shapes of pylons used for cable-stayed bridges. (a) Portal frame with top cross member. (b) Pylon fixed to pier and without top cross member. (c) Pylon fixed to girders and without top cross member. (d) Axial pylon fixed to superstructure. (e) A shaped pylon. (f) Laterally displaced pylon fixed to pier. (g) Diamond-shaped pylon

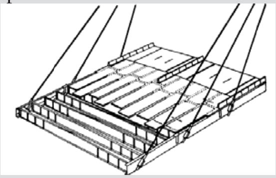
Cables : is generally used in a generic sense to indicate a flexible tension member. Several types of cables are available for use in cable-supported bridges. Number of cable planes: There are three basic transverse cable of configurations are following.

Cross sections of cable-stayed bridges showing variations in arrangements of cable stays. (a) Single-plane vertical. (b) Laterally displaced vertical. (c) Double-plane vertical. (d) Double-plane inclined. (e) Double-plane V-shaped.



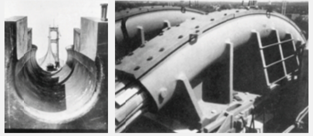


Deck/ Stiffening Girder Types: Transverse to the longitudinal axis of the bridge, the cable stays may be arranged in a single or double plane with respect to the longitudinal centerline of the bridge and may be positioned in vertical or inclined planes

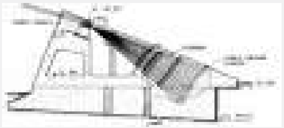


Composite steel-concrete superstructure girder of a cable-stayed bridge.

Cable anchorages and Connection: Saddles atop towers of suspension bridges may be large steel castings in one piece or, to reduce weight, partly of well-meant. The size of the saddle may be determined by the permissible lateral pressures on the cables, which are a function of the radius of curvature of the saddle. Other saddles of special design may be required at side piers to deflect the anchor-span cables to the anchorages. Also, splay saddles may be needed at the anchorages.

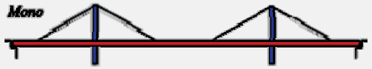
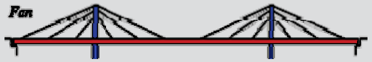
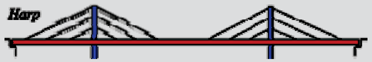
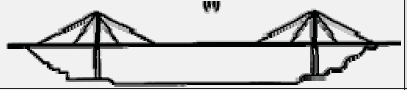
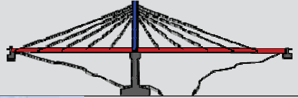
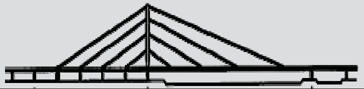
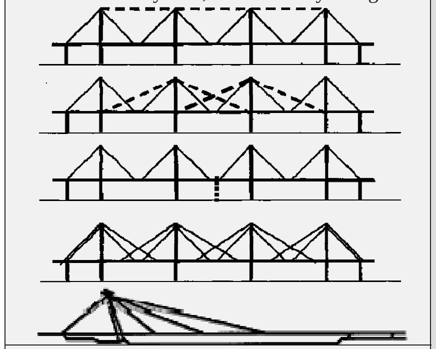
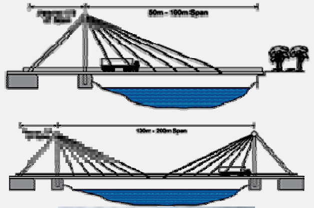
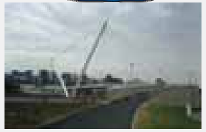
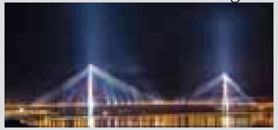
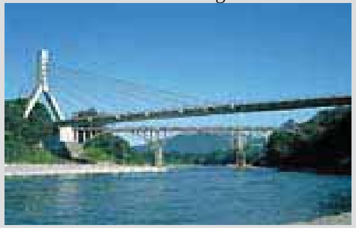


Pylon saddle.- Pylon saddle used for the Hennepin Avenues Bridge.

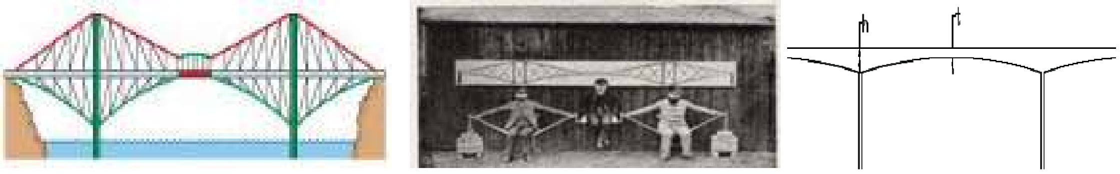


Anchorage for Verrazano Narrows Bridge.

Table 5-6: Arrangement of the Stay Cables and Suspension Bridges.

Arrangement of the Stay Cables				Suspension Bridge
Radial or Converging Systems	Fan or intermediate system	Star System	Harp or Parallel system	
				
Radial System, Single Stay Bridge 	Fan Double 	 Abdoun Bridge - Jourdan	Harp System, double stay Bridge 	 Golden Gate Bridge - USA
Radial System, double Stay Bridge 	Fan Triple 	 Zhivopisny Bridge - Russia	Harp System, Triple stay Bridge 	
Radial System, Triple Stay Bridge 	Fan multiple 		Harp System, Multiple stay Bridge 	 The Humber Bridg
Radial System, Variable Stay Bridge 	 Vancouver Skybridge/ Normandie Bridge  William H. Natcher Bridge		 The Sunshine Skyway Bridge  River Wear Bridge- UK	 Akashi Kaikyo Bridge  Ness Island pedestrian bridge
  Knnt Bridge - Eurka skyway - UK	 Russky Bridge - Novosilsky  Puente de la Unidad Bridge - Mexico		 Chichibu Bridge - Japan	 Verrazano Narrows Bridge
References: http://www.jfeeng.co.jp/en/products/infrastructure/bridge/br03.html Roger L. Brockenbrough & Frederick S. Merritt: "Structural Steel Designer's Handbook"- Section 15 Arch bridges- AISC, AASHTO, AISI, ASTM, AREMA, and ASCE-07 Design Standards- Fourth Edition- Mcgraw-Hill publications- USA- 2000-p15.5 Neil Parkyn: "Superstructures- The World's Greatest Modern Structures" -Merrell publications,-London- UK-2004-p30-35		http://karinarodriguezcoronado.pbworks.com/w/page/12678894/Bridges http://happypontist.blogspot.com.eg/2012_05_01_archive.html	http://www.pbs.org/wgbh/nova/tech/build-bridge-p3.html Bernhard Graf : "Bridges that changed the world" - Prestel Publishing- Frankfurt- Germany-2002-p96-97. http://mary08.pbworks.com/w/page/20434746/Bridges%202	https://neil.fraser.name/writing/bridges/islands.html http://www.dreamstime.com/photos-images/modern-cable-stayed-bridge-zhivopisny-bridge-moscow.html http://www.steel-bridges.com/cable-stayed-bridge.html

For small footbridges, the cantilevers may be simple beams; however, large cantilever bridges designed to handle road or rail traffic use trusses built from structural steel, or box girders built from pre-stressed concrete. The steel truss cantilever bridge was a major engineering breakthrough when first put into practice, as it can span distances of over 1,500 feet (460 m), and can be more easily constructed at difficult crossings by virtue of using little or no false work. [1] figure (5-29), (5-30) and (5-31)


Model of truss Cantilever bridge

Postcard of Benjamin Baker's human cantilever bridge model.

Model of concrete Cantilever bridge

Figure 5-29: Cantilever Bridge Concept[2]

- **The construction Materials for Rigid frame Bridges:**

Mainly Concrete and Steel are the material used for Cantilever Bridges.

Concrete Cantilever Bridges


Skye Bridge, United Kingdom Raftsundet Bridge, Norway

Steel Cantilever Bridges


The Astoria–Megler Bridge- Washington- USA

Forth railway bridge over the Firth of Forth, Scotland

Mississippi River Bridge in Baton Rouge, USA.

Figure 5-30: Examples of Cantilever Bridges [3]


Other Types of Cantilever Bridges[4]

Ring Road- Maadi direction From Hadabet Elahram

6th Of October Bridge- Ramses street- By researcher

Figure 5-31: Examples of Concrete Cantilever Bridges

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[1] - Honorio. Jose Diogo: "Conceptual design of long-span cantilever constructed concrete bridges"- Master Thesis- Structural Design and Bridges- KTH Royal Institute of Technology is a university in Stockholm- Sweden-2007-p 16-17.

[2] - http://www.britannica.com/technology/cantilever-bridge

[3] - https://www.pinterest.com/pin/435934438901181728/

[4] - http://www.123rf.com/stock-photo/cantilever_bridge.html?mediapopup=10927958

5-2-6- Truss Bridges

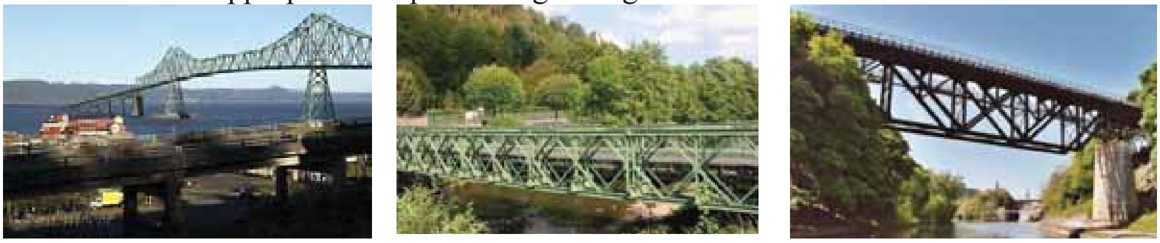
A truss is a structure made of many smaller parts. Once constructed of wooden timbers, and later including iron tension members, most truss bridges are built of metal.[1]

The truss is a simple skeletal structure. In design theory, the individual members of a simple truss are only subject to tension and compression forces and not bending forces. Thus, for the most part, all beams in a truss bridge are straight. Trusses are comprised of many small beams that together can support a large amount of weight and span great distances. In most cases the design, fabrication, and erection of trusses is relatively simple. However, once assembled trusses take up a greater amount of space and, in more complex structures, can serve as a distraction to drivers.[2] figure (5-32) and (5-33)

A. **Types of Truss Bridges**:

Types of trusses bridges are also identified by the terms deck, pony and through which describe the placement of the travel surface in relation to the superstructure. The king post truss is the simplest type; the queen post truss adds a horizontal top chord to achieve a longer span, but the center panel tends to be less rigid due to its lack of diagonal bracing.

As shown in figure (5-34) different types of truss bridges shapes to help architects to choose the most appropriate shape to bridge design.



The Astoria Bridge over the Columbia River in Oregon

Bailey bridge over the Meurthe River, France.

Deck truss railroad bridge over the Erie Canal

The Astoria Bridge

Abandoned Bridge in New Castle

The Bridge of Peace over the Kura River in Tbilis

Figure 5-32: Examples of truss bridges[3]

Webb bridge, Melbourne, Australia[4]

Figure 5-33: Truss bridges Unique Shapes

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1 - http://pghbridges.com/basics.htm

2 - http://www.eng-forum.com/articles/articles/Truss.htm

3 - http://mary08.pbworks.com/w/page/20434746/Bridges%202

4 - Chris van Uffelen's: "Masterpieces: Bridge Architecture + Design"- Braun publications-USA-2009-p11and12.

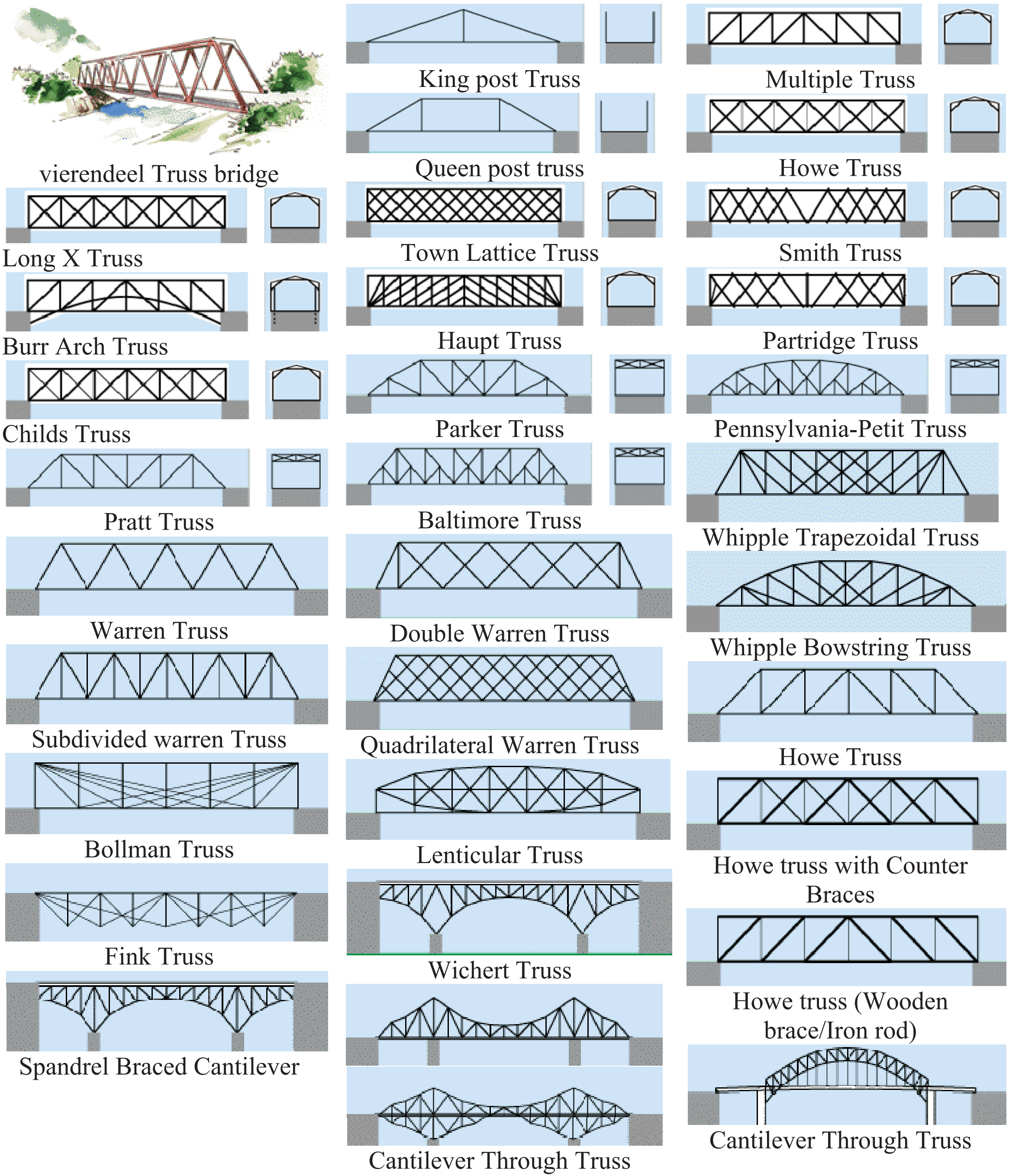

Figure 5-34: Types of Truss Bridges[1]

5-3- Actions and Loads on Bridges

5-3-1- Actions on Bridges

An action is an assembly of concentrated or distributed forces (direct), or imposed or constrained deformations (indirect actions), applied to a structure due to a single cause. An action is considered to be a single action if it is stochastically independent, in time and space, of any other assembly of forces, or imposed or constrained deformations, acting on the structure.

Actions can be qualitatively classified according to their variation in time, or space, or according to their dynamic nature.[1]Figure (5-35)

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[1] - http://www.eng-forum.com/articles/articles/Truss.htm

5-3-1-1-Principal Actions Include:

- permanent and long term actions (Dead loads, earth pressure due to retained fill or retained water, etc)
- Transit and variable actions (primary live loads traffic, railway loading, footway loading, Cycle loading, restraint action, etc)
- Short term actions (erection loads, dynamic loads affected by equivalent static impact factors, etc) [2]

Transit secondary forces "forces due to accidents" example: (Antirion Bridge, Greece)

Transit and variable actions (primary live loads traffic)-6th of October bridge

Figure 5-35: Actions on bridge[3]

5-3-1-2- Supplementary actions include:

- Transit secondary forces due to primary live loads of traffic like (barking forces, collision with bridges parapets, etc)
- Transit forces due to natural causes (Wind actions, flood actions, earthquake actions, etc)

5-3-2-Loads on Bridges:

Bridge structure is like any other structure should be designed to resist the different kinds of loads. any bridge consists of the upper part (superstructure) and the lower part (substructure) so the loads on bridge may be divided to (loads on superstructure and loads on substructure).[4]

Conclusion of Major loads on bridges:

- Dead loads (self weight of substructure, weight of fill supported by foundation, Dead loads of superstructure, etc)
- Earth pressure and differential settlement (different movement joints of bridge components)
- Exceptional loads (snow, earthquake, etc) [5]
- Loads during construction (combinations of any of loads above can be critical for incomplete substructure during stage of construction)
- High way traffic loads (Normal and abnormal traffic loads)
- Natural actions (Wind and flood actions, etc) [6]

As shown in figures (5-36) loads on bridge are studied. Also As shown in figure (5-37) classifications of actions on bridge are illustrated.

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1 -- Liebenberg, A. C: "Concrete Bridges: Design and Construction"- Longman Scientific and Technical- Longman Group UK Limited- Burnt Mill- Harlow-UK-1992 p 156

2 - Croce.Pietro and Malakatas Nikolaos : "Actions on Bridges"- presentation -EUROCODES Bridges- Background and applications-2010.

3 - Yolonda Maxwell: "Famous Bridges of the World- Measuring Length, Weight, and Volume"- (Math for the Real World: Proficiency Plus)- Rosen Classroom publications- USA-2005- p105.

٤ -فيصل محمود ابو العزم: "الكباري بين التصميم المعماري و الانشاء" - دراسة تحليليه - رسالة ماجستير - قسم عمارة - كلية الفنون الجميله - جامعة حلوان -٢٠٠٣ - ص ٦٦-٧٦.

5 - Obrien.Eugene J., Keogh.Damien L. and Alan J. O'Connor: "Bridge Deck Analysis" -2nd Edition- CRC Press publications- USA-2014- p 2.

٦ -جورج صبحي راغب: "جماليات انشاء الكباري - رؤية خاصه من وجهة النظر المعمارية"- رسالة ماجستير- قسم عمارة- كلية الهندسة- جامعة القاهره- ١٩٩٨- ص ٦٩-٧٨.

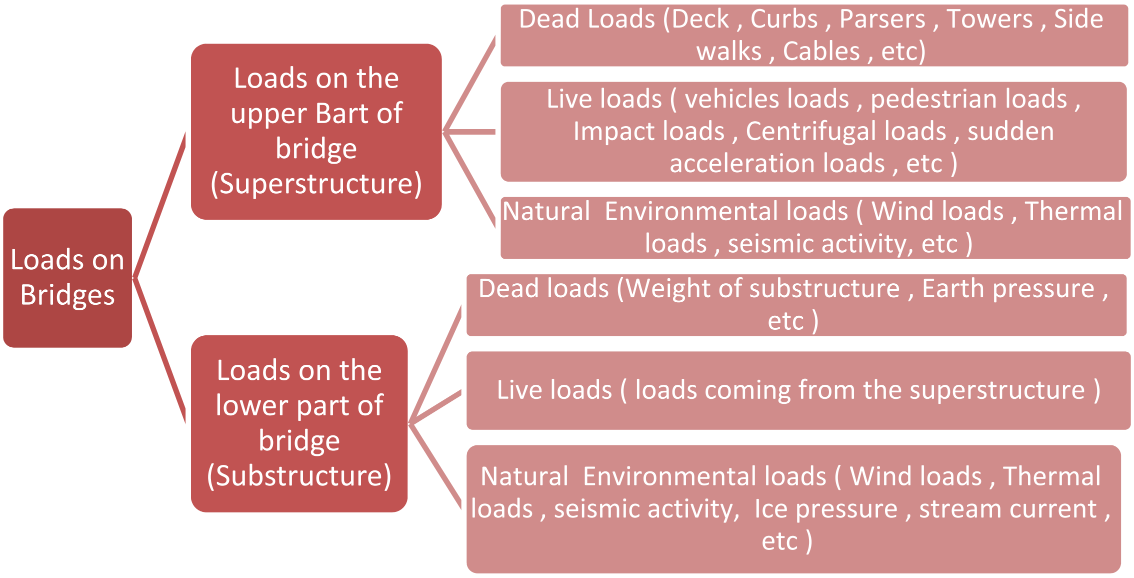

Figure 5-36: Loads on Bridges Parts[1]

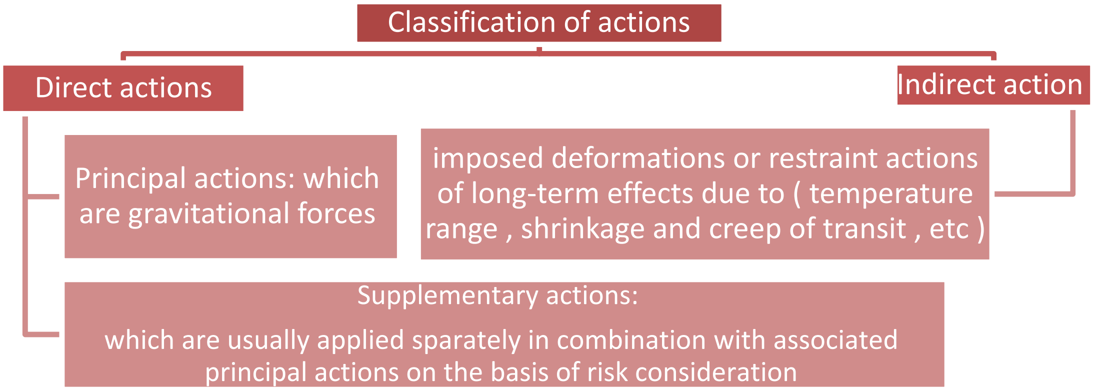

Figure 5-37: Classification of actions[2]

5-4- Bridges Construction Methods:

There are many construction methods differ in details from Construction system to another, also differ from material to another material. These construction methods could be sorted as shown in figure (5-38) and table (5-7).

Bridge deck as the biggest and the most important structure element in bridges have several construction methods. As shown in table (5-8) Most used construction methods for bridge's decks are discussed.

5-5- Relationship Between Bridge's Structure and Bridge's Body

(Bridge deck is the part which used by pedestrian or vehicles).

There are three cases of relationships:

- Bridge body is upper bridge structure
- Bridge body is passing through bridge structure
- Bridge body is under bridge structure. Figure (5-39)

Also there are several relationships between The bridge structure / body with other bridges or buildings structures.

- The bridge is over other bridges structures.

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[1] - Taly, Narendra: "Design of modern highway bridges" - Mcgraw-Hill College Division publications-USA-1997- p237.

[2] - Kong, F : "Hand book of structural concrete bridges"- pitman- London- UK-1982- p28.

- The bridge is under other bridges structures
- The bridge is passing through other bridges structures
- The bridge beside other buildings.
- The bridge is passing through building. figure (5-40)

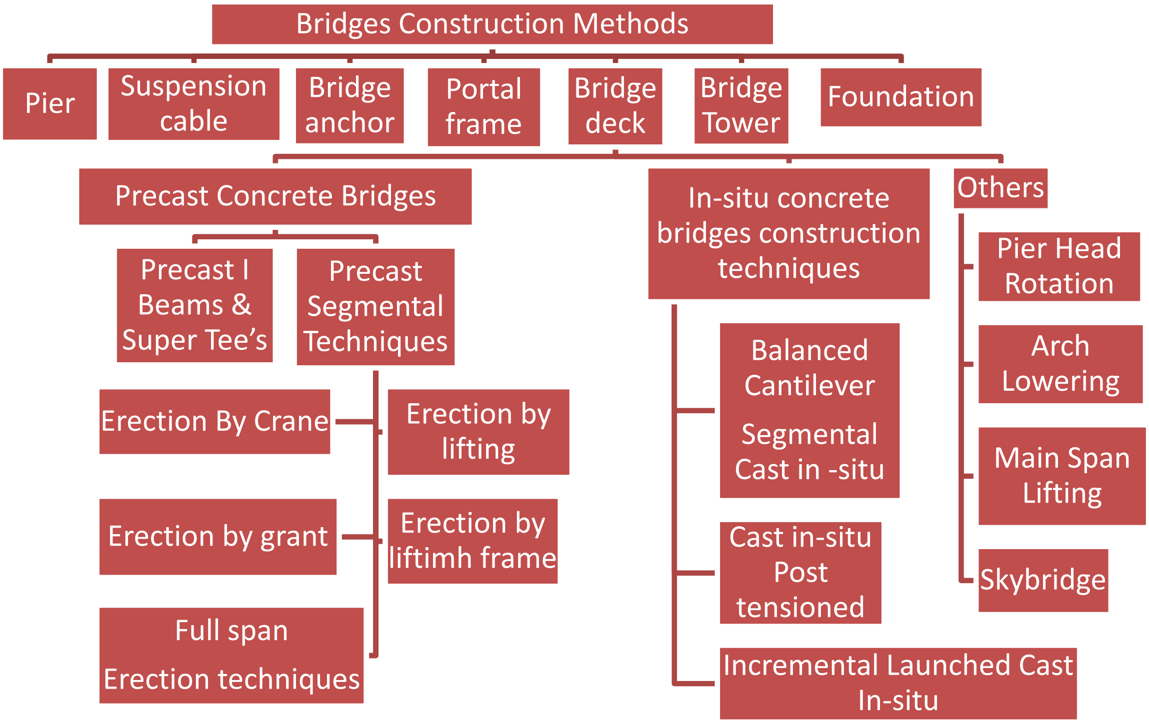
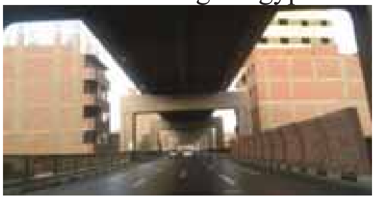


Figure 5-38: Bridge construction methods[1]

Examples of connections between bridges bodies, Lanes, Branches and structure[2]

Bridge body is passing through bridge structure Desouk Bridge- Egypt



The bridge is passing through other bridges structures. Saft Ellaban corridor two layers- by researcher

Figure 5-39: Relationship Between Bridge's Structure and Bridge's Body

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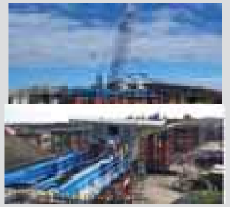
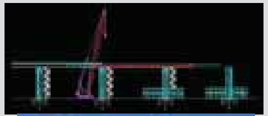
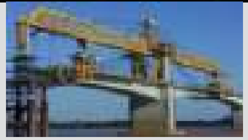
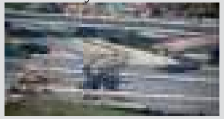
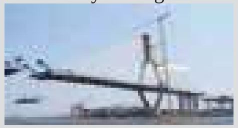
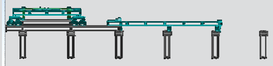
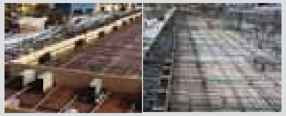
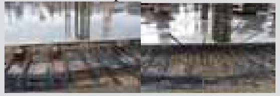
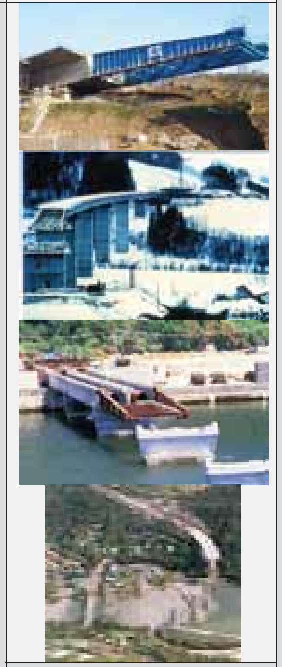
[1] - By researcher

[2] - http://umarticles.blogspot.com.eg/2011/10/worlds-most-complex-and-unique-roads.html

Table 5-7: Bridges Parts construction methods

	Foundation	Pier	Bridge Tower	Portal frame	Suspended Cable	Bridge anchor	Bridge deck
Structure Element Brief	foundation is required to support the bridge towers, portal frames or piers Usual foundation methods such as H-pile, pipe-pile, bore-pile or precast concrete pile can be used for such purpose.	Pier is the vertical supporting structure for usual spanned bridges. Pier is more suitable for bridge with maximum width of deck up to about 8m. Usually bridge pier is constructed using in-situ method with large panel formwork.	This is the vertical supporting structure only for cable suspension or cable-stayed bridges. The tower is usually construction in high-strength concrete using in-situ method. Mechanical climb form is most efficient for casting the bridge tower. In some cases, the tower can be constructed in a structural frame type.	A portal usually consists on two piers on each side with cross beam in between to support the deck. In this case the width of deck can be up to 20m (6 traffic lanes). In some situations the height of a portal frame can be up to 50m from ground. Climb form can be used in this high headroom cases. The erection of a complicated false work system to support the portal construction is usually involved.	For suspension and cable-stayed bridges for the hanging, support or counter-balancing of the bridge deck	Required only for suspension or cable-stay bridges to resist the pull from the suspension cable or counter-span of the bridge. Bridge anchor can be of gravity type using great mass for the counter-balancing, or using ground anchors for the same purpose.	The horizontal part of a bridge that support pedestrian or traffic activities. The construction methods for the deck is shown in Table (5-8)
Structure Element Construction Method example	 The foundation of the bridge tower of Ting Kau Bridge on Japan	 Forming the foundation, frame work, pier supports for piers of elevated highway bridges	 The foundation for the Bridge Tower of Tsing Ma Bridge on Japan	 False work for the construction a portal frame  Single piers and portal frame to support the bridge deck	 Spinning of the suspension cable using steel thread	 Cable anchor of Tsing Ma Bridge (Japan) on Ma Wan side with the suspension cable fixed onto it. The anchor structure also serves as the abutment for the future bridge deck	
Reference	Carmichael. Jason and Gager. Arthur: "Highway Bridge Design and Construction" Bachelor thesis- Faculty of Worcester polytechnic institute WPI-Massachusetts-USA-2009.p17-25. La Violette.Mike: "Bridge construction practices using incremental launching" Research to American Association of State Highway and Transportation Officials (AASHTO)-Highway Subcommittee on Bridge and Structures- Bridge Engineering Center- from Center for Transportation Research and Education -Iowa State University Ames- Iowa-USA-2007-p 30-40			https://structurae.net/structures/tsing-ma-bridge https://structurae.net/structures/ting-kau-bridge http://yee.co.uk/another-bridge-example-big-bridge-test/ Wong. Raymond: "Construction of Bridges"- paper- Division of Building Science and Technology- City University of Hong Kong-Japan-2012. Trayner, David: "Bridge Construction Methods" -presentation at Post-tensioning institute of Australia limited PTI- Concrete institute of Australia-2004.			

Table 5-8: Bridges Girder/ superstructure construction methods

Precast Concrete Bridges			**In-situ concrete bridges construction techniques**			**Others**
Precast I Beams and Super Tee's	**Precast Segmental Techniques**		**Balanced Cantilever Segmental Cast in -situ**	**Cast in-situ Post tensioned**	**Incremental Launched Cast In-situ**	
1. Description • Standard Beams can be pre and or post tensioned. • Cast on site or in existing PC Yard 2. Advantages • Cheap • Simple to erect 3. Disadvantages • Limited in length • Less efficient • Bad aesthetics   Cebu South Coastal Road - Philippines	1. Description • Complete deck cast, delivered and erected in unique cells • Segments are pre-stressed together using external and or internal tendons. • Typically in Span by Span or Balanced Cantilever mode 2. Advantages • Structurally efficient and good aesthetics • Complete with deck when erected ,Rapid and safe • Cast during substructure works – overlap of activities 3. Disadvantages • Casting yard setup • Need extra space to be casted **Precast segmental erection techniques** 1. Erection on False work  M7 Crane Erection on False-work- Germany 2. Erection by Gantry A. Span By Span – "Simply Supported" B. Balanced Cantilever   Bridge Over Mekong River - Laos	 Northern Gateway Alliance – NZ, Waiwera Bridge 3. Erection by Crane  Balanced Cantilever Segmental Erection by Crane - HongKong 4. Erection by Lifting Frame  Industrial Ring Road - Bangkok 5. Full Span Erection Techniques   MRT Full Precast Span Erection - Singapore  Taiwan High Speed Rail Contract	 Formwork Travelers 2nd Link Singapore - Malaysia  Seacliff Bridge - Form traveler  MFT on Taiwan High Speed Rail C215  Gungahlin Drive Ext - Canberra	 Stressed ribbon pedestrian bridge, Grants Pass, Oregon There are two types of Cast in-situ Post tensioned • Bonded post-tensioned concrete • Unbounded post-tensioned concrete  1 2 1. Rolls of post-tension cables 2. Pulling anchors for post-tension cables  3 4 3. Pulling anchors for post-tension cables 4. Pulling anchors for post-tension cables  5 6 5. Post-tension cables stripped for placement in pulling anchor 6. Positioned post-tension cables  7 8	 7. Post-tension cable ends extending from freshly poured concrete 8. Post-tension cable ends extending from concrete slab  9 10 9. Hydraulic jack for tension cables 10. Cable conduits in formwork	•Pier Head Rotation •Arch Lowering •Main Span Lifting •Sky-bridge  Examples on Bridges different construction methods according to bridge's unique structure system
References	http://www.cement.org/cement-concrete-basics/products/prestressed-concrete http://www.bbrnetwork.com/technologies/construction-methods.html http://www.steel-bridges.com/tech-over-truss-bridge.html		Carmichael. Jason and Gager. Arthur: "Highway Bridge Design and Construction" Bachelor thesis- Faculty of Worcester polytechnic institute WPI-Massachusetts-USA-2009- p17-25.		Trayner, David: "Bridge Construction Methods" -presentation at Post-tensioning institute of Australia limited PTI- Concrete institute of Australia-2004. http://www.bbc.com/news/uk-england-london-20533457	

Gate Tower with bridge through it- Japan[1]

Building beside and under 6th of October bridge and Elquba bridge- Egypt- By researcher

Figure 5-40: Relationship between Bridges structure and other Building's Structure

5-6- Conclusion

As shown in table (5-8) most important bridge construction materials with mechanical properties are studied, Also as shown in table (5-9) most important bridge structure systems with their advantages and disadvantages are summarized.

As discussed earlier in this chapter, bridges structure divided to several parts, first part is bridge construction materials, second part is bridge structure systems, third is factors affecting on bridge structure as loads, actions and bridge construction methods.

The risks involved in constructing any particular bridge may play a significant part in the assessment of the cost of construction and should therefore be minimized.

Bridge structure system, materials and construction methods are the main items effecting bridge function and bridge aesthetics, There are many factors to use bridge structure system, Material and construction method as:

- Bridge functional and Aesthetical design.
- Bridge expected costs compared to bridge budget.

Expected time to construct the bridge and catching the planned time schedule

5-6-1- Concluded Prerequisites

AP: Construction Materials Selection
AP: Structure Systems Selection
AP: Construction Methods Selection

5-6-2- Concluded Credits

CR: The influence of Site/Context/Concept on Structure Materials Selection.
CR: The influence of Site/Context/Concept on Structure Systems Selection.
CR: The influence of Site/Context/Concept on Construction Methods Selection.
CR: Whole Bridge Structure Integrity.

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[1] - http://www.amusingplanet.com/2012/01/gate-tower-building-with-highway.html

Table 5-9: Conclusion of Most Important Bridge Construction Materials[1]

Material	Mechanical properties	Achieved structure systems
Timber (Wood)	• Good resistance to Tensile stress parallel to it's fiber direction. • Good resistance for shear stress in direction perpendicular on its fiber direction.	• Suspension Bridges. • Arch Bridges. • Trusses Bridges. • Beam Bridges.
Stone/ Masonry	• Good resistance to compressive stress.	• Arch Bridges.
Cast iron	• Good resistance to compressive stress.	• Suspension Bridges. • Arch Bridges. • Trusses Bridges. • Beam Bridges. • Frame Bridges.
Wrought iron	• Good resistance to tensile stress.	• Suspension Bridges.
Steel	• Good resistance to compressive, Tensile, shear and bending stress	• Suspension Bridges. • Arch Bridges. • Trusses Bridges. • Beam Bridges. • Frame Bridges.
Aluminum	• Good resistance to compressive, Tensile, shear and bending stress • Light weight. • Corrosion resistance.	• Suspension Bridges. • Arch Bridges. • Trusses Bridges. • Beam Bridges. • Frame Bridges.
Reinforced Concrete	• Good resistance to compressive, Tensile, shear and bending stress	• Suspension Bridges. • Arch Bridges. • Trusses Bridges. • Beam Bridges. • Frame Bridges.
Composite material	• Good resistance to compressive, Tensile, shear and bending stress • Corrosion resistance.	• Suspension Bridges. • Arch Bridges. • Trusses Bridges. • Beam Bridges. • Frame Bridges.

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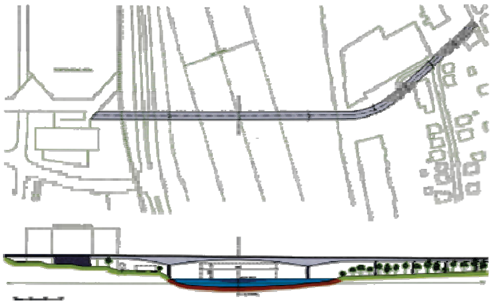
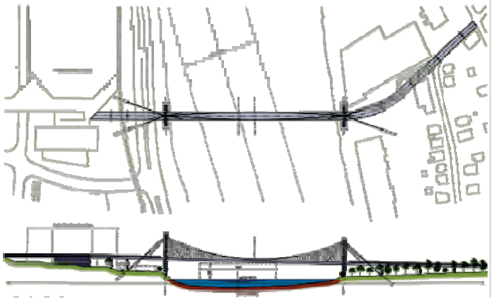
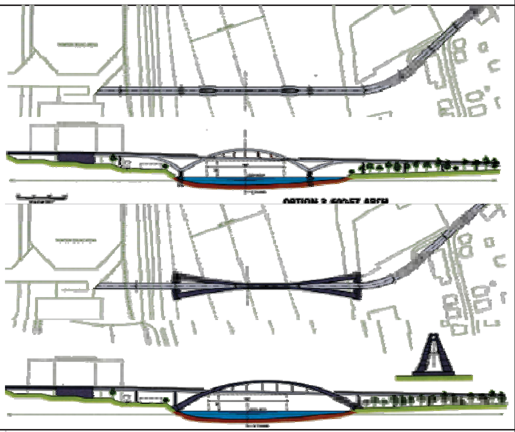
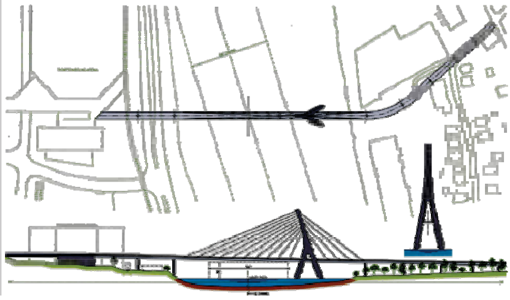
1 - By researcher

Table 5-10: Conclusion of Most Important Bridge Structure Systems[1]

	Structure System sketchs	Advantages and dis-advantages
Beam Bridges		**Advantages** They carry pedestrians, automobiles, trucks, light and heavy rail, and is the simplest of many types of bridges. They usually resist the bending that may occur with heavy loads. **Disadvantages** They usually cover relatively short distances. As they are lengthened, they need more supporting piers (pillars). This makes them unsuitable if there needs to be a lot of space underneath them. Short span until the 250 feet.
Susbension Bridges		**Advantages** They carry cars, trucks, light rail, and they also can be really long, and built high over the water to allow the passages of tall ships. Although they have good aesthetics. **Disadvantage** High vibrations build in magnitude due to some regular energy input. Can not be used for heavy rail crossings.
Arch Bridges		**Advantages** Bigger span than a beam bridge. They can made of almost any material. A great resistance. **Disadvantages** Expensive construction.
Cable stayed bridge		**Advantages** High speed of construction and low cost. Simple cable repair or replacement. Economical cable , slender and lighter structure with great distances span. The lighter weight of the bridge though an advantage during an earthquake. **Disadvantages** The lighter weight of the bridge though a disadvantage in a heavy wind. Cable stayed bridge design is complex.

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1 - http://sites.dartmouth.edu/hu/design-experience/

Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

- Introduction
  - Introduction
  - Research Problem Approach
  - Research Problem
  - Research Goal
  - Research Hypotheses
  - Research Methodology
  - Research Scope
  - Research Importance
- Part 1 : Theoretical Study
  Bridges And Sustainability Overview
  - Chapter 1: Bridge's Art, Science and Construction Historical Development
  - Chapter 2: Sustainable Bridges
- **Part 2: Analytical Study**
  Developing a Rating System for Egyptian Bridges Architectural Evaluation
  - **Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages**
    - Chapter 3: Different Types of Bridges and Architecture
    - Chapter 4: The Relationship between the Bridge and its Context
    - Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form
    - **Chapter 6: Bridge's Different Parts and their Relation with Bridge's Shape and Form**
    - Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design.
    - Chapter 8: Design Process of a Sustainable Bridge and Architect's Role
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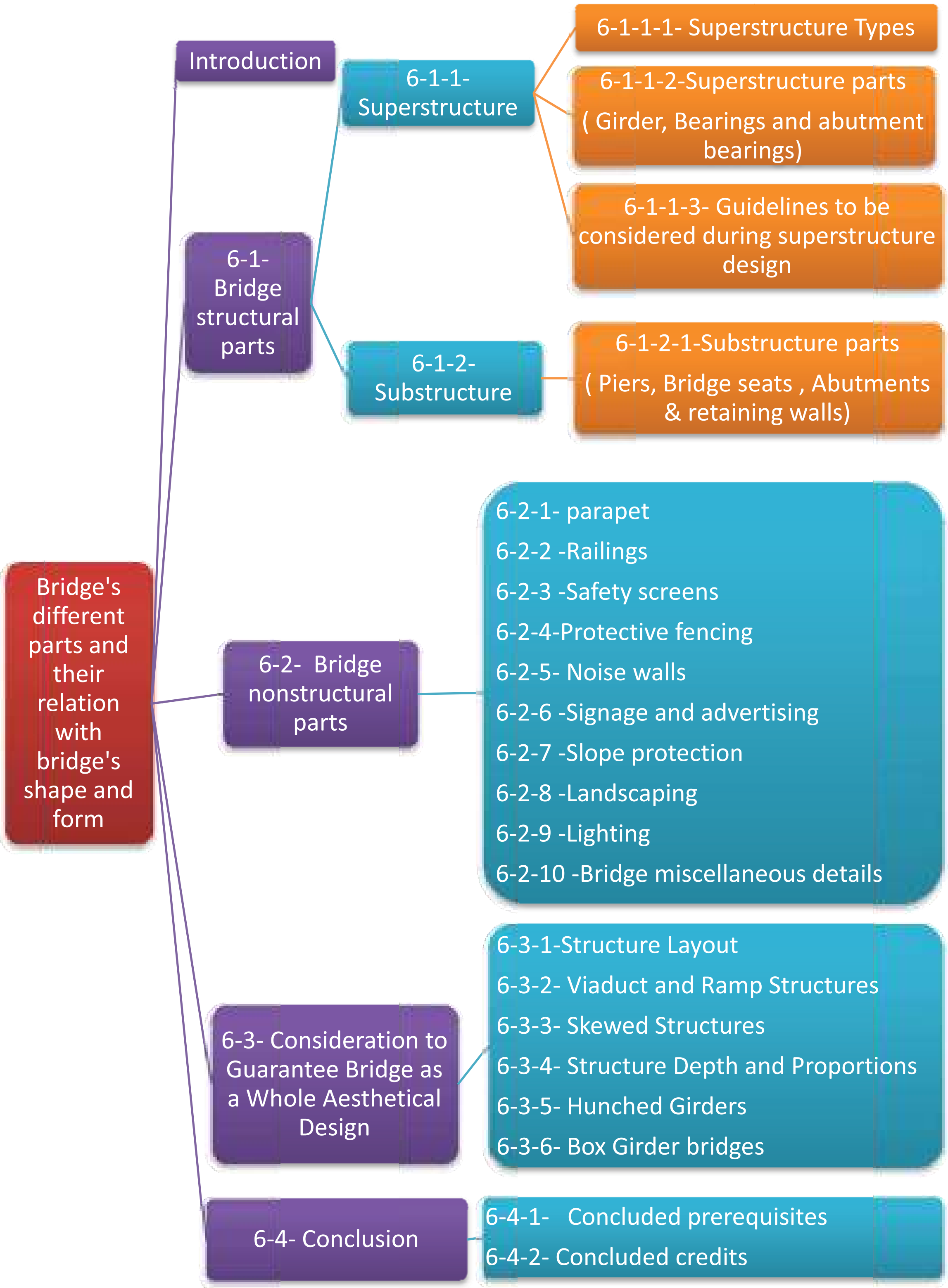
    Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage
    - Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community
- Part 3: Inductive Study
  Developing an Egyptian Sustainable Bridge Rating System
  - Chapter 10: Sustainability Assessment Concepts
  - Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation
- Chapter 12 : Conclusion and recommendations
- Appendices

Chapter 6 : **Bridge's Different Parts and Their Relation with Bridge's Shape and Form.**



Chapter 6 structure: Bridge's Different Parts and Their Relation with Bridge Shape and Form

Chapter 6: Bridge's Different Parts and Their Relation with Bridge's Shape and Form

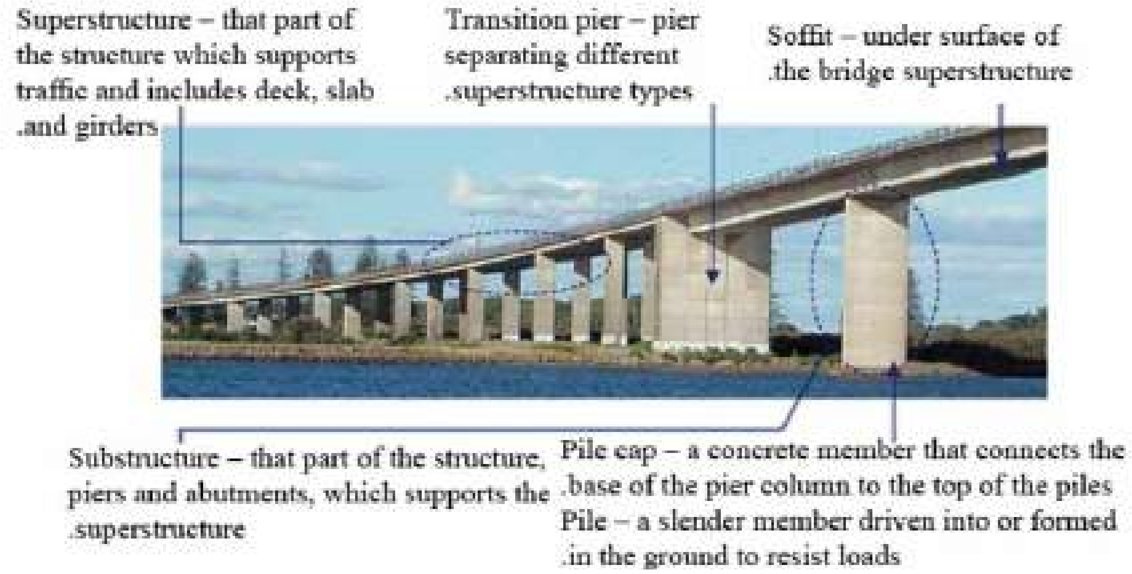
Introduction

It is often said in relation to design that ‘the devil is in the detail’. What is meant is that it is often the small things that can make or break a design, and this is especially important with bridges where the details are highly visible. This chapter is discussing every detail in the bridge starting from big essential structural element (superstructure and substructure) containing all visible structural details which make the bridge safe,
to nonstructural details which is not affecting bridge safety but effects on bridge final shape and form. There are four important aesthetical considerations in bridge details:

- Details design must be considered as part of the whole bridge design.
- The design of the details should minimize the potential for staining.
- The bridge detail should not impair the view from the bridge.
- Good access for inspections and maintenance should be considered early in the design phase.

6-1- Bridge structural parts

A problem that can obstruct meaningful debate between designers is consistency of terminologies. The following annotated photographs figure (6-1) set down the terminologies used to define bridge parts and should be understood by all involved in the bridge design process.



Superstructure – that part of the structure which supports traffic and includes deck, slab .and girders

Transition pier – pier separating different .superstructure types

Soffit – under surface of .the bridge superstructure

Substructure – that part of the structure, piers and abutments, which supports the .superstructure

Pile cap – a concrete member that connects the .base of the pier column to the top of the piles

Pile – a slender member driven into or formed .in the ground to resist loads

Figure 6-1: Bridge structural parts (by researcher)

<u>6-1-1- Superstructure</u>

Since the superstructure is a major structural element in any bridge, the challenge is to make it seem thin and light through a selection of the superstructure type, continuity of the spans, superstructure depth and shape characteristics, and details.

The major visual design goals of the superstructure are:

• Apparent slenderness
• Continuity
•A strong consideration for its relationship with the substructure.[1]

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[1] -"Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- p III-1 to III-28.

6-1-1-1- Superstructure Types

The superstructure type defines the structural system used to support the bridge self-weight and applied loads. It can be an arch, girder, rigid frame, truss or cable-supported type structure. The most memorable aspect of the structure is determined when the overall shape of the structural members is established.

- Multiple girder systems, such as steel plate or box girders, pre-stressed

concrete girders and concrete box girders, are common structural systems for everyday bridges.

- Arches or rigid frames are occasionally used in situations where visual features, atypical site conditions or project requirements make their use appropriate.
- Cable-supported bridges are often used in special situations where visual impact is important or where site conditions require a long span solution.

Each structure type has optimum span-to-depth ratios, cross-sectional shapes, details and use limitations, which have aesthetic implications. The primary visual consideration related to structure type is structure depth.

Generally, thinner structures with longer spans are more visually transparent and pleasing than deeper structures or structures with shorter spans.

The apparent depth of a bridge is the combined depth of the girder, deck slab and edge railing. If this dimension becomes too large, the bridge may appear bulky and more of a barrier than a crossing.[1]

6-1-1-2- Superstructure parts

Superstructure is consists of different parts as girders, bearings and abutment bearings.

6-1-1-2-A- Girder

The horizontal alignment of the girders is also important especially on curved bridges. In general it is preferable to avoid a large scale faceted appearance created when using a series of straight girders by using shorter facets or curved girders, however ensuring a curved parapet mitigates the jagged appearance of straight girders underneath.

- **Girder elevation**

The girder is seen in elevation and its cross sectional shape are important considerations. Therefore, Taken consideration during bridge girder design are discussed in (Table 6-1)

Hunched girders are expressive and responsive to the forces in the bridge. They can often be more distinctive and elegant than single depth beams.[2]

- **Girder cross section**

The parapet fascia and overhang provide the strongest opportunities to make the bridge seem more slender than it really is. The following techniques are suggested:

- Divide the fascia surfaces by shadow and/or physical breaks.
- Change the relative brightness of different fascia surfaces by changing their angle so they reflect more or less sunlight.
- Remove the divisions between fascia surfaces by introducing curvature. [3]

The cross sectional shape of the girder should be considered with attention to the following principles as shown in Figure (6-2):

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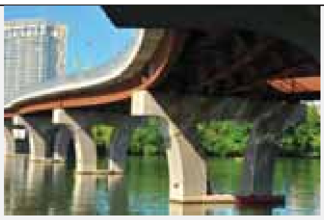
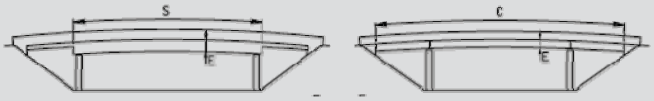
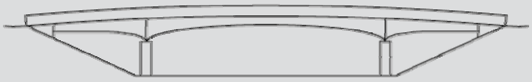
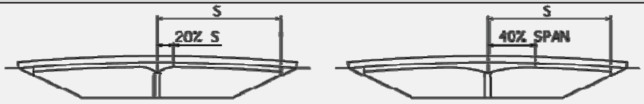
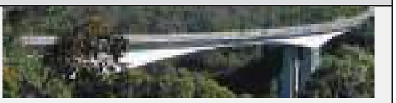
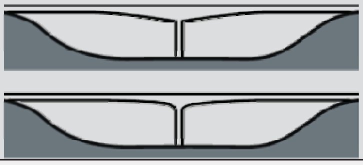
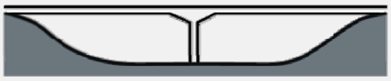
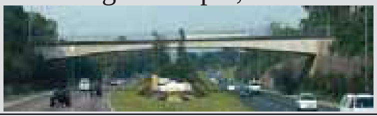
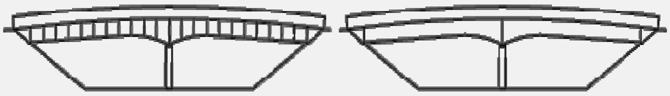
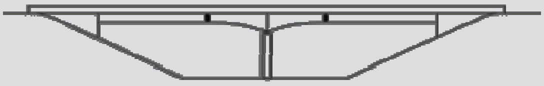
[1] - Frederick Gottemoller:"Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009-p21-30

[2] "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 50-53

[3] -"Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- 5-1 to 5-13.

Table 6-1: Taken Consideration during Bridge Girder Design

Use curved girders for curved roadways.	 Placing straight girders on a curved bridge produces unappealing scalloped shadow	 Curved Bridges Design
Structural continuity improves bridge appearance by allowing more slender girders.	 Ordinary Better	
Use tapered spans to transition between girders of different depths		
Haunches and continuity make the bridge seem thinner.		
Haunches between 20 and 40 percent of the span length are more attractive.	 Ordinary Better	
the angle at the point of the haunch should be between 135 and 160 degrees	 Ordinary Better	
Three or five span haunches are generally aesthetically very elegant, balanced structures.		 The hunched girders on Mooney Creek bridge Australia, demonstrate the principles of span, taper and curvature.
Long haunches smoothly tapering out are much more graceful and responsive than short abrupt haunches.		
Avoid a sharp angle between haunch and beam.		The hunching is made less elegant by the angle of transition between hunched section and horizontal beam
Even with single spans, curving the girder can provide an expression of elegance.	Bridge example, USA. 	
Vertical stiffeners should not be placed on the exterior of the fascia girders because they divide the girder and make it appear deeper	 Ordinary Better	
Bolted field splice locations should be balanced on fascia girders.		

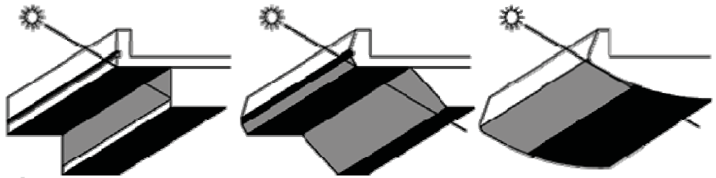
Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009-p 6,10,12and20.
http://entnet5.com/~c15376x1/wp-content/uploads/2015/05/descus1.jpgx

A curved soffit will provide a gradation of tone and minimize a sharp line beam base

An angled connection will minimize this effect.

A very acute angle provides a deep shadow nearly all of the time.

The effects of cross section differences on appearance. Also maximizing the overhang will increase the duration of shadow.



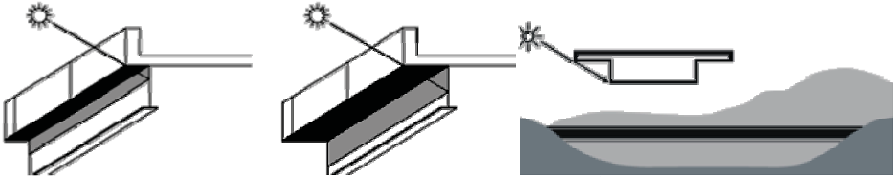
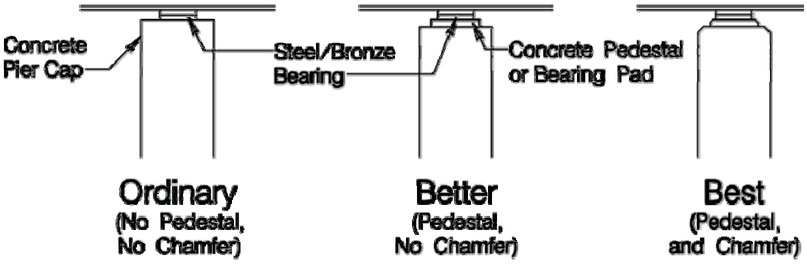


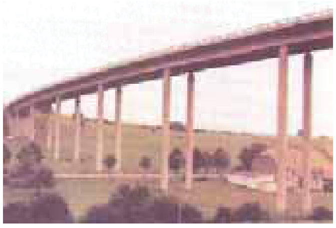
Figure 6-2: Girder Cross Section Design Considerations[1]

6-1-1-2-B- Bearings:

Bearing types are generally selected based on performance and preferred practice of the owner. Pier bearings that appear high and narrow will usually make the bridge seem more slender and light. However, a designer should never select a bearing type based solely on this criteria. The use of pedestals or chamfers at pier tops or bearing areas can be used to accentuate the bearing point.[2] figure (6 -3)



The use of pedestals and chamfers to accentuate the point of bearing



Bearing silhouetted against the sky. (Germany)

Figure 6-3: Different Bearings Types Examples[3]

6-1-1-2-C- Abutment bearings:

No subject produced more passionate debate at Bridge-scape and at the seminars than whether to hide bearings at abutments. The consensus was that they should be hidden. A minority felt the question should be answered by the nature of the girder abutment joint: when the girder is acting integrally with the abutment, the bearing should be hidden. Otherwise it should be exposed. Designers should explore the question for themselves. There is no hard, fast rule. The usual practice is to hide the abutment bearings behind concrete cheek walls.[4] figure (6 -4)

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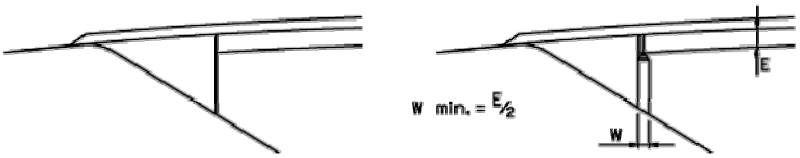
1 -"Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p IV-26 and IV-27

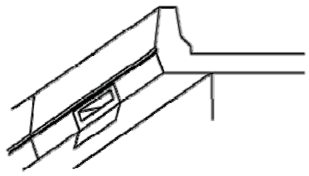
2 -"Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 5-1 to 5-13.

3 -"Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p III-13and14.

4 -"Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 5-1 to 5-13.



Hidden Bearing Exposed bearing
Suggestion for bearings at abutments

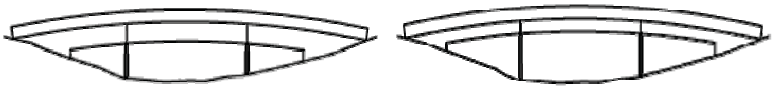


Example of a through-parapet scupper with its outlet integrated in the parapet design

Figure 6-4: Examples of Abutment Bearings[1]

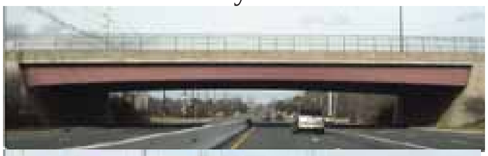
6-1-1-3- Guidelines to be consider during superstructure design:

- Continuous multi-span structures are typically shallower than simple span structures. In the case of single point interchanges, this may be helpful in reducing the impression of massiveness.
- Hunched girders can be very effective in reducing the mid span structure depth and providing a more visually interesting opening beneath the structure. In addition, the hunched girder profile often provides an interesting visual rhythm on multi-span bridges.
- Rigid frame bridge structures create continuity with substructures and may be appropriate for single or two-span bridges. They may also be combined with hunching to provide a shallow arch opening beneath the bridge.
- Slant leg piers or delta frames may be suitable for providing continuity with supports and creating geometric openings beneath a bridge. This approach may be
- particularly attractive at the crest of a vertical curved alignment to frame the view.
- Consistency is important in the selection of an appropriate structure type.
- Use of different structure types over the length of a bridge should be avoided as it often interrupts the visual line created by the superstructure and is contrary to developing a sense of unity and integrity.
- It is preferable to use the same depth of girder for the entire bridge length and not change girder depths based on the length of each individual span.
- When a series of bridges is seen as a group, such as an interchange or a corridor, it is preferable to use the same structure type.[2] figure (6-5)



Slender is better than deep.

Ordinary Better



This bridge utilizes a hunched girder design with battered abutments to create an attractive span. The center median pier was eliminated to frame the view beyond the bridge and provide a gateway opening into the adjacent development. New Jersey, USA.

This multi-level system interchange uses a common superstructure type to visually unify a complex geometry. Denver, Colorado

Figure 6-5: Slender Girder versus Deep Girder and Bridge Interchanges.[1]

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[1] -"Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p III-15.

[2] - Frederick Gottemoller:"Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p21-30.

6-1-2- Substructure

There are four basic substructure elements: piers(with it's head stock and pier caps), abutments, wing walls (retaining walls) and bridges seats.

The term pier is used to refer to the collective system of columns (or shafts) and pier caps that support the superstructure at a single location. The appearance of piers is primarily influenced by their proportion: their width relative to their height and the configuration of the pier cap with the pier column. Tall piers benefit from simplicity, fewer lines, and slender proportions.

Traditional short piers are more difficult to design from an aesthetic standpoint because the pier cap is often large and visually clumsy in relation to the total pier.[2] (figure 6-7)

6-1-2-1-Substructure Parts

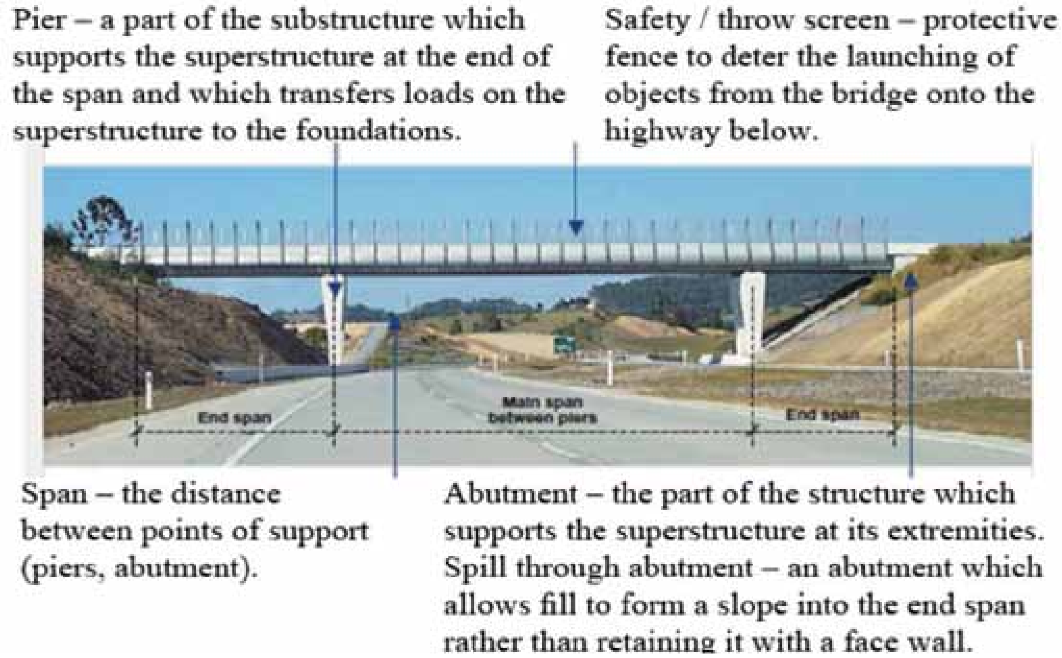


Figure 6-6: Bridge Substructure Parts (by researcher)

6-1-2-1-A- Piers

In this part, a brief on piers categories, types, parts and protection are discussed as shown in figure(6 -7) and (6-8).

- **Pier Families**

Multi-span bridges often have piers of widely varying heights. Bridges over rivers, large bodies of water, and deep valley cuts are examples. The designer challenge is to create a family of pier designs that look good individually and as a group. The designer should select a basic pier shape, or type, and vary its proportions through the different heights. An even greater challenge is to design piers when the bridge widens or branches.

- **Piers categories according to The pier height :**

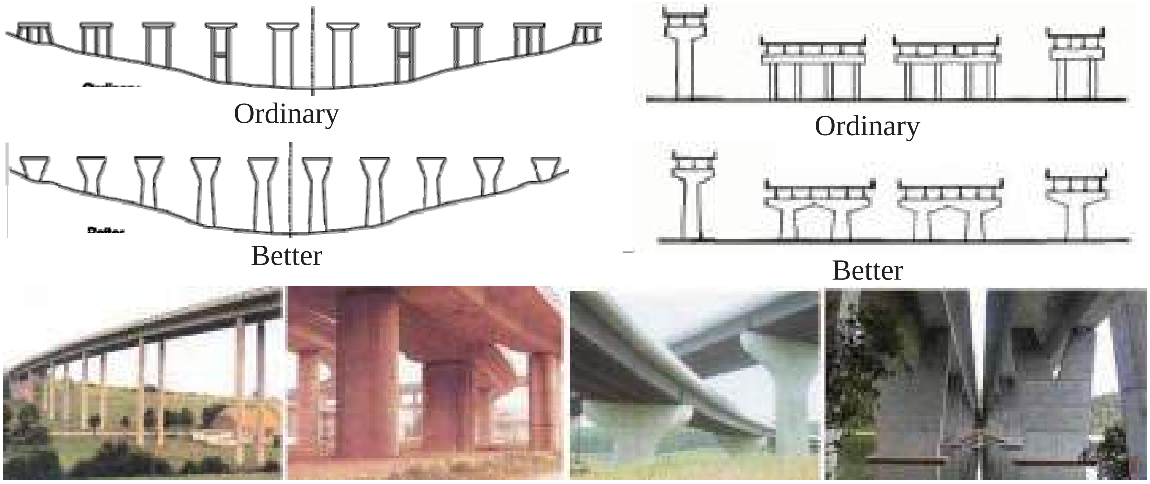
Piers are best analyzed in two categories: short piers (wider than they are tall) and tall piers (taller than they are wide). As shown in (Table 6 -2) a comparison between short and tall piers.

For a series of piers which vary in height or width through a structure, pick a shape or series of shapes which, by varying its proportions, will look good both tall and short, wide and narrow.

---

1 - Gauvreau, P:"Innovation and Aesthetics in Bridge Engineering"- Canadian Civil Engineer -Canada -2007-p10-12.

2 -"Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p 5-1 to 5-13.



This example solves the height variation problem by keeping things simple.

The differences in pier sizes overwhelm the attempt to maintain consistency through the use of similar shapes. The result is a mismatch.

piers with parapet. Interchange, Prince Georges County

The bridges over the Georges River at Alfords Point utilize piers with a taper and triangular void. This ‘Y’ shaped pier is a refined and attractive way

Figure 6-7: Piers Families according to Width Variation[1]

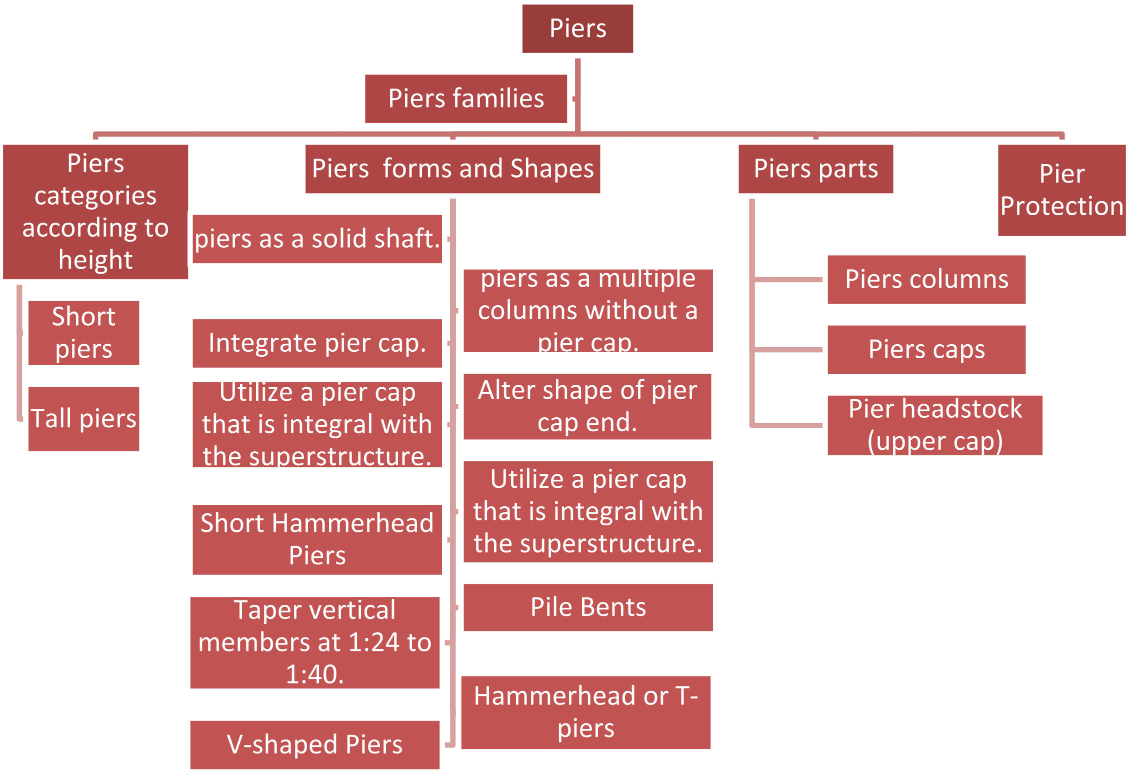


Figure 6-8: The Bridge Piers study (by researcher)

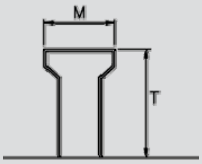
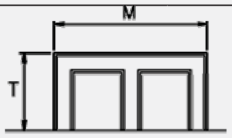
- **Piers forms and shapes**

There are different forms of piers, the most used piers categories are discussed in Table (6 -3)

---

[1] -"Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p IV22-23.

Table 6-2: A Comparison between Short and Tall Piers. [1]

	Tall Piers		Short Piers	
Sketches		Tall pier M<T M: Pier height T: Pier length		Short pier M>T M: Pier height T: Pier length
Introduction and definitions	Tall piers are those piers whose height (T) exceeds their width (T). Tall piers are easier to design than short piers because the structure and aesthetics work toward the same goals: proportion and simplification, The taller a pier is, the more it lends itself to single shaft elements. Straight pier shafts are appropriate for most any height of a tall pier. When pier heights (T) begin to approach the span length, tapering the shaft can maintain the structural capacity required at the base and preserve the slenderness of the pier. Tapers of 1:24 to 1:40 work well in most situations, with lesser tapers used for taller piers.		Short piers are considered to be those piers with width (T) that exceed their height (T). A design issue that is common among all types of short piers involves the geometrics of the columns, shafts, and pier caps that are used to construct the pier. The geometry of these individual elements should be selected from the same shape family: circular, rectangular, etc. Such as rounded pier cap ends and circular columns would appear more visually correct than square pier cap ends and circular columns. Ideally, a consistent shape will be carried to the abutments, railings and other elements of the bridge	

- **pier parts**

Any pier is consists of three main parts pier column, pier caps and pier headstock (upper cap). Main taken considerations during pier parts design are discussed:

Taken considerations during pier columns design:

- The width of columns perceived by the viewer is normally controlled by light reflecting from the column surfaces and edges.
- Beveled edges and surface treatment make columns appear thinner.

Taken considerations during pier caps design:

As piles are needed to support piers in soft ground, pile caps are often a feature of bridges crossing water courses. They perform an additional function in navigable waterways in that they help protect the pier. For safety reasons, they
need to be visible to boats and shipping.

They present an aesthetic challenge in that they form the footing to the pier.

Where pile caps are visible there are some guiding principles:

- Pile caps should mimic the shape of the pier as far as possible. The proportion of pier size to pile cap size should be considered. Imbalanced proportions should be avoided.
- In general, pile caps should be placed underground and not be exposed on land. This is particularly the case with short piers.

Taken considerations during pier headstock (upper cap) design:

Contemporary pier caps, which sit on top of the columns, were born of utilitarian function and are probably a holdover from trestle construction. Their function is to distribute the loads of the narrowly spaced girders among the wider-spaced columns.

When viewed from beneath the bridge, normal to the pier, this makes perfect sense. However, when viewed from a position approaching the bridge, the function of pier.

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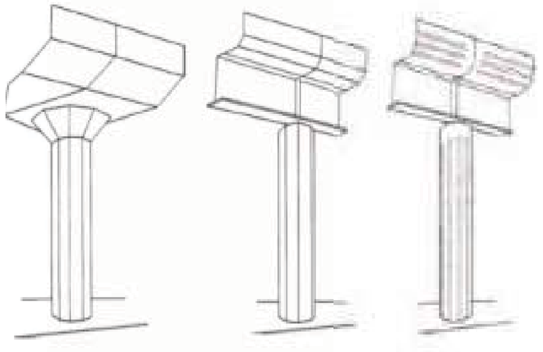
[1] -"Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 5-1 to 5-13.

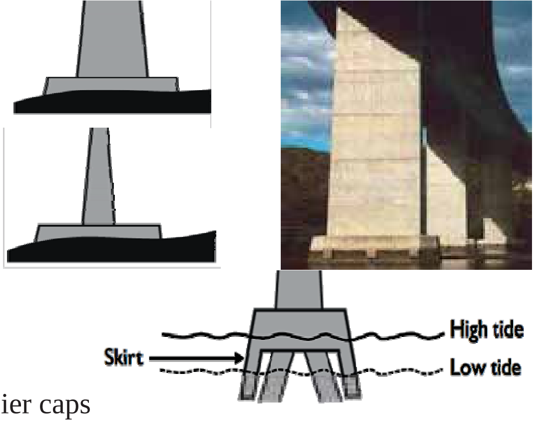
caps becomes less obvious and the observer is left with a subtle question regarding the purpose of the pier cap.

Pier upper caps can be eliminated or minimized by:

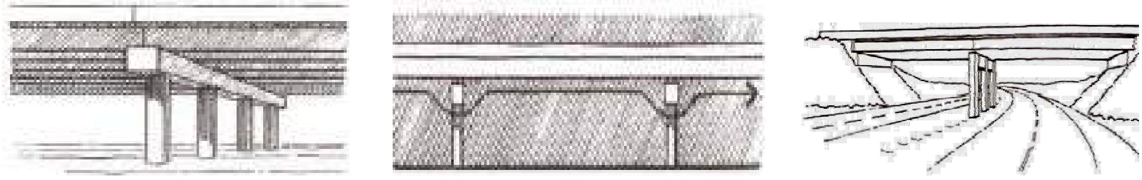
- Use of inverted T-shaped pier upper caps
- Eliminating the cantilevered portion of the pier upper cap
- Incorporation of the pier cap into the superstructure (integral pier cap).[1] Figure (6-9)



A-Pier column Beveled edges and surface treatment make columns appear thinner



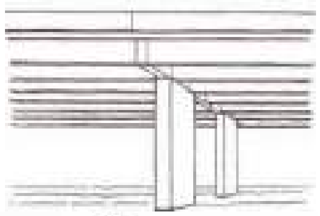
Pier caps



B-upper cap end creates disturbing visual hot spot

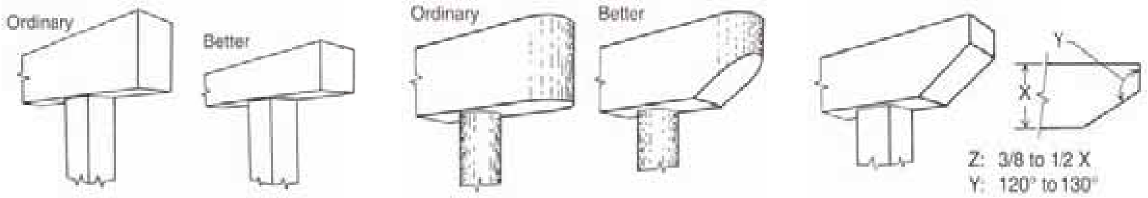
C-Prominence of the upper cap end surface Disrupts flow of horizontal lines

D-Pier upper cap integrated with columns minimizes visual disruption



E-Integral upper cap eliminates visual Disruption The end of the pier cap can be minimized by:

- Reducing its mass and reflective surface
- Beveling or tapering the surfaces of the pier cap end Minimizing the height of the upper cap



F-Reducing upper cap height diminishes visual hot spot

G-Rounding the upper cap end reduces its Prominence

H-Beveled upper cap end guidelines

Figure 6-9: Piers Design considerations[2]

• pier protection

When a pier is in a median or next to a shoulder and the required recovery area is not available, protection for errant vehicles must be provided. The standard solution is the use of traffic barrier.[3] Figure (6-10)

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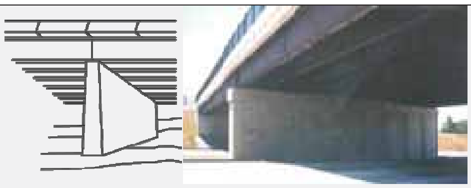
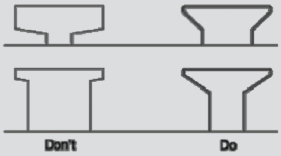
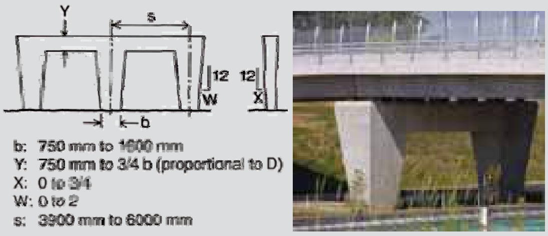
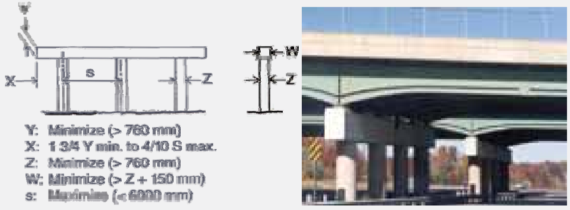
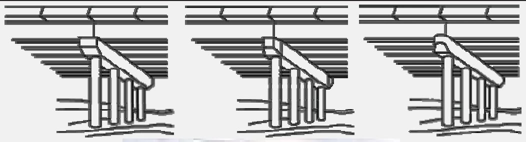
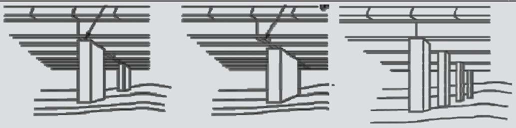
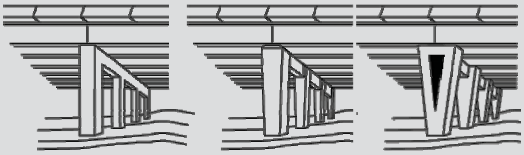
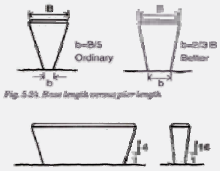
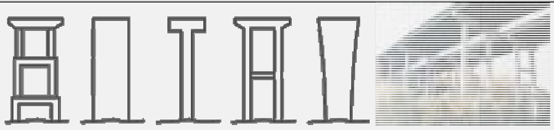
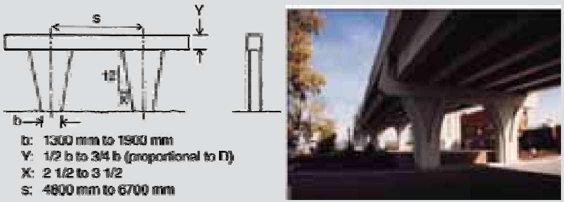
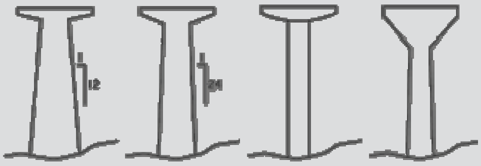
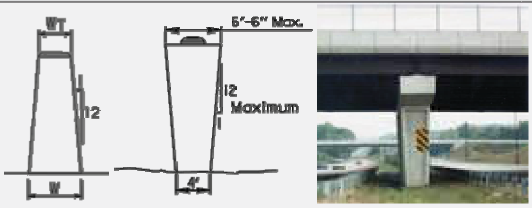
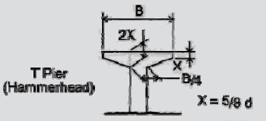
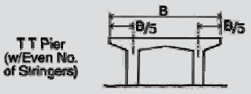
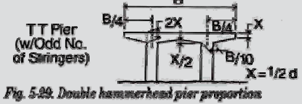
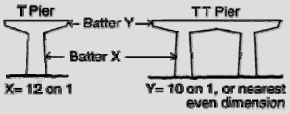
[1] -"Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995-p 5-1 to 5-13.

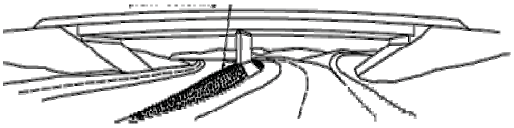
[2] - Same Previous Reference

[3] -"Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p IV-26 and IV-27

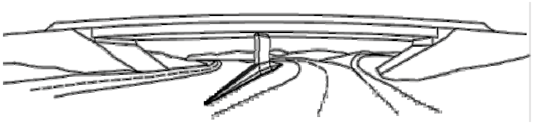
Table 6 -3 : The Most Used Piers Forms.

A: piers as a solid shaft	 Solid shafts pier in a bridge Boulevard, Anne Arundel County,	**H: Short Hammerhead Piers**	 Short hammerhead piers should be avoided because they can appear to be disproportionate  This solid shaft is too thin. Bridge at Prince Georges County
B: Multi-column bent with integrated pier cap	 Bridge on the Pacific Highway. NSW	**I: Multi column bent with cantilevered cap**	 There are five separate elements in this pier: four cylinders and one rectangular prism., Prince Georges County
C: Alter shape of pier cap end	  Grade Separation at Wabamun	**J: Utilize a pier cap that is integral**	 De-emphasized and incorporated pier caps piers as a multiple columns without a pier cap.  Bridge in Dun bow - USA
D: Integrate pier cap.	  Avenue Over Deerfoot Trail  MacKenzie Blvd. Bridge	**K: V-shaped Piers**	Columns and pier caps can be eliminated entirely by using a wall that is narrower at the base than at the top. This type of pier is referred to as a V-shaped pier. Make base lengths at least 2/3 the pier length.   batter of V shaped piers  Bridge at salah salem road
E: Pile Bents	 every effort should be made to minimize the number of piles used for the bent, providing redundancy is not compromised. Worst to best from left to right Simplicity equals elegance; the tapered columns accommodate structural needs within a single smooth shape. Baltimore	**L: V-shaped columns with cantilevered pier**	 Wabasha bridge, Minnesota
F: Taper vertical members at 1:24 to 1:40.	 Ordinary - Better - Ordinary - Better The effect of too much taper and the necessity of integrating pier cap and shaft	**G: Trapezoidal and Inverted Trapezoidal**	 Properly proportioned.(Broken land Parkway, Howard country
M: Hammerhead or T-piers	 Fig. 5-28. Hammerhead pier proportion guidelines   Fig. 5.29. Double hammerhead pier proportion guidelines  		Hammerhead piers in a series should be consistent in appearance, e.g., same size, shape, proportions, details. Hammerhead pier shafts should not be shorter than the cap-beam depth plus **2** meters.

Reference: "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 5-1 to 5-13.



The desirability of integrating protective devices into the pier design



The desirability of integrating protective devices into the pier design

Figure 6-10: Examples on Piers Protection[1]

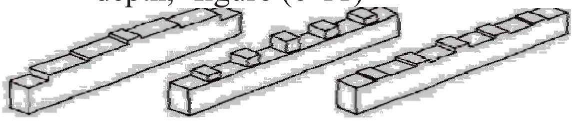
6-1-2-1-B - Bridge Seats

Conventional pier caps and abutments must often provide support for multiple girders at different elevations.

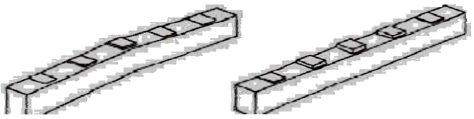
On wide structures and on bridges with super elevation, the difference in elevation between bridge seats can be substantial. The designer has the option of either providing individual seats of varying height to account for the elevation difference, or stepping the top of the pier cap or abutment. The designer should incorporate the changes in elevation into the pier cap geometry rather than providing excessively high bridge seats. The upper edges of the pier cap, or abutment face, should also be formed separate and distinct from the bridge seats. Making this distinction will provide a continuous visual line from one end of the pier cap or abutment face to the other.

Considerations for bridge seats should include the following.

- Limit the height of the tallest bridge seat to 200 mm. If more than 200 mm in elevation difference is required, step the top of the pier cap to accommodate the elevation difference. Detail the edge of the bridge seat 75 mm back from the face of the pier cap.
- Vary the elevation of the bottom of the pier cap to approximate a constant depth,[1] figure (6-11)



Ordinary bridge seats



Better bridge seats

Figure 6-11: Examples of Bridge Seats[1]

6-1-2-1-C- Abutments and Retaining Walls

The function of the abutment is to support the bridge at each end. Its visual job, as well as its structural job, is to mediate between earth and structure.[1]

Visually, abutments define the start and end of a bridge. The viewer perceives the bridge to initiate at the first sign of exposed concrete and terminate at its counterpart on the opposite[1]

- **Abutment Placement and Height**

Abutment placement and height determine how a bridge begins and ends and, for shorter bridges, how the structure is framed. The abutment placement also establishes the shape of the end-span opening, which can have a significant influence on what can

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[1] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 5-5-5-6.

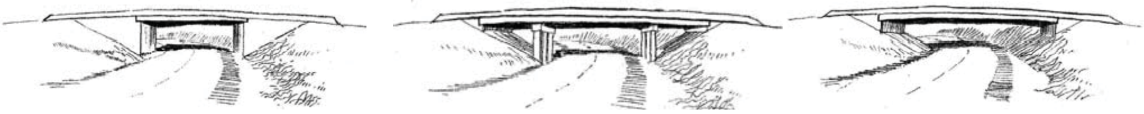
[1] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 5-14.

[1] - Same previous reference

[1] - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p IV27 to IV38.

[1] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 5-8 to 5-13.

be seen beyond the structure and how well the structure relates to adjoining uses.[1] Figure (6-12).



Visual confinement

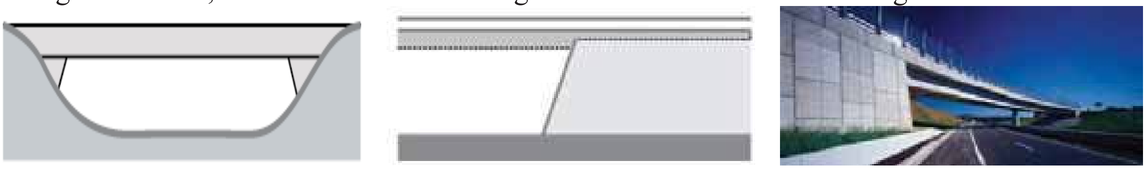
Opening up the view

More view and safety

Bridge in Denver, Colorado.

bridge in Nabiac

Bridge in Colorado



The inward angled abutments are an attractive detail which visually emphasizes the span

The slight angle of the abutment makes a more aesthetically pleasing outcome

Pacific Highway in Yelgun

Bridges Examples in Australia

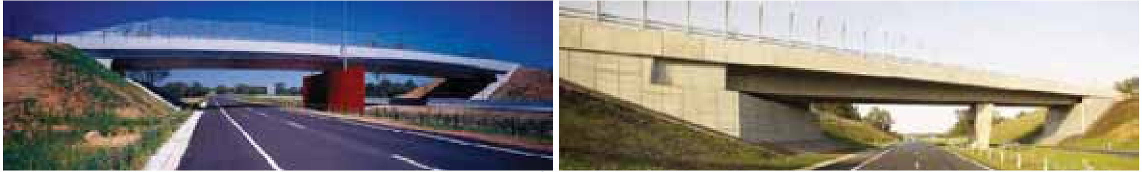


Figure 6-12: Bridge Abutments Examples[2]

- **General Guidelines for Abutments Height:**
  - Minimum exposed abutment height (H) = 1/2 girder depth. Otherwise the abutment will not look big enough for its function.
  - Maximum exposed abutment height (H) = 1/3 height of first pier and/or vertical clearance.
  - Carry the parapet profile across the abutment. Carry as much of the deck overhang as feasible across the abutment.[3]
  - When one side of the bridge is higher than the other, keep abutment proportions the same.[4]
  - As a first choice, align wing walls with the upper roadway:
    Abutment wing walls should generally be aligned with the upper roadway. This makes the bridge seem longer and provides a logical place to tie in pedestrian screen and traffic barrier with beam. Sloping abutments frame the opening and make the bridge seem more continuous [5] Figure (6-13)
- **Landscaping at Abutments:**

Landscaping at abutments can become a major determinant of the visual impact of thebridge, particularly for small abutments height bigger than half depth. Abutments of

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[1] - Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch-Australia-2005- p 66-69.

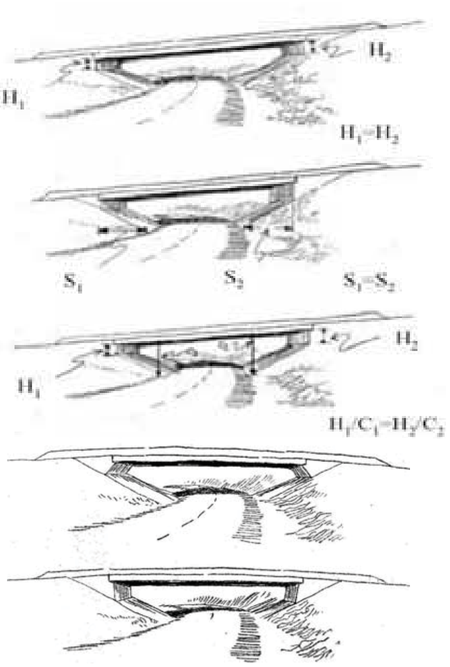
[2] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p 63-64.

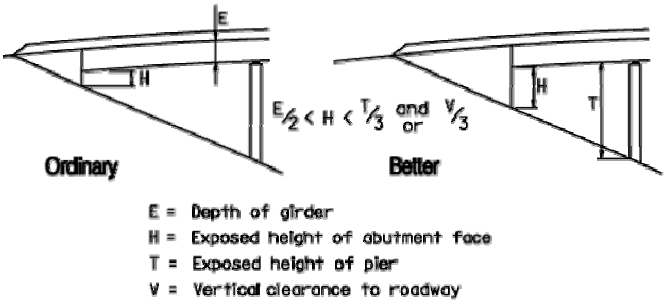
[3] - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pIV27 to IV38.

[4] - Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch-Australia-2005- p 38.

[5] - Same Previous reference, p 66-69.

this size can be obscured by landscaping after a few years of growth. Figure (6-14)



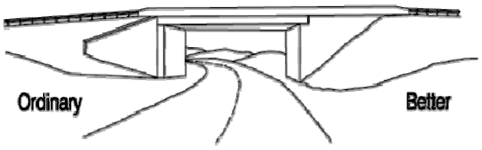


Relation of abutment height to end span height

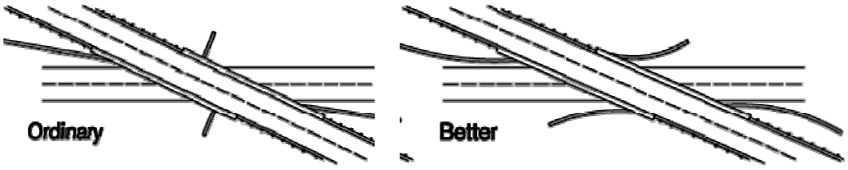
Two examples from Australia
Sloping abutments frame the opening and make the bridge seem more continuous

Figure 6-13: Abutment Height Considerations[1]

The good effect of abutments hidden by landscaping



The wing wall should usually follow the upper roadway.



Wing walls on a heavily skewed structure should parallel the upper or lower roadway.

Figure 6-14: Abutments landscaping and Skewed Wing Walls[2]

- **Abutment different shapes**

There are different shapes of abutments, As shown in Figure (6-15) some innovative abutments shapes.

- **Abutment materials and finishing's:**

Abutment finishing's design considerations:

- Keep surface treatment of abutments consistent with parapet details and pier design; any pattern should have an obvious relation to the main lines of the structure.
- For medium to high abutments an opportunity exists to draw attention to the abutment.
- One must decide whether to do that, and why. In most situations, it is better to keep the attention on the superstructure first and piers second. In any case, simple is
- usually better than complex.[1] Figure (6-16)

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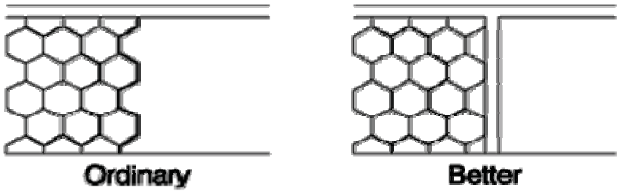
1 - Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch- Australia-2005- p 38-40.

2 - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pIV-32-35.

Massive abutments have tall continuous faces, which may be vertical or battered either inward or outward. Strong slab-like forms sharply define the bridge ends, often giving it a monumental appearance or a distinct contrast with the surrounding landscape, Denver, USA[2]

Articulated abutments have complex geometry and may consist of a series of layered or textured surfaces to break up the scale of an otherwise massive structure. Colorado, USA

Figure 6-15: Different Shapes of Abutments[3]



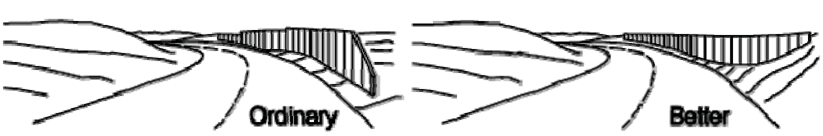
Different examples of abutments finishing which add a good shape to bridges

Figure 6-16: Abutment Materials and Finishings[4]

- The profile of the top of the wall should be developed into a continuous straight line or smooth curve, and grading should be varied to fit to the top of the wall. Do not use sharp breaks or chorded curves. These can be eliminated by a smooth cap. Dips in walls should be avoided.
- Patterns for retaining walls seen primarily from a moving car must be large enough to be recognized at highway speeds; minimum element size is four inches. Figure (6-17)

<u>Copings and/or Capping:</u>

Copings can do wonders to give a wall a finished look. The depth of copings is extremely sensitive to the height of the wall and may have to vary to obtain an attractive appearance, especially near the ends of walls. [5]



The visual benefits of a smoothly curved alignment and profile

The surface treatment is acceptable. A capping would have improved the shape

Figure 6-17: Retaining Walls Examples[6]

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1 -" Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005 -pIV-35

2 - http://denverurbanism.com/2012/03/eve-of-demolition-denvers-15th-street-bridge.html

3 - "Bridge aesthetics source book"- The American association of state highway and transportation officials - USA- 2010-p28.

4 - Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch- Australia-2005- p 66-69.

5- " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pIV-35to IV-39

6 - Same previous reference

6-2- Bridge Non structural parts

As shown in figure (6-18) non structure parts,

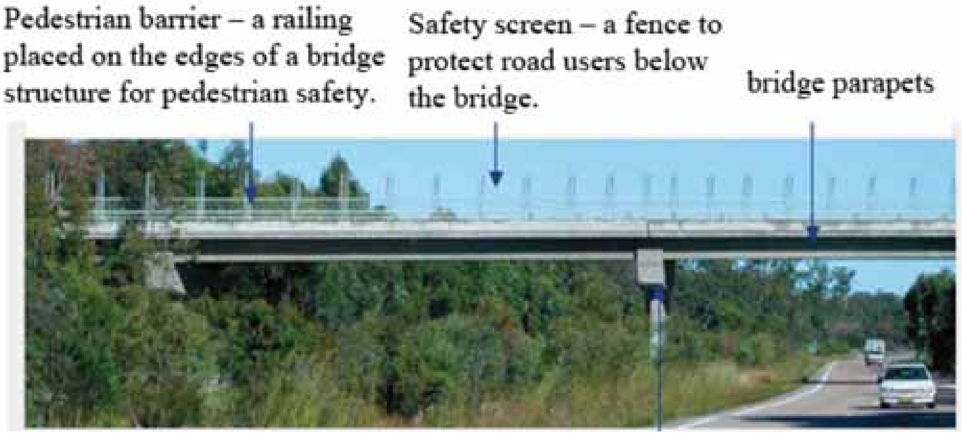

Figure 6-18: Bridge Non Structural Parts (by researcher)

6-2-1- Parapet

The outer face of the parapet can be one of the most important aesthetical elements of a bridge. For most bridges it is the highest element and often the most dominant in long distance views. It can also be the longest piece of the bridge and as such an opportunity to express the span and horizontal nature of the structure.

The following principles should be considered in the design of the parapet:

- They should appear as a continuous uninterrupted face, extending the full length of the bridge with a generous overlap of the abutments.
- A continuous neat, sharp edge will help define them against the background.
- The proportions between their depth, the deck overhang and the girder depth should be carefully considered.
- Shaping the parapet if it is too deep can assist in visually balancing proportions.
- Maximizing the shadow cast on the girder and superstructure will further accentuate and express their form.
- The outer face should generally be a smooth single plane surface on a continuous curve (if the bridge is not straight) and slanted slightly outwards towards the bottom to better catch the sunlight.
- The top should angle towards the road, to channel rainwater onto the bridge, minimizing staining of the outside face.
- Consideration should be given to extending the parapet below the deck soffit to hide drainage pipes.[1]

As shown in figure (6-19) bridge parapets examples an relation with other bridge parts are discussed.

6-2-2- Railings

they have a major impact on the overall appearance of the structure. designers should consider the railing in terms of the total visual image of the structure.

Considerations for railings should include the following.

- The outboard face of crash-tested barriers may be architecturally treated for the aesthetic benefit of the structure.
- The Preliminary Bridge Plans Engineer must be consulted for all bridge projects

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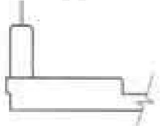
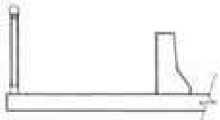
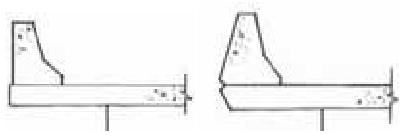
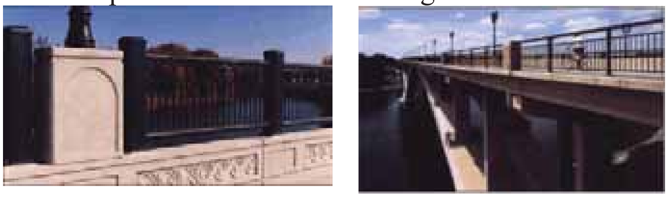
[1] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p 48-49

- to determine the rail system requirements or architectural treatments that may be considered for a particular bridge.
- If crash-tested barriers are not required, consider treatment of the parapet and railing to complement the overall visual design theme of the bridge.
- Consider ending rail systems and pedestrian screens with tapers to avoid abrupt changes.
- Avoid connecting the guardrail to the rail system with through-bolts as the details clutter the appearance of the bridge.
- Avoid setting the outboard face of the rail system flush with deck fascia unless the interface of the rail system and the deck is detailed to address its visual appearance.

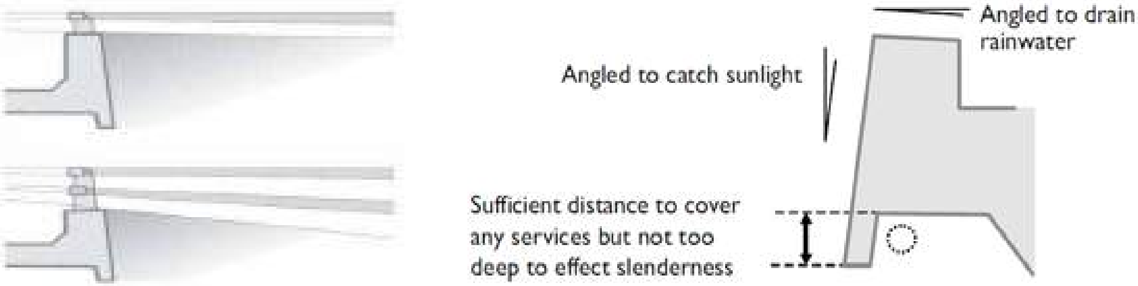

Parapet


Railing


Barrier examples


Treatment of parapet and metal railing offers pedestrian visual stimulus, Crookston, Minnesota


The Pacific Highway bridge over the Brunswick River has a parapet that satisfies the above requirements.



Parapet details to guarantee good view for passengers and perfect functions


The line of the parapet on the bridge over Woronora River at Sutherland is an important bridge element. It is sharp, smooth, catches the light, helps provide shadow and unifies the structure.

Figure 6-19: Bridge Parapets Examples and Relation with other Bridge Parts[1]

Consider pitching the top of the rail system toward the roadway side where staining is less visible and easier to clean. [2] Figure (6-20)

- **Ornamental Railing Systems**

Ornamental railing systems offer the designer a unique opportunity to develop a significant visual effect for the pedestrian and the highway user alike. Central to the visual design of ornamental rail systems are four factors: the shape, the proportions, the quality of the material, and the color. The combination of these factors determines the

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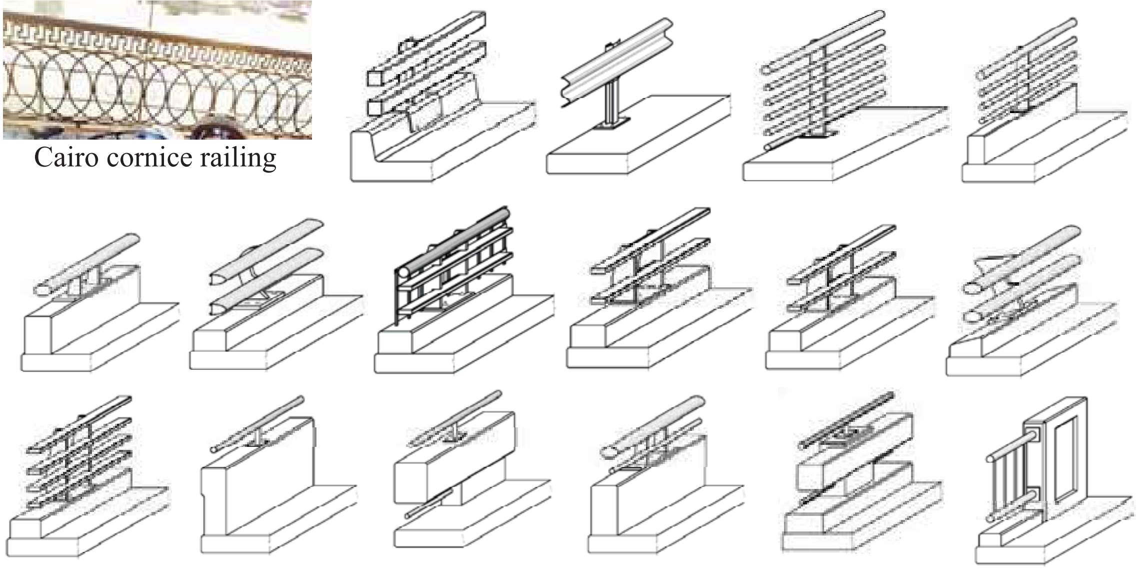
[1] - "Design manual for roads and bridges" volume 1 highway structures- approval procedures and general design -section 3 general design- part 11- the design and appearance of bridges- USA-1998- p 5/1-5/3.

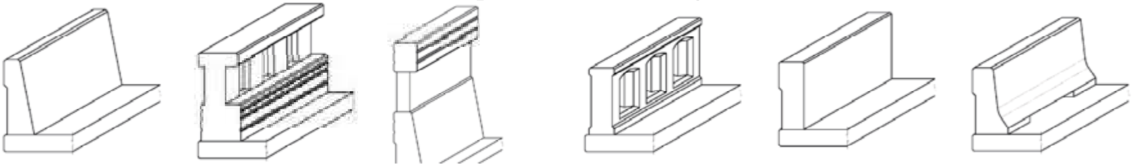
[2] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 6-3 to 6-4.

visual impression of the rail system to the viewer. [1]



Cairo cornice railing

Examples of Steel railings



Examples of concrete railings

Figure 6-20: Bridge Railing examples[2]

6-2-3- Safety Screens

The safety screen is designed to prevent objects being thrown from the bridge and damaging vehicles or injuring people below. These screens should be an integral part of the bridge design.

There are several aesthetical considerations for safety screens, protective fencing and noise walls:

- The bridge screen being a peripheral element to the true function of the bridge should avoid obscuring the superstructure.
- Screen posts should align with the safety barrier posts and be perpendicular to the bridge, not vertical (below 4 percent gradient).
- The screens should extend to the ends of the bridge span.
- There should be a neat, elegant transition to the bridge barrier safety screens; a simple taper or stepped drop in height can help with this, but is not always necessary. Figure (6-21)

6-2-4- Protective Fencing

Occasionally, special fencing is needed to protect pedestrians, secure the bridge and make it difficult for people to jump from the bridge. It is a detail like any other and needs to be approached by designers so that the aesthetics of the existing bridge are not affected and the fence is integrated with the whole design.[3] Figure (6-22)

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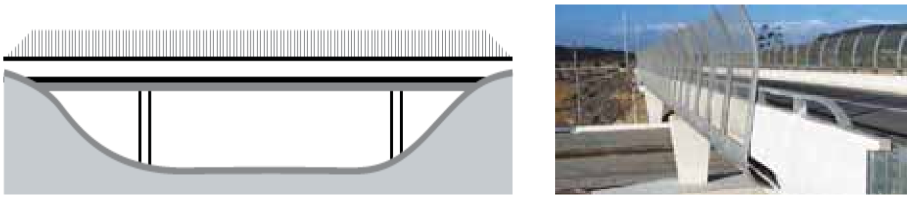
[1] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 6-4 to 6-7

[2] - "Bridge Railing Manual"- Department of Transportation- Texas-USA- 2014-p A-5 to A-30

[3] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p 74-76



The two elements are separate yet are related in design and material. A slight misalignment in supports would have affected the design outcome. A more sustainable solution would be an integrated barrier and screen.

An integration between railing and bridge parts

The flaring of the screens matches the flaring of the piers.

Bridge barriers and safety screen posts are aligned and integrated. The bridge parapet is expressed and not obscured

Figure 6-21: Safety Screens examples (Different bridges at Australia)[1]

Fencing on Pedestrian Bridge at Jack London Square, Oakland retains its transparency for people crossing the tracks.

Angled Missile proof Fencing in Atlanta

Figure 6-22: Protective Fencing Examplse[2]

6-2-5- Noise Walls

By nature of their function, noise walls are usually very large elements that can dominate a visual field.

Although many of the visual objectives for retaining walls apply, noise walls need not parallel the roadway alignment to the same degree as retaining walls. Noise walls may follow the irregularities of local drainage or property lines, resulting in an irregular alignment.

Noise walls share most of the same visual design objectives as retaining walls.

Noise walls should be aligned so that they relate to topographical features and surrounding communities. Alignment and connection to bridges and retaining walls should be well detailed. Use of noise walls on bridge structures requires special detailing and consideration of the mass, scale, and proportions of the total visual composition.[3] Figure (6-23)

6-2-6- Signage and Advertising

With the exception of name plates and navigation signs, signage should be kept off bridges if at all possible. They add clutter and complexity and detract from the structure. They also obstruct views from the bridge. However, there are many situations where the

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[1] - http://www.landmarkpro.com.au/products/pedestrian-bridges.html

[2] -"Santa Rosa Bicycle and Pedestrian Bridge"-Feasibility Study- Prepared for the City of Santa Rosa- Texas- USA-2010. http://ci.santa-rosa.ca.us/doclib/Documents/BikePedBridgeFeasibilityStudy.pdf. P 3-13and 3-14.

[3] - " Guidelines on Design of Design of Noise Barriers"- Noise Barriers Environmental Protection Department -Highways Department- Government of the Hong Kong- Hong Kong- China- 2003-p16-19.

The principle applied to a bridge in Australia motorway was to use transparent noise walls on bridges, to allow views of the landscape for motorists and improve views of the bridge from its surroundings. Also they retain the slenderness of the structure[1]

Ugly Noise walls at ring road - Saft ellaban corridor (by researcher)

Figure 6-23: Noise walls Examples

highway layout requires placement of signs on the structure. In these cases these signs should be designed as a part of the total bridge.

Designers should coordinate the bridge design with the Design and Operations Section of the Office of Transportation Engineering to identify potential sign placement and design requirements.

Considerations for signs on bridges should include the following.

- When a bridge has more than one sign, the vertical dimensions of the signs should be consistent to promote visual continuity.
- Consider aligning the top of the sign with the top of the railing, and align the bottom of the sign with the bottom of the superstructure for fascia-mounted signs. This objective should not interfere with the function or clarity of the message.
- Consider using internally lit signs where elimination of the external light sources (and associated grating and support) is beneficial.
- Consider painting the back side of the sign and its support elements a color that is compatible with the bridge itself.[2]
- If a bridge and its location is deemed suitable as an outdoor advertising site then the advertising structure needs to be designed as an integrated bridge element with consideration of its visual effect. As a minimum, the soffit of the bridge should not be obscured and the sign should not block views of the key structural elements such as cables, arches and bearings or views from the bridge.[3] Figure (6-24)

- **Note features off the bridge.**

Quite often we take the time and effort to develop a structure that is pleasing in appearance, yet, when the structure is viewed in its completed state, the attractiveness is significantly diminished by a myriad of other highway elements light standards, traffic lights, ground mounted signs, etc.

The bridge designer should make himself aware of all of these features during the

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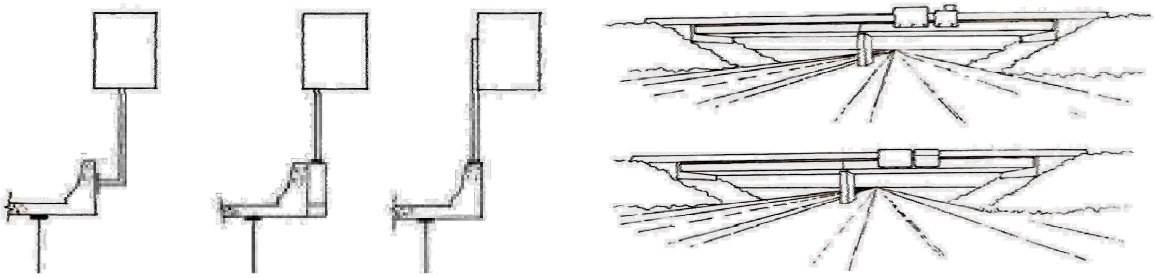
[1] - " Noise wall design guideline -Design guideline to improve the appearance of noise walls in NSW "-The center for urban design-Roads and maritime services- New South Wales- Australia-2016-p11.

[2] -"Traffic Signs Manual"- Chapter 7 The Design of Traffic Signs- Department for Transport -Department for Regional Development (Northern Ireland) Scottish Government Welsh Government, London, UK-2013- p7.

[3] -"Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 77.

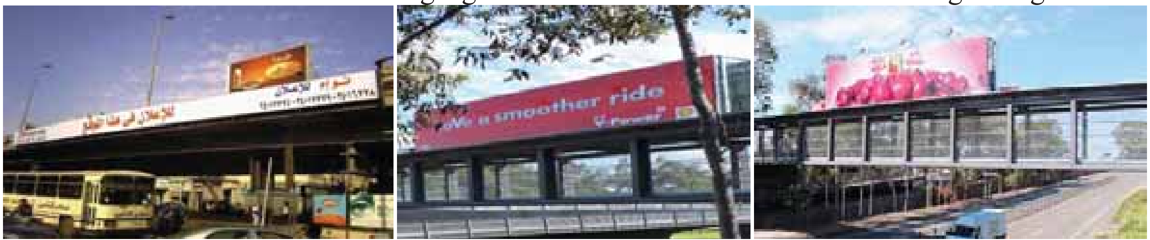
design phase and where possible, work with the other disciplines in minimizing the impacts of these items on the structure appearance.[1] Figure (6-25)



Ordinary Better

Alternate methods of mounting signs

Signs on bridges should ideally be simplified and related to the bridge design



Advertising on Eldokki bridge[2] Road in Western Sydney[3]

Figure 6-24: Bridge Signage and Advertising

Signs should be part of Bridge whole design, at these examples of bridges in USA, Signs look not good because they have no relation to the bridge

Figure 6-25: Features off the Bridge examples.[4]

6-2-7- Slope Protection

Slope protection is both a landscaping feature and a structural component. However, it should be comprised of a landscaping material, such as riprap, and placed so that it looks like part of the landscape. Riprap has the advantage of having plants growing in it and blurring the edge with the landscape. Figure(6-26)

For bridges over highways, use only enough slope protection to cover the area beneath the bridge where plants cannot grow. Drainage channels from the bridge should be accommodated with separate channels, stabilized planting or buried piping.[5]

Reasonable slope of stone makes it easy for the landscape to grow over it

Concrete slope protection may lack the flexibility to deal with drainage and soil problems

Figure 6-26: Slope Protection examples (in USA)[1]

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[1] -" Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p VI-2 to VI-3

[2] - http://www.2madv.com/upload/images/adv/adv7.JPG

[3] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 6-9.

[4] - Previous reference

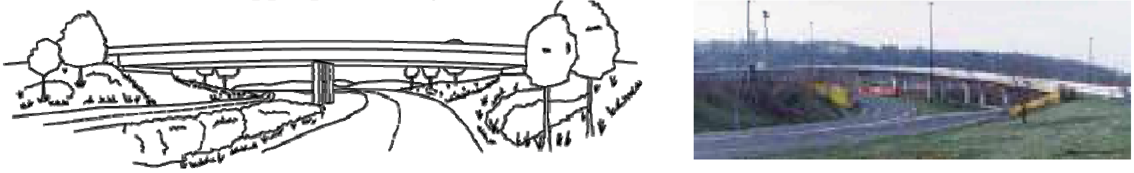
[5] -" Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-pVI-6 to VI-9

6-2-8- Landscaping

Landscaping should enhance an already attractive structure. It should not be relied upon to cover up an embarrassment or hide some unfortunate detail. Conversely, it should not be allowed to grow up to hide some important feature that is crucial to the visual form of the bridge. Landscaping can be a more economical and effective way to add richness and interest to a design rather than special surface finishes or materials. For example, a large, plain concrete abutment can be effectively enhanced by well-chosen landscaping around the bridge.[2]

- **Concept Development**

The application of landscape concerns, such as environmental suitability, topography, and existing vegetation, is part of the site analysis and conceptual development process for the bridge as a whole. This process will produce a consistent design intention for adjacent landscaping and the entire route. It is important again to look at a theme for an entire route where appropriate. Figure (6-27)



Continuity of landscaping patterns enhances the continuity of the scene.

Figure 6-27: Bridge Landscaping[3]

6-2-9- Lighting

A. Lighting of Roadway

The three areas of concern are: type of light standard, location of light supports, and location of conduits.

Wherever possible, avoid placing roadway lighting on bridges. If lighting on a bridge cannot be avoided, place roadway lighting poles in some logical relationship to the structure itself, such as at supports or placed symmetrically around the supports. Lighting elements should be designed as part of the bridge with supports elegantly designed and well detailed. Bridges at USA and Australia as shown in figure (6-28)

Considerations for lighting should include the following.

- Place light poles in some logical relationship to the structure, symmetrical to superstructure, over a pier, in sequence with railing posts and should be related to other bridge parts.
- Coordinate the location of pedestrian and traffic lighting. Integrate poles and fixtures with structure type and the rail system.
- Recognize inherent symmetries or other major characteristics of the overall structure, and locate lights accordingly.
- Maintain the horizontal line of the railing with as little interruption as possible. Keep the light pole mounting continuous with the railing and consistent with any ornamental features or construction joints.
- Mount lights under structures in some consistent relationship to the structural elements.
- Recognize and plan for the appearance and location of conduits, junction boxes

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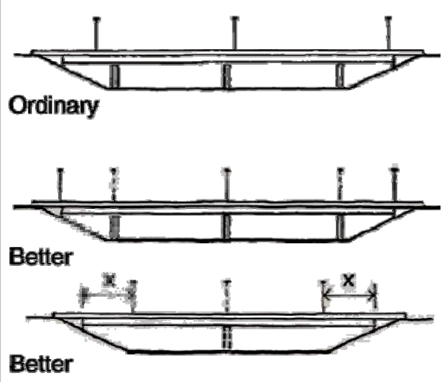
[1] -" Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-pVI-6 to VI-9

[2] - "Beyond the Pavement"- RTA urban design policy- procedures and design principles- Australian Government-Australia- 2009 p 89.

[3] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p36.

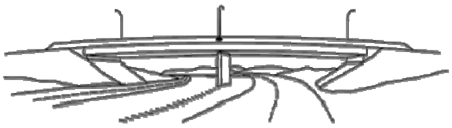
ballasts, and so forth early on in the design process. locate these items at inconspicuous areas on the structure.[1]



Light pole positioning guidelines

The pole should be on pier, Lighting column place is not good

Lighting column is considered part of bridge design



Lighting supports organized around structural features

At these examples lighting add special effects to bridge appearance

Figure 6-28: Roadway Lighting Elements Locations[2]

B. Accent Lighting and Feature lighting

There are specific bridges that, because of their size, their location in the community, the environment or their symbolic importance, deserve to be lit.

There are two basic approaches in this situation:

- Floodlight the bridge. This will not replicate the daytime appearance, since the shadow areas and the color effects will be unavoidably different. However, it does come closest to giving a complete picture of the bridge.
- Outline significant features of the bridge in lights, or otherwise light only significant portions of the bridge. This probably works best when the lighting is designed to create a pattern of the basic structural form. Such an approach can be used to enhance nighttime safety for boaters. Figure (6-29)

Both of these techniques require a great deal of specialized expertise and experience. It is also very important to evaluate the effect of this lighting on nearby properties, and nearby residences in particular.[3]

There is an opportunity to light the bridge as a whole depending on context, cost, safety and environment constraints. Where appropriate feature lighting of bridges can extend

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1 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995 p 6-11.

2 - "Bridge Aesthetics Design guidelines to improve the appearance of bridges in NSW" - The Government Architects Office - RTA Operations Directorate- Bridge Section & RTA Road Network Infrastructure Directorate- Urban Design Section- New South Wales- Australia- 2003-P46.

3 " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p VI-6.

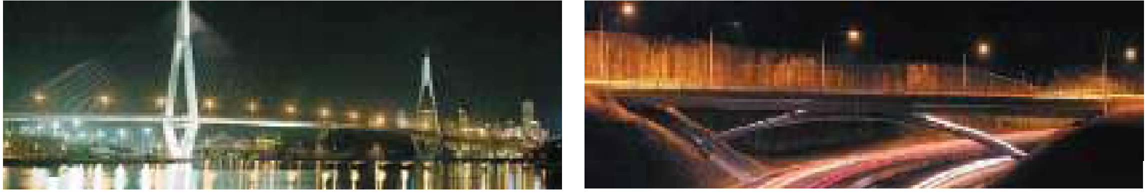
the aesthetic benefits of a bridge throughout a day and make them a positive presence in the night.

Bridge of peace - Tbilisi

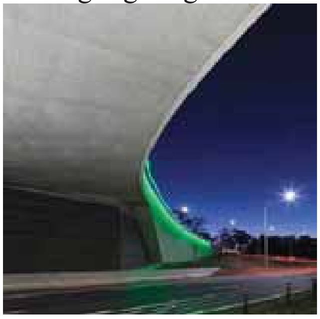
Lighting is used in various ways to highlight the columns, ramps and mark the interchange as a whole. This is an entire composition in lighting which makes the interchange visible, safe and beautiful. Examples at Australia

Dubai lighting bridges[1]

London new pedestrian bridge competition[2]



Highlighting structure systems at Anzak bridge on the left and kiama bridge on the right



The underside view of the bridge is visually an important part of the space under the bridge. In this example in Canberra the slopped girder creates a smooth lightly textured surface. LED lighting enhances the effect and also identifies the bridge Examples from Korea

Night lighting on the Sydney Harbour Bridge showing the dramatic effects of the pylons and arch lit up.[3]

Figure 6-29: Bridge Accent Lighting Effect on Bridge Design[4]

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[1] -http://www.lighting.philips.com.eg/systems/system-areas/public-spaces/bridges-monuments-facades.html

[2] - http://www.dezeen.com/2015/11/25/bystrup-wins-nine-elms-to-pimlico-bridge-contest-river-thames-london/

[3] - "Bridge Aesthetics Design guidelines to improve the appearance of bridges in NSW" - The Government Architects Office - RTA Operations Directorate- Bridge Section & RTA Road Network Infrastructure Directorate- Urban Design Section- New South Wales- Australia- 2003-P 46-47.

[4] - http://english.visitseoul.net/event-festival/Banpodaegyo-Moonlight-Rainbow-Fountain_/8741

Lighting can also enhance the safety and passive surveillance around a bridge. Lighting should be energy efficient, avoid light spill and be easy to maintain. It should also respect the structural qualities of the bridge accentuating the materials and main structural elements such as piers, arches and girders. That is not to say the
feature lighting should not be dynamic and creative.

LED lighting systems can be designed to provide both subdued and imaginative effects at different times of the day or calendar.[1]

6-2-10- Bridge Miscellaneous Details

The visual objective for the detailing and design of drain pipes, conduits, and utilities should parallel that of detail design. The designer should strive to make these objects as unobtrusive as possible and keep details simple.
structure. [2]

Considerations for drains, conduits, and utilities should include the following.

- Keep pipe and conduit systems simple with minimal fittings. Consider the visual design of the bridge when locating and placing the pipe/conduit. Conceal conduits and pipes between beams.
- Avoid placement on the outside of the fascia girder or along the rail system. Place drains on the least visible side of piers.
- Use a configuration that is consistent with the pier shape.
- Color drain pipes and conduits the same color as the structural element on which they are mounted.
- Run exposed drain pipes in lines that are either parallel or at right angles to the main line of the structure.
- Avoid using internal drainage systems and placing pipe drains inside columns due to potential freeze damage.
- Eliminate drainage inlets on bridges where possible.
- Place utilities between girders and above the lower edge of girders. **[3]**

A. Drainage

Attention to drainage details on and around the structure is essential if durability performance is to be optimized Water stains on wing-wall and face of abutment seat Consider the overall impact on the elevation view when determining the number and position of deck drains.[4]

Eliminate scuppers on bridges where possible. For bridges over bodies of water, this can be almost anywhere on the bridge, provided environmental concerns are addressed. For bridges over land, scupper locations cannot Scupper outlet pipes should be located on the inside of the fascia girder. The scupper outlet pipe should be straight and extend to just below the bottom of the girder. Simplify drainage systems as much as possible. Internal drainage systems should be avoided. Hide drain pipe systems wherever possible. Paint drain pipes and conduits the same color as the structural element against which they are mounted. Through-parapet scuppers should be carefully considered and integrated into the design of the superstructure.[5] Figure (6-30)

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1 -"Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p 87-90.

2 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995-p 6-8 to 6-9.

3 -(" Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p III-1 to III-28.

4 -Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch- Australia-2005-p 86-89.

5 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995-p 5-1 to 5-13.

Oldman River Bridge

Mcleod River Bridge At Whitecourt

Deck drain fabricated from steel to match the girders

A better attempt needs to be made to conceal the deck to grade drain

Mcleod River Bridge

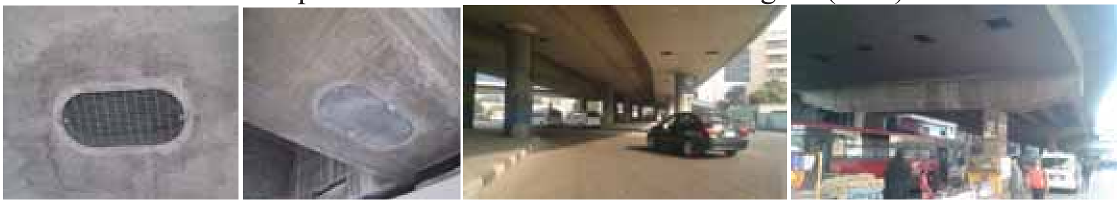
Deck drain hidden by the wing-wall does not have to match the girder color

Figure 6-30: Bridge Drainage Examples (in New South Wales- Australia)[1]

B. Utilities and Access

Utilities and access should be hidden because they don not have a pleasant shape.

- Typically cables are accommodated in the continuous PVC duct available in the curb, or alternatively cast into the structure.
- Abutment seats can be too high for inspection access to the bearings, without the use of a ladder so addition access is needed.
- The centre of the head-slope is not the preferred location for an abutment drain. It increases the risk of head-slope erosion.
- Access hatches provided in the soffit of the slab.[2] Figure (6-31)



Bridge at Dunbow Road, Deer foot, USA[3]

6th of October bridge - Tahrir square - utilities (Researcher)

Figure 6-31: Bridge Access and Utilities Bad Examples

C. Joints and connections

Joints and connections of bridge structures are an opportunity to enhance the bridge design and provide another level of detailed aesthetic interest. Differentiate between bearings and other connections should be recognized in the design.[4] Figure (6-32)

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[1] - http://www.skyscrapercity.com/showthread.php?t=477115

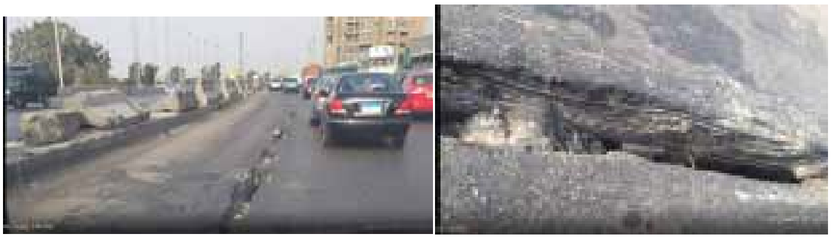
[2] - Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch-Australia-2005-p 90-92.

[3] - http://forum.skyscraperpage.com/showthread.php?t=127346andpage=218

[4] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p72.

El-Gamaa bridge expansion joints and drainage

6th of october bridge



Ring road - Marriotia corridor (Some Egyptian bad examples of joints and connections on bridges)

Figure 6-32: Bridges joints and connections examples.[1]

6-3- Consideration to Guarantee Bridge as a Whole Aesthetical Design

Most important considerations are discussed during in different structure systems and parts in this part. Figure (6-33)

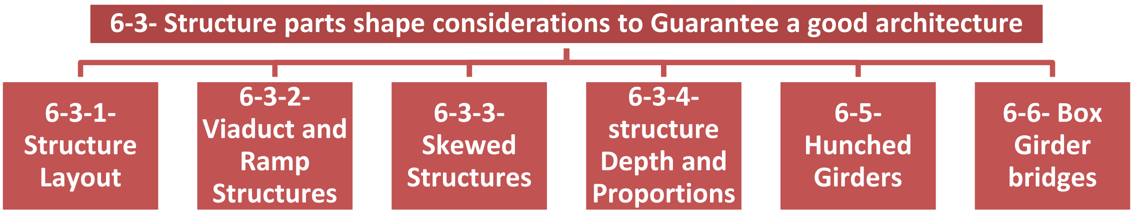


Figure 6-33: Structure parts shape considerations to guarantee a good architecture[2]

6-3-1- Structure Layout

Structure layout considerations should include the following.

A. A single-span structure represents the ultimate bridge - provided consideration is given to the proportions of the structure.

B. Two-span structures lend themselves to a freeway environment, but cause a split composition effect in natural settings. And this structure is not preferable.

C. Multiple-span structures with an odd-number of spans will appear visually correct because of the absence of a pier in the center of the bridge.

From an aesthetical standpoint, horizontally curved alignments call for curved superstructures (curved steel girder or box girder) because they allow the structure to reflect the lines of motion and reinforce the structure's function. Curved superstructures also eliminate the scalloped shadows created by the overhangs of curved decks on straight girders. Structures with vertical clearance limitations lend themselves to integral, or framed-in, pier caps. Integral pier caps can provide flexibility in pier location and emphasize the continuity of the superstructure by visually eliminating the pier cap.[3] Figure (6-34)

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[1] - By researcher

[2] - By researcher

[3] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 5-1 to 5-13.

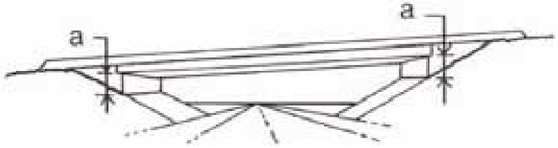
Single, Double and multi span bridges proportion considerations:

Single span structure:

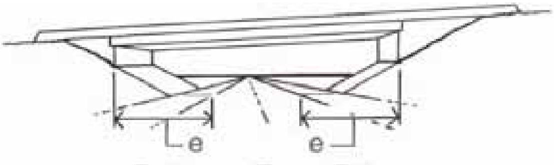
At one end of the spectrum is a bridge with deep abutments and a short span length. The opening beneath this bridge will approximate a square. the total bridge length approximately equals the vertical clearance. In this instance, the abutments provide a large mass, and the proportions play a more important role than does slenderness.

- A lower slenderness ratio (Width to height) perhaps 10%, is appropriate for this idealized situation.

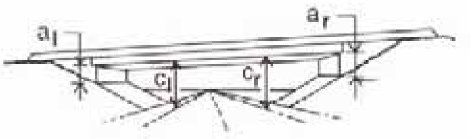
At the other end of the spectrum is a bridge with shallow abutments and a long span length. The opening beneath this bridge will form a flat rectangle. As the span length begins to exceed the height, the slenderness begins to play a more important role. Abutment depth should be proportional to girder depth with shallower abutments used for shallower depth girders. In this instance, a slenderness ratio of 20% is more appropriate for harmonious proportions[1]



Ordinary: Equal Height



Ordinary: Equal Offsets



Better: a1/cl = ar/cr

Figure 6-34: Substructure Should be Proportional to Vertical Clearance[2].

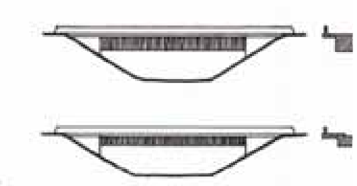
Double span Structures

- Increase the mass of the central pier to organize the composition around this element.
- Increase the visual prominence of the abutments and superstructure while decreasing the visual importance of the pier. This later option diminishes the duality by returning attention to the whole structure form.

Multiple span Structures Figure (6-35)

- Maintain a constant depth of structure throughout the length of the bridge.
- Minimize the height of the abutments to keep the end spans visually balanced.

Single-span Structures

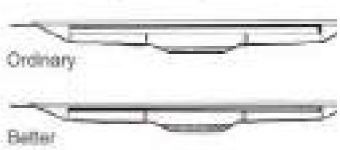


Need for slenderness controls over need for proportion on longer spans

Double span Structures

Prominence of abutments and super-structure focuses visual attention of entire composition, Burlington Northern over Beam Avenue, Maplewood, Minnesota

Multiple span Structures



Slender structure on proportionate piers provides a better appearance than a deep structure on slight piers

Figure 6-35: Structure Depth Considerations[3]

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[1] -"Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 5-1 to 5-13.

[2] - http://www.archiexpo.com/prod/big-r-bridge/product-143528-1536237.html

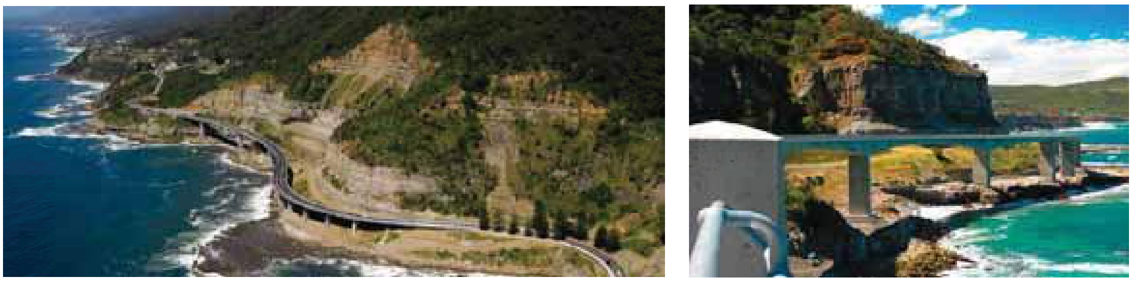
[3] - http://www.listofwonders.com/top-10-worlds-most-beautiful-modern-bridges

6-3-2- Viaduct and Ramp Structures

Developing the structure layout for viaducts and ramps requires considering the vertical geometry, the height of the bridge, and the general outline of the topography. The orientation of the bridge to the ground creates different-shaped spaces beneath the bridge. These spaces can be rectangular or triangular depending on this orientation,[1] Figure (6-36)

Favorable foundation conditions - viaduct

(e is constant) Spans proportional to height



Sea Cliff Bridge - Australia (Spans proportions to height)

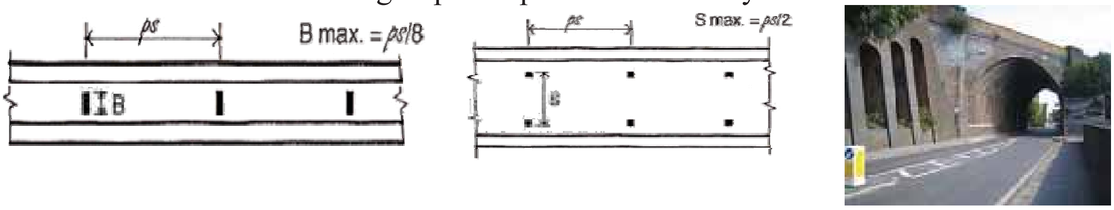
Figure 6-36: Viaduct and Ramp Structures[2]

6-3-3- Skewed Structures

Skewed bridges can create visual obstacles as well as structural difficulties. Oblique views of the bridge from the roadway beneath (or from near- by communities) are important. Figure (6-37)

Considerations for skewed bridge layout should include the following:

- Maximize the deck overhang to minimize the width of the substructure units.
- Maintain piers parallel to each other or radial to a curved superstructure.
- Keep the pier shapes as simple as possible.
- Consider abutment relocation to eliminate side piers.
- Consider the use of integral pier caps when necessary.[3]



Pier width considerations - skewed bridges

Column spacing to span length ratio - two column piers

Southdown Road skew bridge-England

Figure 6-37: Skewed Bridges design Considerations[4]

6-3-4- Structure Depth and Proportions

Consideration for structure depth should include the following items:

- Continuous girders will provide a more slender structure than simple spans.
- Steel girders will provide a more slender structure than precast concrete I-beams.
- Concrete slab bridges often look very light because of their minimal structure depth.

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١ - جورج صبحي راغب: "جماليات انشاء الكباري - رؤية خاصه من وجهة النظر المعمارية"- رسالة ماجستير - قسم عمارة- كلية الهندسة- جامعة القاهره- ١٩٩٨ - ص٤١٥-٤٢٠.

2 - http://www.industrytap.com/bike-walk-drive-offshore-parallel-coast-sea-cliff-bridge/17884

٣- جورج صبحي راغب: " الجمال و الابداع في عمارة الكباري" - رسالة دكتوراة- قسم عمارة- كلية الهندسة- جامعة القاهره- ٢٠٠١-ص ٣٦-٣٧.

4 - http://www.geograph.org.uk/photo/558815

- Pay special attention to proportions when the depth of a girder (d) is less than the rail height.

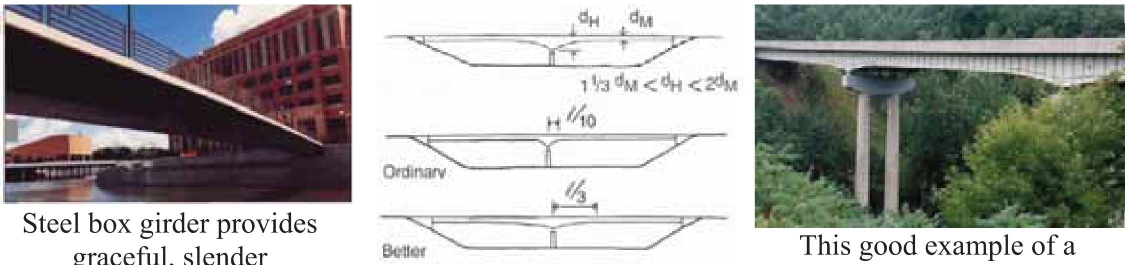
6-3- 5- Hunched Girders

There are Considerations for hunched girders which should include the following.

- Provide parabolic haunches rather than circular or linear haunches.
- Avoid the use of haunches on tall piers when the openings are predominantly vertical.
- Provide a substantial pier beneath the haunches. This element should provide a corresponding strong visual support for the concentrated loads at that point.
- Haunches should be proportional to the span length. Use the span as a guide for the length of one side of the haunch.
- Limit the depth of haunches to twice the mid span depth.
- Limit the angle subtended by the haunch to between 135 and 160 degrees; otherwise the bearing point will look too delicate to support the girder.

6-3- 6- Box Girder Bridges

Consider removing the divisions between fascia surfaces by introducing curvature, leaving the viewer no clues by which to judge the depth of the structure.[1] Figure (6-38)



Steel box girder provides graceful, slender presentation, Rochester; Minnesota

Haunch depth proportions

This good example of a hunched girder makes structure looks slender Baltimore

Figure 6-38: Box and Hunched girders Design Considerations[2]

6-4- Conclusion

In this chapter, Bridge parts were discussed. These parts could be divided to structural parts (superstructure) which have all traffic loads and movement, (substructure) which transfer the previously mentioned loads to the ground and hold the superstructure.

Also there are bridges non structural details which were discussed, and Consideration to Guarantee Bridge as a Whole Aesthetical Design were mentioned .

At the end of this chapter, structural parts shape considerations were discussed through different structure systems to guarantee best bridge architectural design.

6-4-1- Concluded Prerequisites

AP: Bridge Parts Architectural Integration

6-4-2- Concluded Credits

CR: Superstructure Types Selection.
CR: Superstructure Parts Aesthetical Consideration.
CR: substructure Types Selection.
CR: substructure Parts Aesthetical Consideration.
CR: Non-structural Parts Aesthetical Considerations.

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[1] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 94-1 to 4-11.

[2] - Same Previous Reference

جـــامعة حـــــــلوان
كليـــة الهندســــة بالمــطريـــة
قسم الهندســــة المعمارية

نظام مستدام للتقييم المعماري للكباري في مصر

إعداد
م/ محمد أسامة سيد احمد
رسالة مقدمة إلى كلية الهندسة بالمطرية – جامعة حلوان
كجزء من متطلبات الحصول على درجة الماجستير فى الهندسة المعمارية

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القاهرة, ٢٠١٦

Helwan University
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Sustainable Rating System for Architectural Evaluation of Bridges in Egypt

Thesis Compiled and Presented by
Architect: Mohamed Osama Saied Ahmed

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Architectural Engineering

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Assistant professor- Architectural Department
Faculty of Engineering- Mattaria - Helwan University

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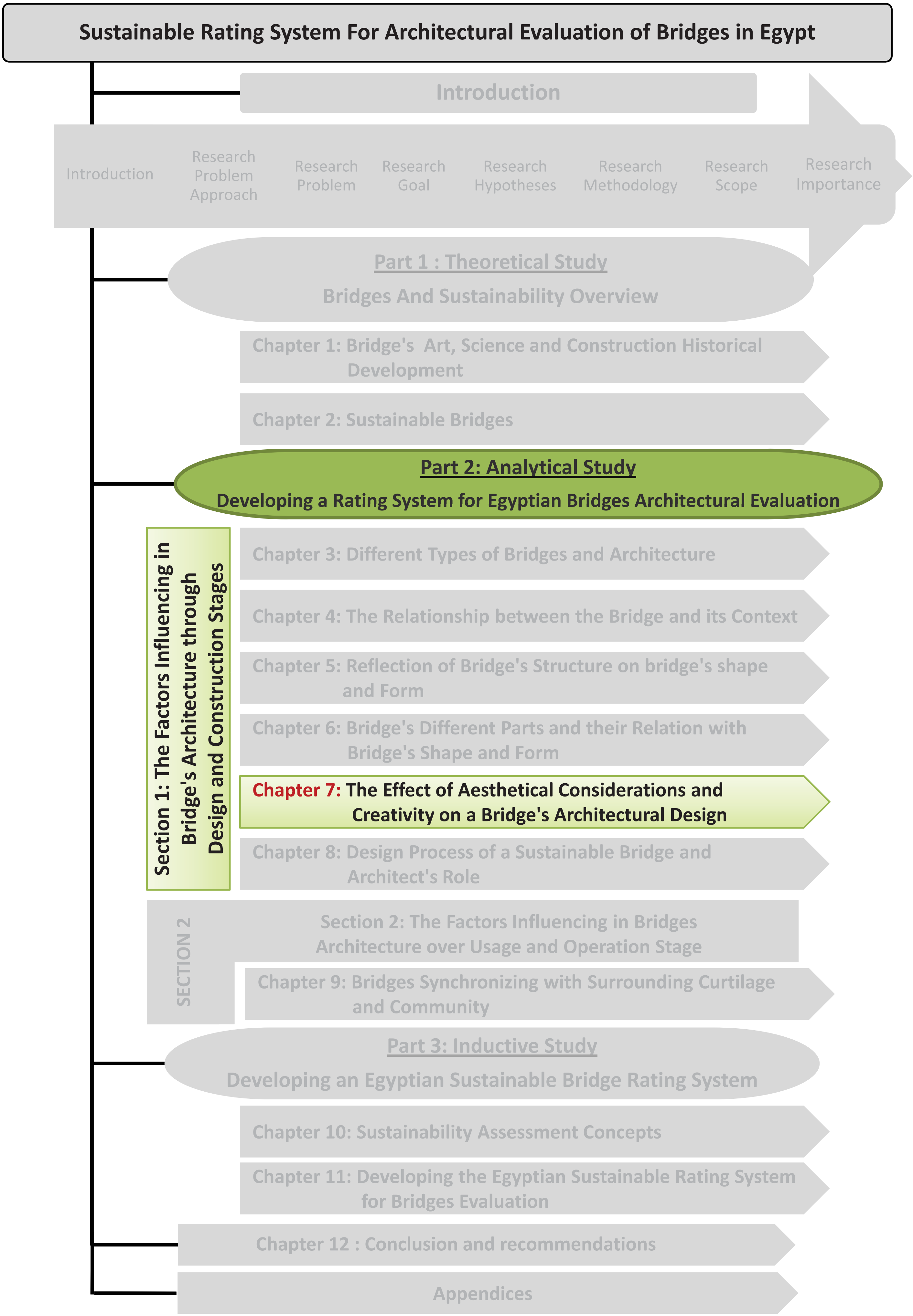
Teacher - Architectural Department
Faculty of Engineering- Mattaria - Helwan University

Cairo, 2016

اسال كل من يتلقي رسالة الماجيستير الدعاء
لوالدي العميد/ اسامة سيد احمد بالرحمة و الغفران
و ان يتقبل العمل كصدقة جارية.



Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

Introduction

Introduction | Research Problem Approach | Research Problem | Research Goal | Research Hypotheses | Research Methodology | Research Scope | Research Importance

Part 1 : Theoretical Study

Bridges And Sustainability Overview

Chapter 1: Bridge's Art, Science and Construction Historical Development

Chapter 2: Sustainable Bridges

Part 2: Analytical Study

Developing a Rating System for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages

Chapter 3: Different Types of Bridges and Architecture

Chapter 4: The Relationship between the Bridge and its Context

Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form

Chapter 6: Bridge's Different Parts and their Relation with Bridge's Shape and Form

Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design

Chapter 8: Design Process of a Sustainable Bridge and Architect's Role

SECTION 2

Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community

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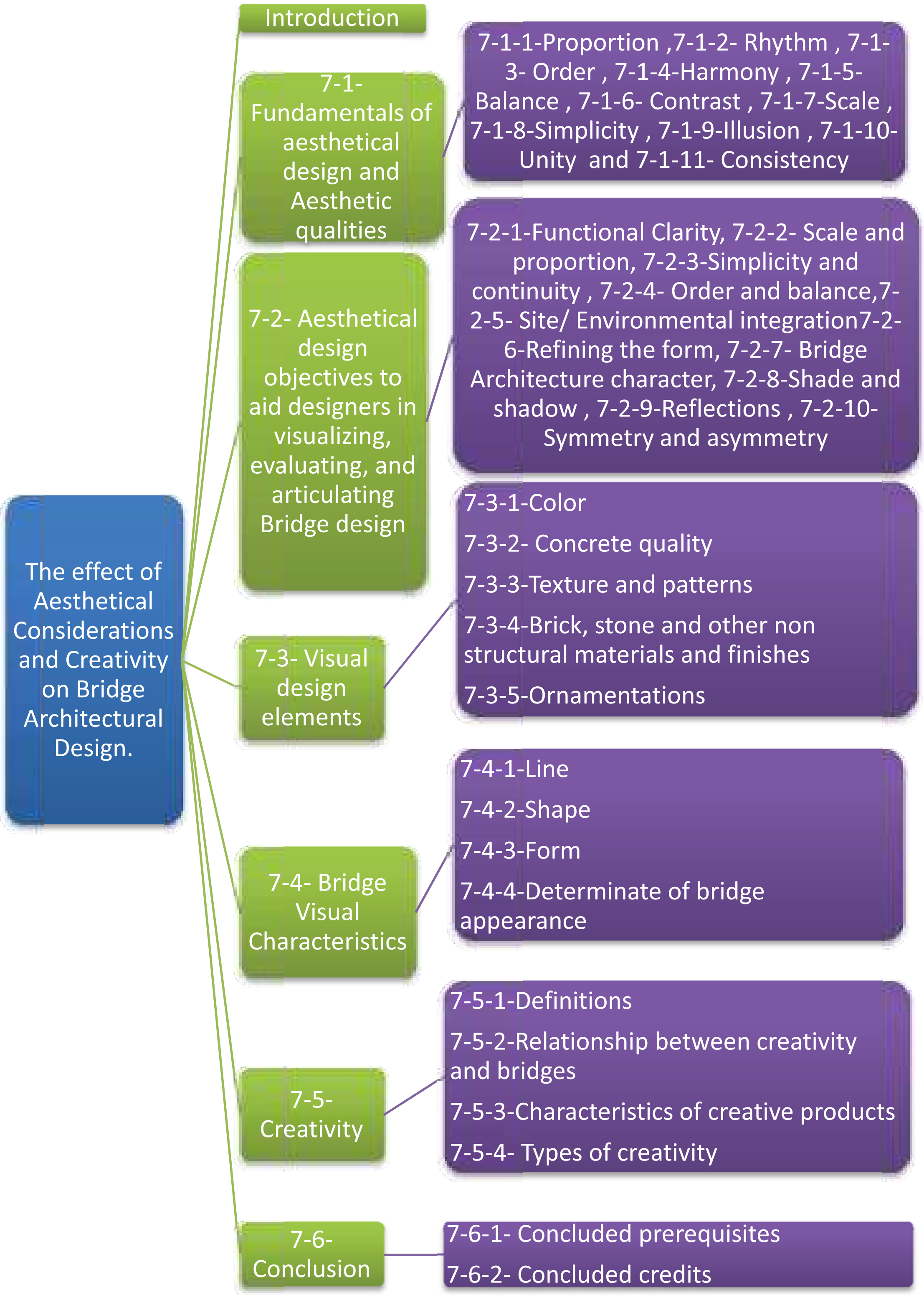
Chapter 10: Sustainability Assessment Concepts

Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Chapter 12 : Conclusion and recommendations

Appendices

Chapter 7 : The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design.



- The effect of Aesthetical Considerations and Creativity on Bridge Architectural Design.
  - Introduction
  - 7-1- Fundamentals of aesthetical design and Aesthetic qualities
    - 7-1-1-Proportion ,7-1-2- Rhythm , 7-1-3- Order , 7-1-4-Harmony , 7-1-5- Balance , 7-1-6- Contrast , 7-1-7-Scale , 7-1-8-Simplicity , 7-1-9-Illusion , 7-1-10- Unity and 7-1-11- Consistency
  - 7-2- Aesthetical design objectives to aid designers in visualizing, evaluating, and articulating Bridge design
    - 7-2-1-Functional Clarity, 7-2-2- Scale and proportion, 7-2-3-Simplicity and continuity , 7-2-4- Order and balance,7-2-5- Site/ Environmental integration7-2-6-Refining the form, 7-2-7- Bridge Architecture character, 7-2-8-Shade and shadow , 7-2-9-Reflections , 7-2-10- Symmetry and asymmetry
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    - 7-3-2- Concrete quality
    - 7-3-3-Texture and patterns
    - 7-3-4-Brick, stone and other non structural materials and finishes
    - 7-3-5-Ornamentations
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    - 7-4-2-Shape
    - 7-4-3-Form
    - 7-4-4-Determinate of bridge appearance
  - 7-5- Creativity
    - 7-5-1-Definitions
    - 7-5-2-Relationship between creativity and bridges
    - 7-5-3-Characteristics of creative products
    - 7-5-4- Types of creativity
  - 7-6- Conclusion
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Chapter 7 structure: The Effect of Aesthetical Considerations and Creativity on Bridge Architectural Design.

Chapter 7: The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design

Introduction

Bridge design is a process requiring the use of science, technology, and artistic judgment for its finest design solution.

Aesthetics, the study of the mind and emotions as they relate to the sense of beauty, is concerned with visual appearance and quality. In bridge design, as in architecture, excellence is achieved by integrating science, technology, and aesthetics. The bridge designer must strive to understand the creative artistic process, as well as scientific and technical principles, and merge the most fundamental concepts into a unified theme for an expressed purpose. The principles of aesthetics that stimulate the senses in most viewers are proportion, order, simplicity, balance, color, and texture. Design excellence requires designers to orchestrate these aesthetic principles with the physical and geometric components of a structure. The appropriate application and integration of these principles, together with sound structural and functional design, can result in bridge forms that exhibit strong visual character and quality.[1]

The two visual concepts used to develop, describe, and express visual ideas are: visual design elements and aesthetical qualities.

Visual design elements and characteristics define visual perception. These elements include line, shape, form, color, and texture. They can be used to articulate visual concepts.

Aesthetical qualities result from employment of visual design elements and are used to describe a visual composition.

Aesthetical qualities of design are intangible, perceived qualities arising from the relationships of design elements. The properties of aesthetic qualities are proportion, rhythm, order, harmony, balance, contrast, scale, and unity, These properties are basic elements of creative design compositions common to all fine arts as well as bridge architecture. The discussion below describes these basic qualities as they relate to aesthetical design.[2]

7-1- Fundamentals of Aesthetical Design and Aesthetic Qualities

Fritz Leonhardt, German author and bridge designer, expressed the concept of geometric proportion very succinctly: "For structures it is not sufficient that their design is 'statically correct.' A ponderous beam can be as structurally correct as a slender beam but it expresses something totally different Proportion helps to successfully define the relationship among structural elements and implies the order of significance of the elements. In design, the most obvious proportional relationships are based on relative size and shape of the elements. There can also be proportional degrees of surface texture and color.[3]

7-1-1- Proportion

Proportion is a method of creating a sense of order by assigning appropriate relative sizes to the various elements. The goal is appropriate proportions between the various parts of a structure comparing its height, width and depth, solids and voids, and

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[1] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p1-3.

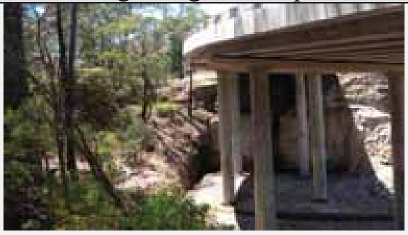
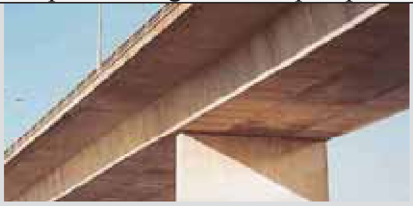
[2] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p 44

[3] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p 41-42.

comparing areas of sunlight and shadow.[1]

As shown in table (7-1), most important proportion consideration during bridge design are studied.

Table 7-1: Important Proportion Consideration during Bridge Design

The slenderness ratio	The proportion between depth of superstructure and bridge span is an important ratio	 Captain Cook Bridge over the Georges River has a ratio of 1:18 and together with its gentle vertical curve has a very slender appearance.
The relationship between the bridge height and span	As a general rule the higher the bridge the wider the span. it is generally not practical to vary span with height unless two or more superstructure types are used.	 Elsalam bridge in Egypt As an example for relationship between the bridge height and span
The relationship between pier thickness And superstructure depth	The ratio of pier width to superstructure depth should also be considered carefully. Bridges with all thin piers relative to superstructure depth can appear odd, as can the opposite.	 The pier widths used on this bridge In Kerrigan- USA appear too thin and almost spindly in comparison to the depth of the girder and parapet.
The relationship between deck overhang and parapet depth	The ratio of deck overhang relative to parapet depth is also considered a significant aesthetic proportion.	 The generous deck overhang is important to consider as part of the bridge cross section. Stockon

References: http://www.arabcont.com/projects/Images/canl-3-l.jpg
Gauvreau, P. 2002. The Three Myths of Bridge Aesthetics. In *Developments in Short and Medium Span Bridge Engineering 2002*, pp. 49-56.

7-1-2-Rhythm

Is the regular recurrence of any like elements in, on, or around a structure. It requires that the elements have some similarity of visual characteristics in addition to a modulated placement. In bridges, for example, major rhythms are created by the repetition of similar pier shapes. Minor rhythms may be created by the spacing of light poles, post spacing within a railing, or even the horizontal rustication on a pier.

Modulating the placement of these elements can create visual flow or movement across the scene. A good example of this is when pier spacing gradually increases near the

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[1] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p 41-42.

main span when a bridge crosses a wide river or lake.[1] Figure (7-1)

7-1-3-Order

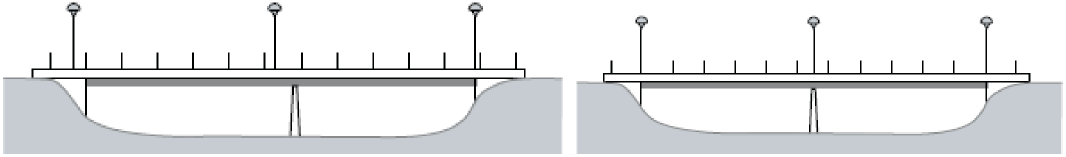
Order refers to arrangement. It is the arrangement of design elements so that they work together as a unit without visual confusion. The whole arrangement works as a unit with each element having a proper place and function. The selection of a constant girder depth throughout the structure is an element of good order. Order is also achieved by limiting the lines and edges of a structure to only a few directions. Under the rule of order, the regular recurrence of similar elements in a composition creates a natural flow, known as rhythm, that is satisfying to the eye. Figure (7-1)

Concept of rhythm   Visual order and disorder, respectively

Figure 7-1: Rhythm and order

- **Complexity and Order**

As Leonhardt (1984) writes, this should not lead to overall monotony through endless repetition. To avoid confusion and displeasure, he also gives advice to limit the number of spatial directions into which the lines and edges of the structure run. He also cautions to consider the three-dimensional appearance of substructure and superstructure. “We must also check the appearance of the design from all possible vantage points of the future observer. Often the pure elevation on the drawing board is entirely satisfactory, but in skew angle views unpleasant over lapping are found. We must also consider the effects of light and shadow”.[2] Figure (7-2)



Ordinary   Better

Figure 7-2: Rearranging the Parts Provide an Ordered and Pleasing Shape

7-1-4- Harmony

Harmony is the relation between the elements of a design based on similarity of their visual characteristics. The relationship must be complementary. If the planes or lines in a design have more dissimilar characteristics than they have similar characteristics, they are not likely to be perceived as harmonious. This is most readily achieved by using the Law of the Same or the Law of the Similar. **Law of the Same**: Harmony may be perceived or created in a structure or composition of structures that attains order through the repetition of the same elements, forms, or spaces. **Law of the Similar:** Harmony may be perceived or created in a composition that attains order through the repetition of similar elements, forms, or spaces.[3] Figure (7-3)

7-1-5- Balance

Visual balance is the perceived equilibrium of design elements around an axis or focal

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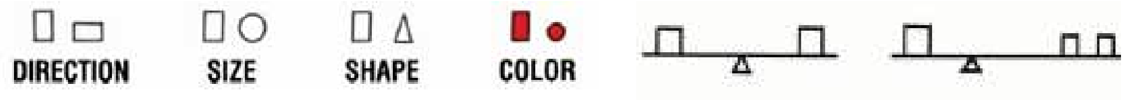
[1]- "Bridge aesthetics around the world"- Committee on General structures, subcommittee on bridge aesthetics- Transportation research board- National research council- Washington- USA-1991- p 115

[2] F. Leonhardt: " Brücken: Ästhetik und Gestaltung". (In German and English, translated title: Bridges: Aesthetics and Design.) The MIT Press- Cambridge- UK-1984-p 28

[3] - "Bridge aesthetics around the world"- Committee on General structures, subcommittee on bridge aesthetics- Transportation research board- National research council- Washington- USA-1991- p162.

point. Rather than a physical balance, it may also refer to equilibrium of abstract elements of the design such as masses, visual weights, texture, etc. Visual balance is fundamental to all successful compositions.[1]figure (7-3)



Harmony depicted as a function of shape, size, direction, and color

Visually balanced compositions

Figure 7-3: Harmony and Balance

7-1-6- Contrast

One principle of contrast is the dynamic relationship among parts of a design based on complementary opposition of visual characteristics. Contrast relieves the monotony of simple harmony by complementing harmonious characteristics of Some design elements with their opposites, thus adding a heightened awareness of each other. Swiss bridge engineer, Christian Menn, exemplified this concept in some of his works. In one instance, he erected a delicate and graceful concrete structure in a rugged, gray alpine gorge. This graceful bridge is foreign to the natural character of the craggy mountain background. Yet by sharply contrasting this elegant bridge with the rugged mountain setting the strongest qualities of each were dramatized.

A second principle of contrast is that of dominance This concept relates to one of two contrasting elements commanding the visual attention over the other. one becomes the supporting background. in terms of design, a dominant theme is essential in organizing the design into a pleasing aesthetics experience.[2]Figure (7-4)

Contrast in shape and color

The Ganter Bridge designed by Menn in Switzerland 1980

Figure 7-4: Contrast in Bridges Design[3]

7-1-7- Scale

Scale refers to the size relationship among various features of the structure and between the total structure and its surroundings. Since design concerns itself with things that are to be used by people, a connection exist between the human body and designed objects. We often refer to structures that respond to the size of the human form as having human scale., This would be particularly true for a pedestrian bridge or any bridge with high pedestrian usage. When a bridge becomes exceptionally large, many of the component

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[1] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p-43-44.

[2] - New York State DOT, Bridge Manual, Section 23 https://www.nysdot.gov/portal/page/portal/divisions/engineering/structures/repository/manuals/brman_4th_edition/section23_4-06.pdf

[3] - https://www.pinterest.com/pin/381680137139837898/

elements lose their human scale. Elements such as piers, pylons, or superstructure members may take on monumental scale. Here it becomes more important that the structure be in scale with the surrounding environment. In architecture we deal primarily in 4 scales:

- Human scale (The Man size scale).
- Intimate scale.
- Monumental Scale.
- Shock Scale.

Human scale (The man-sized scale) is what we are used to. Our houses are typically built to this natural scale. A man feels comfortable walking through our doorways. The ceiling neither bumps his head, nor is lost in the shadows.

Intimate scale are smaller than what is normal. Not Lilliputian. These do not shock you, but they are smaller than what we expect. Not everybody would recognize intimate as a separate category. It is more of a sub-category of human-scale

Monumental scale is impressive. Our public buildings are monumental. This is a statement of hierarchy. Those institutions represented by those buildings are bigger than us and we should stand in awe of them.

Shock scale can be either smaller or larger, but it is so out of the ordinary that it jolts us. You sometimes see it in art, and in architecture that strives to shock. [1]

7-1-8-Simplicity

Refinement of design should generally be pursued. Embellishments and ornamentation often do little to change the basic aesthetics of a structure.

Refinement of a structure, so that it better represents the forces that it is designed to withstand, is generally a feature of a bridge of aesthetic merit. This is often referred to as honesty of form and design integrity.

Nonetheless, it is unwise to insist that a bridge is perfect only if nothing can be omitted; there may be good reasons for avoiding total refinement based upon local context.[2]

7-1-9- Illusion

What people perceive is not always what is really there. Our vision is susceptible to manipulation and illusion. Designers can use illusion to improve the appearance of an element. For example, placing a series of vertical grooves on a column will make it appear thinner.[3]

7-1-10- Unity

Unity is presented last because it encompasses the perfect application of all the other qualities. It refers to the combined effects of all other aesthetical qualities applied simultaneously. Unity is the condition, or state, of full resolution of the site and project functions. Unity implies harmony where all of the elements are in accord, producing an undivided total effect. Unity provides the observer with a sense of wholeness, generated by some central or dominating perception in the composition. Figure (7-5)

7-1-11- Consistency

Consistency of form is an important aesthetic consideration. This is not to say that everything must look the same but that in a particular context there should be a relationship between elements.[4] As shown in table (7-2) examples of Fundamentals of aesthetical design and Aesthetic qualities in bridges are overviewed.

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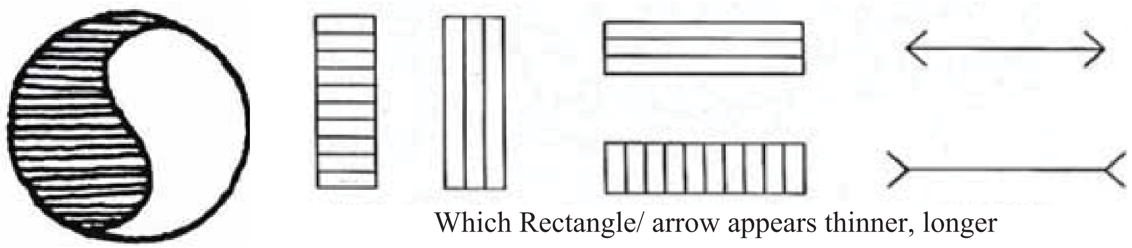
[1] - http://www.house-design-coffee.com/human-scale.html

[2] - "Design manual for roads and bridges" volume 1 highway structures- approval procedures and general design -section 3 general design- part 11- the design and appearance of bridges- USA-1998- p 4/2.

[3] - Bridge aesthetics source book"- The American association of state highway and transportation officials - USA- 2010- p45.

[4] "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 45



Which Rectangle/ arrow appears thinner, longer

Unity concept Some common visual illusions that can assist with highway design.

Figure 7-5: Unity and illusion[1]

7-2- Aesthetical Design Objectives to Aid Designers in Visualizing, Evaluating, and Articulating Bridges Design

Throughout the design process, designers should have aesthetic goals or objectives for the bridges they design, just as we have engineering objectives for safety, economy, serviceability, etc. As with engineering objectives, aesthetic design objectives should be established prior to the start of the design process so they can serve as an aesthetic compass, of sorts. These aesthetical objectives should be considered throughout the design process when decisions are being made about the structure and its setting. Established objectives referred to during the decision making process will help guide designers toward a successful visual design.

Ideally, aesthetical objectives would be quantitative and therefore easily measured. But, given the subjective nature of aesthetics, visual design goals will necessarily have to be qualitative. Only through subjective evaluation can the success of the visual design objective application can be measured. When evaluating a bridge, designers should evaluate each part of the structure in terms of the whole, and the whole structure in terms of the setting and the context.

7-2-1- Functional Clarity

- The purpose of a bridge needs to be defined. Therefore, a fundamental requirement is that the bridge design must fulfill its purpose.
- The structural design must provide an honest structural response to the load-carrying.
- The bridge should reveal itself in a pure and clear form.
- The structure must also serve the physical circumstances of its particular location.
- Geometry of the roadway, the topography, and the presence or absence of other structures or buildings are all design considerations in the selection and development of bridge types and configurations.
- When evaluating functional clarity, designers should ask: Does the bridge serve its function in both deed and appearance? Is the form of the structure appropriate to the function of the structure?

7-2-2- Scale and Proportion

The structure should be in scale with its surroundings. The primary structural elements, span lengths, girder depth, abutment height, should have good proportional and environmental considerations. The structure form should have an appearance of lightness.

- relationships to each other . Generally, no single element should dominate the visual composition. The collective design of the structure should be in scale with the site

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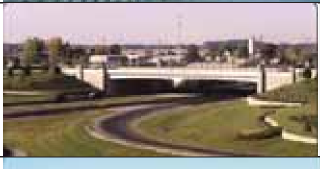
1 - http://www.innovativerigging.com.au/wp-content/uploads/2014/12/img075.jpg

Table 7-2: Examples of Fundamentals of Aesthetical Design and Aesthetic Qualities in Bridges Design.

	Definition	Example	
Order	Order is the arrangement of design elements so that each element has a clear place and function with no visual confusion.	 A confusion of girders and piers it is hard to tell what supports what.	 The repetitive pier shapes and continuous girder depth give this bridge a sense of order.
Proportion	Proportion is a method of creating a sense of order by assigning appropriate relative sizes to the various elements.		The proportions of this bridge, the large depth at the abutments compared to the depth at the crown, give it a very slender appearance. Ottawa, Canada.
Rhythm	Rhythm is a method of creating a sense of order by repeating similar elements in, on or around a structure.		The larger main span creates a variation in the major rhythm of the piers, while the light posts create a consistent minor rhythm. Maryland.
Harmony	Harmony means that elements of a design have visual similarity. The relationship must be complementary.		The shapes of these piers are similar, and thus harmonious, even though their sizes are different. Cheverly, Maryland..
Balance	Visual balance is the perceived equilibrium of design elements around an axis or focal point.		Freeway compositions work best when they are balanced about the median centerline. Avery, Dublin, Ohio.
Contrast	Contrast is complementing the characteristics of some design elements with their opposites.		Contrast in color brings out the arched vertical profile of this overpass. Pennsylvania Turnpike near Somerset.
Scale	Scale refers to the size relationship among various features of the highway and between the highway and its surroundings.	 Highway bridges are very large elements, even when compared to city buildings or people. California.	
Unity	Unity provides the observer with a sense of wholeness. This is generated by some central or dominating perception in the composition.		The arch provides a central feature, , that ties together both the man-made and natural features of this scene. Unity in design between bridge shape, structure movement Maryland.
Illusion	An optical illusion is a visual stimuli that is comprehended by the brain in a way that is different from reality.		The slanted lines of the abutments create the illusion that the girder is longer, and thus thinner, than it really is. Colorado

"Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland-USA-2005-7.. http://www.wilkinsoneyre.com/news/challenge-of-materials-bridge-chosen-as-dyson-design-classic
http://study.com/academy/lesson/what-are-optical-illusions-definition-types.html

- When evaluating the scale and proportion of a structure, designers should ask: Are the substructure elements proportional to the superstructure? Is the size of each bridge element consistent with its respective structural assignment? Is the structure size suitable for its setting and purpose? Does the superstructure seem slender without appearing delicate, or is it ponderous?[1]

7-2-3- Simplicity and Continuity

- The bridge form should appear straightforward and uncomplicated. Simplicity of form and clean lines are align considered attributes of attractive structures.
- The architectural features should enhance the overall appearance. The design should express an overall continuity in appearance.
- Shapes used to form elements should be from the same family. For instance, beveled piers should be used with a beveled barrier rail design; rounded pier designs with a rounded railing.
- The number of materials, colors, and textures should be kept to a minimum. Details should appear consistent.
- When evaluating the simplicity and continuity of a structure, designers should ask: Does the visual composition present a consistent design theme? Can a viewer comprehend the bridge in a glance, or does it require concentration of the viewer.[2]

7-2-4- Order and Balance

- The bridge should exhibit a natural progression of assemblage. Order is achieved by limiting the direction of lines to a minimum. Repetition of visual elements should be used sparingly to develop rhythm; if used to excess it can create monotony.
- The orientation and interaction of the design elements should suggest balance between the elements. The layout and alignment of the elements should promote harmony rather than confusion.
- When evaluating the order and balance of a structure, designers should ask: Does the arrangement of components work together as a unit or promote visual confusion ? Are the lines of the bridge limited to a few directions? Does the visual weight, texture, and mass of the members promote visual balance?

7-2-5- Site/ Environmental Integration

- Bridges must be integrated with their environment, landscape, cityscape, or surroundings.
- This is particularly true where dimensional relationships and scale are concerned, as pedestrians are uneasy and uncomfortable with heavy, brutal forms. The dimensions of the structure must relate to human scale when pedestrians are involved. Bridges should make a positive contribution to the immediate environment in which they are placed.
- When evaluating environment integration, designers should ask: Does the structure type, color, and color scheme complement its surroundings? Does the bridge visually conflict with its adjacent buildings or landscape? Are the materials, and finishes of the bridge native or foreign to the setting?

7-2-6- Refining the Form

- In many cases bodies formed by parallel straight lines appear stiff and static, production uncomfortable optical illusions, So the bridges architect has to check the appearance of the design from all possible vantage points of the future observer.

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1 - "Design manual for roads and bridges" volume 1 highway structures- approval procedures and general design -section 3 general design- part 11- the design and appearance of bridges- USA-1998- p 4/1.

2 - Michele Melaragno: "Preliminary design of bridges for architects and engineers"- Marcel Dekker publications- New York- USA-1998- p 191-195.

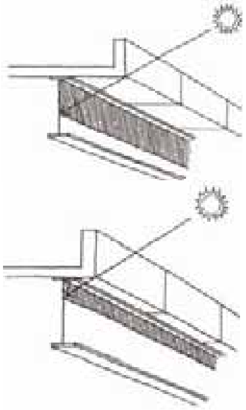
- Often the pure elevation on the drawing board is entirely satisfactory. but in skew angle views un pleasant overlapping are found.

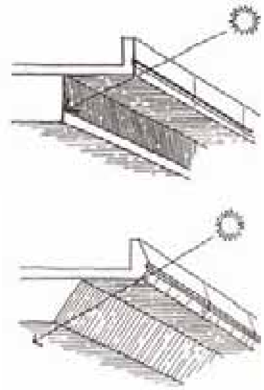
7-2-7- Bridge Architectural Character

- A bridge should has a certain deliberate effect on people. the nature of this desired effect depends on the purpose, the situation, the type of society and on sociological considerations.[1]

7-2-8- Shade and Shadow

- Shade and shadow are important in areas of comparative darkness caused by the interception of light by intervening parts of the bridge or another nearby object.
- Shadow is the term usually used when the intervening object can easily be identify ed. The shadow that the deck overhang of a girder bridge casts on the outside girder can be a very strong component of the appearance of the bridge.[2]figure (7-6)


Overhangs proportional to fascia depth creates a strong shadow line[4]


Surface inclination effects perceived depth


Brooklyn bridge- USA[3]


Shades and shadows help to visually define the bridges of the Big Interchange, Albuquerque, New Mexico

Figure 7-6: Shade and Shadow

7-2-9- Reflections

Images of a bridge visible in the water below can be a very important part of the impression made by a bridge. Reflections of light from the ground below or other nearby objects can also help illuminate the underside of a bridge and influence our impression of it.[5] Figure (7-7)

7-2-10- Symmetry and Asymmetry

- Symmetrical, or formal balance, is also known as bilateral symmetry. It is created by repeating the reverse of a design on the opposite side of the vertical axis each side, in essence, becomes the mirror image of the other. Symmetrical balance is considered formal, ordered, stable and quiet.
- It can also be boring. Symmetrical balance is often used in architecture.
- While symmetry achieves balance through repetition, asymmetry achieves balance through contrast. Asymmetrical, or informal balance, involves different elements that

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١ - جورج صبحي راغب: " الجمال و الابداع في عمارة الكباري" - رسالة دكتوراة- قسم عمارة- كلية الهندسة- جامعة القاهره- ٢٠٠١- ص٣٩-٤٢.

2 - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p40.

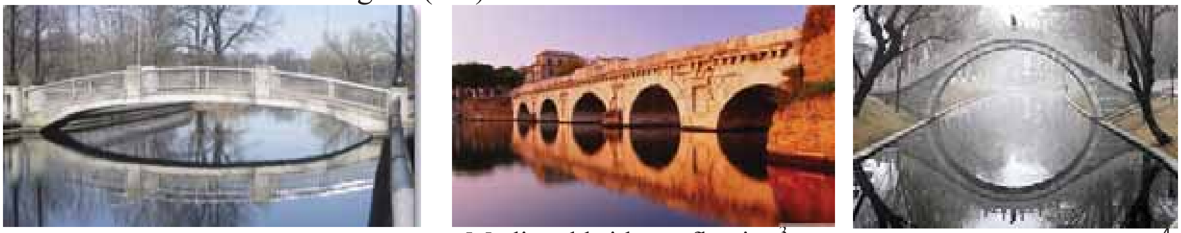
3 - http://i.telegraph.co.uk/multimedia/archive/03131/Brooklyn-bridge_3131494b.jpg

4 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 4-9.

5- Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p40-41.

have equal visual weight; the weight is equal but the elements are not identical.

- Asymmetrical balance is casual, interesting and more dynamic than symmetrical balance.
- Radial balance occurs when all the elements radiate out from a central point and the visual weight is distributed equally.
- Radial balance creates a strong focal point in the center of the design. Clock faces and daisies are examples of radial balance.
- Crystallographic balance, or an allover pattern, is created by repeating elements of equal weight everywhere. Emphasis is uniform; there is no distinct focal point. Quilts and chessboards are examples of crystallographic balance.[1]
- Another important aspect of form is symmetry. Symmetrical bridges as a general rule are often more aesthetically pleasing than non symmetrical bridges since they appear balanced and refined.[2] Figure (7-8)



Bridge reflection, New Jersey. Medieval bridge reflection[3] Sterling Bridge Reflection[4]

Figure 7-7: Examples of Bridges Reflectivity in Water

Symmetry Asymmetry Radial balance - Crystallographic balance

Different spans made non symmetry which bad affected on bridge aesthetics.

These Pacific Highway twin bridges at Boonville have a perfectly symmetrical composition.

The bridges at Yelgun interchange on the Highway led to well designed asymmetrical bridges.

Figure 7-8: Symmetry and Asymmetry[5]

7-3- Visual Design Elements.

The two major goals of color, texture, ornaments and other surfacing materials used for the enhancement of a bridge's aesthetics are:

- To create a positive response from the viewer.
- To differentiate the various parts of the structure's lines so that the structural form and shape is clarified and enhanced.

7-3-1- Color

Coloring is paid much attention to by the visual arts. In entertainment and advertising

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[2] -"Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 42-43

[3] - http://thumbs.dreamstime.com/z/medieval-bridge-houses-lagrasse-reflection-wa-water-france-35436763.jpg

[4] - https://s-media-cache-ak0.pinimg.com/236x/53/4e/c3/534ec3856abe0e593ff0e5b575b3b5b1.jpg

[5] - http://nwrain.net/~tersiisky/design/balance.html

colors contribute much to the image that ought to be conveyed to the audience. Although structures work in a completely different setting, they nevertheless attract people's attention. The Golden Gate Bridge in San Francisco, built from 1933 to 1937, spanning the bay with unique elegance, is much cited as an example of how a bridge can enhance its setting. Brown gives pronounced statement in his comprehensive work on bridges when he calls the red bridge spanning the San Francisco Bay "the world's largest Art Deco sculpture."[1]

Choosing a specific color strongly influences the impression that an object makes. Red usually symbolizes alert and attention, green and brown colors are related to quiet nature, yellow can stand for happiness, and blue can symbolize freshness, energy, and flow.[2] Figure (7-9)

Golden Gate Bridge, California, United States 1937[3]

Glasgow, Glasgow Green, St Andrew's Suspension Bridge-1986[4]

Figure 7-9: Bridge Colors Effect on Bridge Shape

There are differing theories on the use of color. One theory suggests that colors chosen for a bridge should reflect and harmonize with the predominant colors of the highway environment in which it is located. The other viewpoint holds that manufactured objects should look manufactured and should not attempt to match the color of trees, grass, sky or shrubbery because they are not related to such natural features by form. Rather, harmonious colors should be utilized.

Both views have value. Success often depends on the purpose of the project, and how well and consistently a color scheme is designed and carried out. Overall design intentions may be to either contrast or integrate with the surroundings.[5]

The use of color can be very subjective. Some Used approaches include:

- Very light colors may be hard to distinguish especially in direct sunlight.
- Darker colors will fade over time and any flaking will be more noticeable.
- Light colors help to emphasize shadows and provide contrast.
- Bright red, yellow and brown colors tend to emphasize the presence of size and form.
- Light blue and green colors are less bold and tend to diminish the visual importance.
- Reversing the intensity of color can reverse the effect.

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[1] - Brown, D. J : " Bridges"- Macmillan Publishing Company- New York- USA-1993- p 105

[2] - Gunnar Lucko: "Means and Methods Analysis of a Cast-In-Place Balanced Cantilever Segmental Bridge"- Master of Science-Civil Engineering-Virginia Polytechnic Institute and State University- USA- 1999- p 116.

[3] - http://study.com/academy/lesson/what-are-optical-illusions-definition-types.html

[4] - http://www.clydewaterfront.com/projects/glasgow-city-centre/infrastructure/st_andrews_suspension_bridge

[5] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 2-3and2-4.

When selecting a color or color scheme, it should be recognized that the colors will appear different at various stages over the project life because of different hue of different seasons and day times Colors can be applied to the steel components of bridges through the use of paint, galvanizing and atmospheric corrosion resistant material Concrete components of bridges can be colored by using special cements in the mix or by applying pigmented sealers and coatings Care should be taken to ensure that the application of paints and coatings does not significantly increase maintenance costs.[1]
There are big differences between coloring concrete and coloring steel, paints specs should be taken into consideration during design process.
A pedestrian screen is less obvious when its color is black. Black tends to lose itself against most backgrounds. A light gray color is also acceptable. Because signs have strong characteristic colors, the presence of a sign, and its size, on a bridge should be taken into account in the color selection of the bridge.[2] figure (7-10)

Samuel becket bridge, Dublin, Ireland with white color matching to surrounded building.[3]

Each of the safety screens on the Eastern Distributor pedestrian bridges has a different color, but they all form part of an integrated approach and color composition for the corridor.[4]

Same bridge painted three different colors gives different looks. Baltimore[5]

Figure 7-10 : The impacts of different colors on same bridge

7-3-2-Concrete Quality

Bridge aesthetics can be affected by the quality of the concrete finish. This is particularly important if the bridge structure is visible and accessible. It is preferable to use steel shuttering and pre-cast factory made elements for highly visible bridge parts such as piers, girders and parapets to ensure a controlled, high quality finish. Retardants and sealants should be tested to ensure that they do not result in staining when the shuttering is removed. Concrete surfaces close to traffic and accessible to the public should have a class one finish. If the bridge is only visible from a distance then in

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1 - Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch- Australia-2005- p70-75.

2 - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-8 and V-9

3 - Chris van Uffelen: " LINK IT! Masterpieces of Bridge Design"- 1st edition- Braun publications- Switzerland- 2015- p8-11.

4 Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch- Australia-2005- p 70-75

5 - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-3

aesthetic terms the finish is not so critical, although it should be noted that variation in concrete coloration due to staining can be noticed from a wide area.[1]figure (7-11)

Good concrete quality at pedestrian bridge - Cairo Alex road

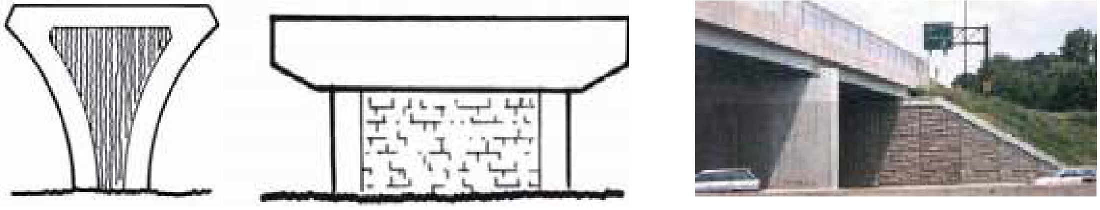
Bad concrete quality - 6th of October bridge

Bad concrete quality - new constructed bridge - Dumitta

Figure 7-11: The Effect of Concrete Quality on Bridge Shape[2]

7-3-3-Texture and Patterns

Texture is found on the surface of all objects and is closely related to form. Texture helps define form through subtle surface variations and shadings. It can be used to soften or reduce imposing scale, add visual interest, and introduce human scale to large objects such as piers, abutments, and tall retaining walls. Distance alters our perception of texture. When viewed from a distance, fine textures blend into a single tone and appear flat. As a rule, the greater the distance or the larger the object, the coarser or larger the texture should be.[3] figure (7-12)



Texture concept

Good use texture bridge at maryland

Figure 7-12: Bridge Texture and Pattern Examples[4]

The keys to Successful Use of Patterns are:

Surface textures and ornamentation can be used to differentiate and clarify the various components of a bridge Surface textures and ornamentation become more important at street and pedestrian speeds.[5]

- Make sure that the pattern is subordinated to, and enhances, the overall design features and proportions of the structure itself.
- Make the pattern large enough to be distinguished from a distance when it will be seen primarily from a moving vehicle on the roadway.
- Horizontal lines should be continuous, and should either be level or follow the major lines of the roadway. They must be carefully controlled, as any irregularities will be immediately obvious
- Textural elements need to be large enough to be read at highway speeds a dimension of about four inches is necessary in elements such as grooves and recesses, and the grooves should be deep enough to create defined shadows.[1] Figure (7-13)

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1 - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 88

2 - By researcher

3 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p2-2.

4 - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005-p V-3

5 - Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch- Australia-2005- p 76-79.

Figure 7-13: Concrete Patterns Examples (Different Bridges in USA)[2]

7-3-4- Brick, Stone and Other Non-structure Materials and Finishes

Non-structural facing materials, such as brick, stone, and pre-cast panels, have been used to provide color or texture on surfaces. These find their most logical application for facings of abutments and retaining walls.

Random fieldstone appears to work best since its size and texture make it visible in the highway environment. Precast concrete panels can work well. The major concerns are surface color and texture and the location of panel joints.[3]

Other types of surface texturing can be used to create patterns, add visual interest and introduce subtle surface variations and shading, which in turn soften or reduce the scale or mass of abutments, piers and walls. There are a variety of form liners available. Some mimic other materials, while others have more abstract or geometric designs.

Consider the following when specifying form liners:

- When simulating another material, such as stone or brick, form liners should be made as realistic as possible. Use color in addition to texture to assist in the simulation.
- When using form liners to simulate another material, avoid suggesting material that would not be utilized in that application. For example, stone texturing on a cantilevered pier cap surface creates disharmony since a stone cantilever would not be stable if constructed.
- When a geometric pattern or texture is used, consider its relationship to the overall bridge composition. The parts must relate to the whole.
- Care should be exercised in the use of form liners for girder fascias or parapet exterior faces. Inappropriate use may disrupt the superstructure lines.[4] figure (7-14)

7-3-5- Ornamentation

Ornamentation created by add-ons should be kept to an absolute minimum unless the structure is in a very special location.

The goal of the engineer should be to develop strength from the shape of the structure and let that structural shape produce the aesthetic impact on its own. However, ornaments can be used to articulate and emphasize the structural shape.

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1 - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-10 to V-10.

2 - http://creativeformliners.com/wp-content/uploads/2013/11/Wingwall_Slope1.jpg

3- " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-10 to V-12.

4 - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009-p32.

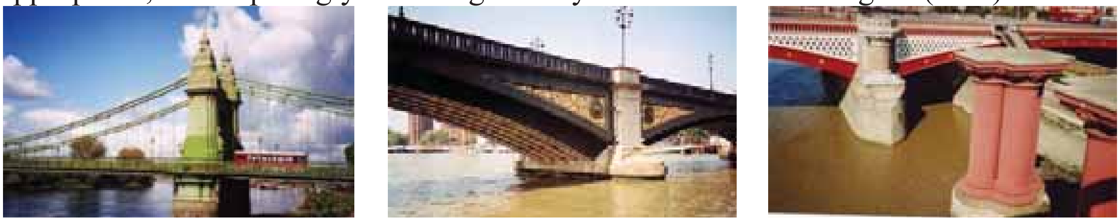
Random fieldstone texture. USA[1]

rick-faced bridge in Annapolis. USA[2]

Glulam Free Span Bridge with Stone Facade[3]

Figure 7-14: Bridge Finishes Examples

Many of the classical systems of architectural ornamentation had their beginning in the elaboration of structural elements. However, ornamental and non-structural surface materials can disguise, detract from or destroy the structural form. Ornament can add additional levels of interest and richness. It is best when restricted to those locations with a high level of importance and exposure. Make sure that the ornamentation emphasizes, rather than camouflages, the structural form. If a bridge is a gateway to a special community, such as a state capital, pylons on the bridge may be appropriate to identify the importance of the structure as a gateway.[4] While attitudes regarding the appropriateness of ornamentation in bridge design have varied over time, some best practices have evolved. Avoid using false structure as ornament. Aside from requiring additional costs to construct and maintain, adding false structure will rarely improve a design and is often viewed as extraneous clutter. Do not use ornament as "make up" to disguise an inappropriate design. The form and composition of an inappropriately designed bridge can rarely be improved by applying ornament. If ornament is appropriate, use it sparingly. Less is generally better than more.[5] Figure (7-15)



Hammersmith Bridge (1887)- London

Battersea Bridge (1890). London

Blackfriars Bridge (1869).

Figure 7-15: Bridge Ornamentation Examples [6]

7-4- Bridge Visual Characteristics

Bridge visual could be defined as how the bridge is received by the passengers and it could be received as a line, shape or form.

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[1] - http://www.reckli.net/formliner/designs/abstract-patterns/

[2] - http://www.naturebridges.com/gallery_new/free_span.php#prettyPhoto[gallery2]/1/

[3] - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-14

[4] - " Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-10 to V-14 and V-15.

[5] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p33.

[6] - http://www.lonwalk.ndirect.co.uk/bridsum.htm

7-4-1- Line (One Dimension)

A line is a direct link between two points, either real or implied. The strongest lines on a highway are created by the pavement edges. Other prominent lines are created by railings, girders, piers, abutments and the top edges of retaining walls and noise walls.[1]

A line may be thought of as a direct link between two points, either real or implied. Lines within the context of a bridge are seen in the profiles of railings, spans, piers, abutments, and wing walls. They are likewise seen in the juncture of different materials and construction joints. Manufactured lines on the landscape may include roads, fences, and the outlines of structures. Lines that are long and straight tend to dominate natural settings that consist of predominantly short line segments.[2]

As shown in figure (7-16), (6-17) and (6-18) the bridge design perception by the viewer as a line, shape or form is illustrated.

Bridge received as a Line because of parallel curvilinear lines.[3]

Verrazano narrows Bridge - New York[4]

Garrapata Creek Bridge [5]

Figure 7-16: Examples of Bridges that Precept as a Line

7-4-2- Shape (Two Dimensions)

Shape is the outline of a two-dimensional surface with spatial directions of height and width.

When a line closes, it forms a two-dimensional surface with spatial directions of height and width. This two dimensional surface can be called shape. While shape delineates horizontal and vertical dimensions, it excludes depth and volume. Sought by the eye, shape quickly identifies many objects. The purest of shapes is a back-lit elevation view, or a silhouette. Depending on one's position and the time of day, bridges may appear as a silhouette. Shape stands out most when an object is clearly separated from the background, either by tone or color contrast, and when viewed from head on. Color contrasts also call attention to shape as the outlines are accentuated.[6]

7-4-3- Form (Three Dimensions)

Form is the three-dimensional array of an object, adding depth to its height and width. The visual experience of moving under or over a bridge is primarily influenced by the form of the bridge, its geometry, span arrangement, horizontal alignment, vertical

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[1] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p38.

[2] - Same Previous Reference

[3] - http://inspirationfeed.com/inspiration/architecture/25-beautiful-bridge-designs-from-around-the-world/

[4] - http://www.aholgate.com/unbltarchtexts/unbltarches1.html

[5] - http://cambriahistory.org/?p=659

[6] -"Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 2-2.and2-3.

profile, relationship to adjacent structures and its relationship to the space or sets of spaces that create its environment.[1]

Examples of shape concepts Bridge in Herzegovina Chengyang Bridge, China

Figure 7-17: Examples of Bridges that Precept as a Shape [2]

Form reveals objects in three dimensions, adding depth to the height and width of shape. The visual experience of moving under or over a bridge is primarily influenced by the form of the bridge, its geometry, span arrangement, horizontal alignment, vertical profile, and relation to adjacent structures.

The form of a bridge is seen in the context of space or sets of spaces that create its environment. Although the eye gathers stereoscopic cues, form is primarily revealed as volumes modeled in light and shadow. Nothing delineates the configuration of a surface as well as a shadow line.[3]

Difference between shape and form

The three-dimensional form of a bridge is a result of the interaction of all its solid elements.[4]

Figure 7-18: Examples of Bridges that Precept as a Form

7-4-4- Determinates of Bridge Appearance

How people react to an object depends on what they see and the order in which they see it. This means the largest parts of the bridge – the superstructure, piers and abutments have the greatest impact. Surface characteristics (color/texture) come next, then details. Therefore, design decisions should be approached in the following order of importance.

Before there is a concept for a bridge, the roadway geometry creates a ribbon in space that can be either attractive or unattractive. The geometry establishes the basic lines of the structure, to which all else must react. A graceful geometry will go a long way toward fostering a successful bridge, while an awkward or kinked geometry will be very difficult to overcome. Examples include:

- Many urban grade separations or viaducts may have minimal clearance above grade and may be perceived by the community as barriers or tunnels. At the opposite extreme, the profile grade of an urban highway may extend upward past the horizon line and raise concerns related to blocking the view shed.[5] Figure (7-19)

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[1] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p39.

[2] - http://inspirationfeed.com/inspiration/architecture/25-beautiful-bridge-designs-from-around-the-world/

[3] - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p2-2and 2-3.

[4] - http://inspirationfeed.com/inspiration/architecture/25-beautiful-bridge-designs-from-around-the-world/

[5] - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p19.

. Viaduct, Denver, Colorado, USA.

Saft Ellaban Corridor - By researcher

Under 6th of October bridge

Ring road - Marriotya corridor entrance - by researcher

At these examples, there is a big difference between the passenger feelings on the lower layer of the bridge and the upper layer of the bridge.

Figure 7-19: Determinates of bridge appearance examples

In the design of a bridge, the horizontal and vertical geometry of a bridge will:

- Be selected to satisfy the requirements of the site conditions
- Relate to the type of bridge crossing.
- Wide bridges that are relatively close to grade often create visual barriers. In this case, use of post-tensioned caps increased the transparency of the substructure when viewed from an oblique angle
- For highway bridges, be selected by the roadway designers to satisfy traffic movement and safety concerns. [1] Figure (7-20)

7-5- Creativity

In one form or another, different definitions state the creativity involves the capacity to make products, either tangible or intangible. Which are both new and valuable. It is not present purpose to arrive at a single definition is generally accepted. Definitions differ according to whether they refer to potential, activities or products.

7-5-1- Definitions

Creativity

Is the integrated socio-individual process (Individual within a community or society) which results in an original work within a certain domain (Art, Science, Business, etc..)That's recognized as a valuable and useful by a society at some point in time.[2]

Creative Thinking

A way of looking at problems or situations from a fresh perspective that suggests unorthodox solutions (which may look unsettling at first). Creative thinking can be

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1 - Evamy. Cohos: "Bridge aesthetics study"- Version 1.0- Alberta infrastructure and transportation- Technical standards Branch- Australia-2005- p9-18.

2 - Abdel Raouf: "A Creativity in Architecture"- Phd thesis- Architecture department- Faculty of engineering- Cairo University- Egypt- 2010- p46.

Bridge in Louise - USA

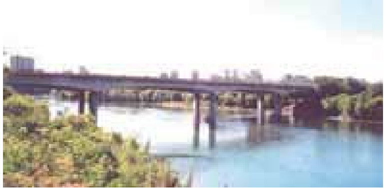
Mackenzie bridge - USA

These bridges have good proportions, with pleasing span to depth ratios[1]

The horizontal and vertical geometry of the bridge have influenced the structural system selected for this bridge -Portugal

The horizontal and vertical geometry of the roadway at this river crossing have resulted in a bridge with an ordinary appearance

Peace River Bridge at Fort Vermillion - USA

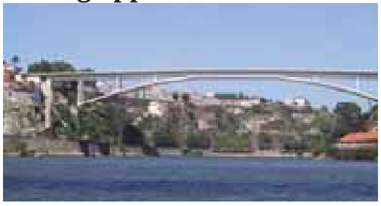


James MacDonald Bridge across North Saskatchewan River, Edmonton

The designers of these river crossings bridges worked within the constraints of the roadway geometry to achieve structures with pleasing appearances.[2]

LRT Bridge across Fraser River in Vancouver is pleasing, long span cable-stayed bridge

White Pass and Yukon Route Heritage Railroad Bridge, Alaska



Modern arch bridge Porto, Portugal

Large valleys with competent rock foundations allow designers to select long span arch structures providing unobstructed views[3]

Figure 7-20: Horizontal and Vertical Geometry Design examples

stimulated both by an unstructured process such as brainstorming, and by a structured process such as lateral thinking.[4]

The Creative Process:

The creative process was divided by " George Kneller in 1965" in five stages:

1. First insight: The creator must have his first insight: The apprehension of an idea to realized or a problem to be solved.
2. Preparation: A thought investigation of the possibilities of the germinal ideas.
3. Incubation: A time of non conscious activity in which the creator's idea go underground.
4. Illumination: Suddenly, the creator grasps the solution to this problem, The concept that focuses all his facts, The thought that completes the claim of ideas on which he is working.
5. Verification: Intellect and judgment must complete the work that imagination has begun.[5]

Alex Osborne (1963) has divided creativity up in more detailed list:

---

1 - http://www.edmontonsun.com/2013/02/06/proposed-edmonton-lrt-bridge-comes-with-a-possible-65-million-price-tag

2 - https://www.pinterest.com/pin/564779609495647730/

3 - http://tipter.com/trips/porto-and-vila-nova-de-gaia-walk-along-the-douro-river-west-of-ponte-luis-i

4 - http://www.businessdictionary.com/definition/creative-thinking.html

5 -Kneller, George: "The art and science of creativity" Holt. Rinehart and winstion publications- NewYork- USA-1965-p31.

Orientation, Preparation, Analysis, Hypothesis, Incubation, Synthesis and Verification.[1]

7-5-3- Characteristics of Creative Product:

As the creativity is generating new ideas, evaluating them effectively, taking action to turn them into new products and services. To classify any product as a creative product it should have many characteristics as:[2]

- Novelty: it means that it is the first time to see such a product.
- Appropriate: appropriate for two things: Utility and aesthetics
- Utility: appropriate for the requested function
- Aesthetics: Beauty is considered a key feature for innovative product.
- Validity: the created product could be executed not just a theoretical idea.[3]

7-5-4- Types of Creativity

There are several types of creativity, but most related creativity types to bridges are shown in figure (7-21):

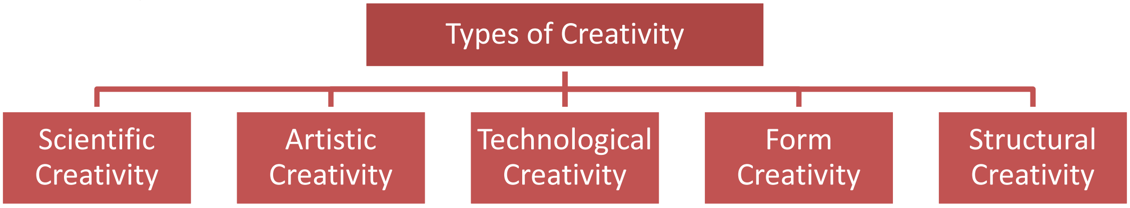


Figure 7-21: Types of creativity[4]

- Scientific creativity: A kind of intellectual trait or ability producing or
- potentially producing a certain product that is original and has social or personal
- value, designed with a certain purpose in mind, using given information.[5]
- Artistic creativity: is spirit and pictures of external things that have freedom understood by perceptive imagination and have reformed into beautiful artistic pieces of art to satisfy the concerns of the mind and feelings.
- Technological, Form and structural creativity will be discussed through this example.[6] figure (7-22)

The Iron Bridge is a bridge that crosses the River Severn in Shrop shire, England. Opened in 1781, it was the first arch bridge in the world to be made of cast iron, and was greatly celebrated after construction owing to its use of the new material.

Figure 7-22: An example of Creativity (The iron bridge)[7]

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1 - Osborn, .: "Applied imagination"- Scribners publications- New york- USA-1963- p117.

2 - http://lateralaction.com/articles/creative-entrepreneur/

٣ - فيصل محمود ابو العزم: " الابداع في تصميم المنشآت المدنية العمرانية" رسالة دكتوراة-قسم عمارة- كلية الفنون الجميلة- جامعة حلوان-٢٠٠٩ -ص ٢٤.

4 - By researcher

5 - Hu. Weiping : "A scientific creativity test for secondary school students"- paper- International Journal of Science Education-Taylor and Francis group- Vol 24-2002- p392.

٦ - علي عبد المعطي: "الابداع الني و تذوق الفنون الجميلة" -دار المعارفة الجامعية- مصر- ١٩٩٧ - ص ٧٩.

7 - http://whc.unesco.org/?cid=31andl=enandid_site=371andgallery=1andandindex=13andmaxrows=12.

Technological Creativity: Iron material was developed to be used in several bridges after this bridge.

Form Creativity: Slender structure elements were used instead of old heavy structure systems, and the outcome is an attractive shape. Grey color was used instead of common beige color these days.

Structural Creativity: steel girders are used to transfer loads for the first time instead of brick or stone arches commonly used in these era.

7-6- Conclusion

In this chapter, The effects of aesthetical considerations and creativity on bridge architectural design were studied . These considerations could be sorted under several points as Fundamentals of aesthetical design and Aesthetical qualities which discuss proportion, rhythm, order, etc.. and Aesthetic design objectives to aid designers in visualizing, evaluating, and articulating their designs which discuss functional clarity, scale and proportion, refining the form, etc....

Also Visual design elements as bridge colors and concrete quality were discussed, bridge perception by the viewer were studied under title bridge visual characteristics.

Finally creativity, Characteristics of creative products and types of creativity were studied.

7-6-1- Concluded Prerequisites

AP: Bridge Aesthetical Considerations Integration

AP: Fundamentals of Aesthetical Design and Aesthetical Qualities:

AP: Aesthetical Design Objectives.

AP: Bridge Visual Design Elements:

7-6-2- Concluded Credits

PR: Fundamentals of Aesthetical Design and Aesthetical Qualities:

Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

Introduction

- Introduction
- Research Problem Approach
- Research Problem
- Research Goal
- Research Hypotheses
- Research Methodology
- Research Scope
- Research Importance

Part 1 : Theoretical Study

Bridges And Sustainability Overview

- Chapter 1: Bridge's Art, Science and Construction Historical Development
- Chapter 2: Sustainable Bridges

Part 2: Analytical Study

Developing a Rating System for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages

- Chapter 3: Different Types of Bridges and Architecture
- Chapter 4: The Relationship between the Bridge and its Context
- Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form
- Chapter 6: Bridge's Different Parts and their Relation with Bridge's Shape and Form
- Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design
- **Chapter 8: Design Process of a Sustainable Bridge and Architect's Role**

SECTION 2

Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

- Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community

Part 3: Inductive Study

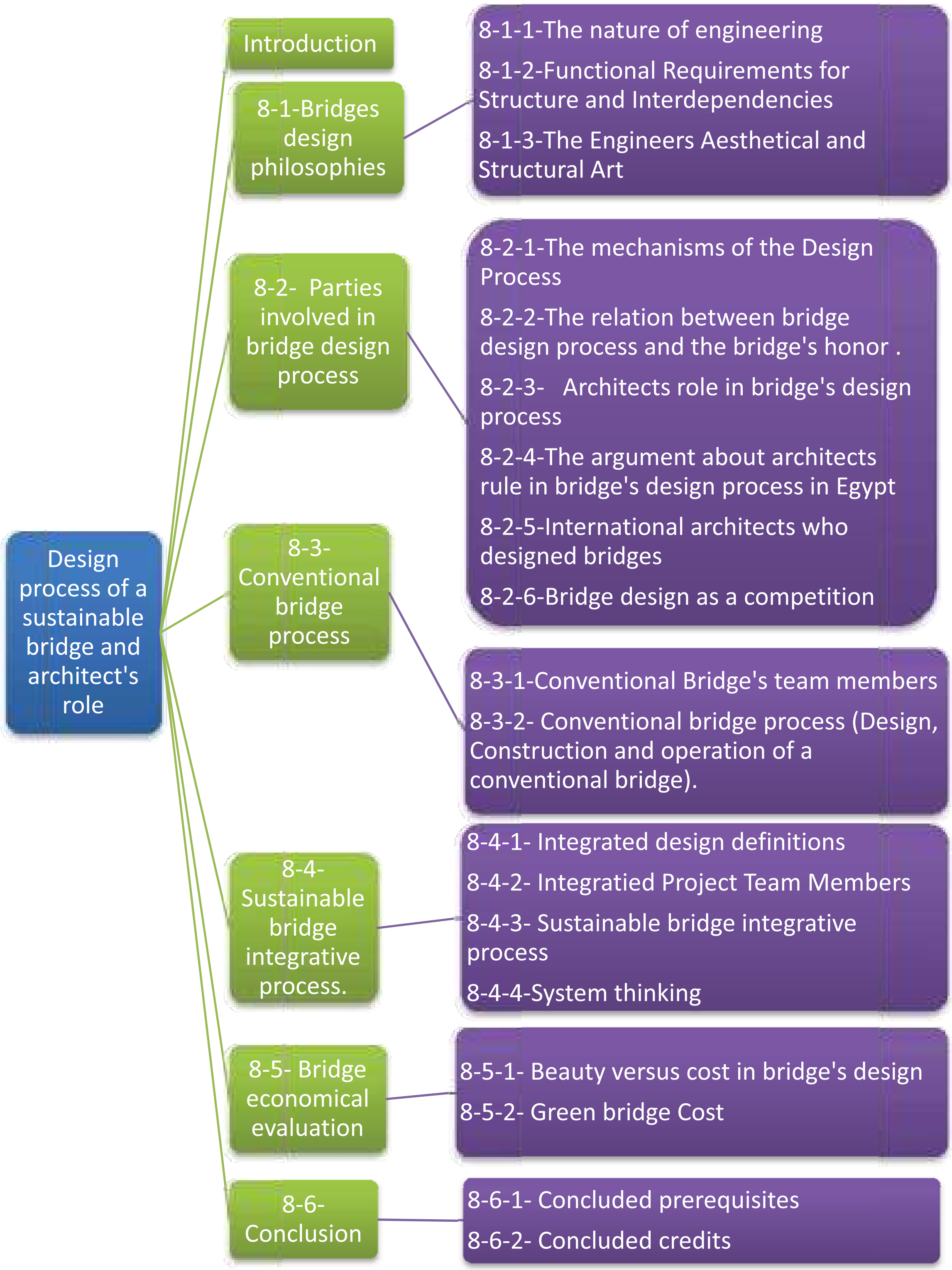
Developing an Egyptian Sustainable Bridge Rating System

- Chapter 10: Sustainability Assessment Concepts
- Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Chapter 12 : Conclusion and recommendations

Appendices

Chapter 8 : Design Process of a Sustainable Bridge and Architect's Role



- Design process of a sustainable bridge and architect's role
  - Introduction
  - 8-1-Bridges design philosophies
    - 8-1-1-The nature of engineering
    - 8-1-2-Functional Requirements for Structure and Interdependencies
    - 8-1-3-The Engineers Aesthetical and Structural Art
  - 8-2- Parties involved in bridge design process
    - 8-2-1-The mechanisms of the Design Process
    - 8-2-2-The relation between bridge design process and the bridge's honor .
    - 8-2-3- Architects role in bridge's design process
    - 8-2-4-The argument about architects rule in bridge's design process in Egypt
    - 8-2-5-International architects who designed bridges
    - 8-2-6-Bridge design as a competition
  - 8-3- Conventional bridge process
    - 8-3-1-Conventional Bridge's team members
    - 8-3-2- Conventional bridge process (Design, Construction and operation of a conventional bridge).
  - 8-4- Sustainable bridge integrative process.
    - 8-4-1- Integrated design definitions
    - 8-4-2- Integratied Project Team Members
    - 8-4-3- Sustainable bridge integrative process
    - 8-4-4-System thinking
  - 8-5- Bridge economical evaluation
    - 8-5-1- Beauty versus cost in bridge's design
    - 8-5-2- Green bridge Cost
  - 8-6- Conclusion
    - 8-6-1- Concluded prerequisites
    - 8-6-2- Concluded credits

Chapter 8 structure: Design Process of a Sustainable Bridge and Architect's Role

Chapter 8: Design Process of a Sustainable Bridge and Architect's Role

Introduction

Seeking a balance amongst practicality, long life, safety, serviceability, constructability and cost efficiency, has been the fundamental challenge of bridge design since the beginning of time.

New trends including the use of innovative construction materials and the detailed consideration of the environmental effects of bridge designs, have become more important. This process has been paralleled by extensive public involvement in the design process, consideration of environmental sustainability, and an increased focus on the way bridges connect with the people who use them. All these considerations must be taken on the design process also it will not be achieved unless an existence of strong collaboration between involved parties in bridge design, construction and maintenance.

8-1- Bridges Design Philosophies

In recent years it has become apparent that the real problems of bridge design include more than the structural or construction issues relating to the spanning of a gap. The public often expresses concern over the appearance of bridges, having recognized that a bridge's visual impact on its community is lasting and must receive serious consideration.[1]

8-1-1- The Nature of Engineering (The Three Dimensions of Structure)

Its first dimension is a scientific one. Each working structure or machine must perform in accordance with the laws of nature. In this sense, then, technology becomes part of the natural world. Methods of analysis useful to scientists for explaining natural phenomena are often useful to engineers for describing the behavior of their artificial creations. [2]

The second dimension of structure is a social one. In the past or in primitive places of the present, completed structures and machines might, in their most elementary forms, be merely the products of a single person; in the civilized modern world, however, these technological forms, although at their best designed by one person, are the products of a society. The public must support them, either through public taxation or through private commerce. Economy measures the social dimension of structure. Figure(8- 1)

The third dimension of technology is symbolic, this dimension that opens up the possibility for the new engineering to be structural art. Although there can be no measure for a symbolic dimension, we recognize a symbol by its elegance and its expressive power. Thus, the Sunshine Skyway has become a symbol of both Florida's Tampa Bay area and the best of late-20th-century technology. [3]

8-1-2- Functional Requirements for Structures and Interdependencies

Functionality, safety, economy, and aesthetics are the four main goals of all engineering efforts. Although technology has advanced considerably during the last century and provided engineers with new challenges in implementation, these four prime issues of engineering have always remained the same. On the other hand, the structure in service need not only be safe but also has to serve its function in an acceptable manner, as also determined by codes and regulations. Serviceability relates to issues such as durability of the structure against deterioration and to adequate stiffness, bridge must not develop

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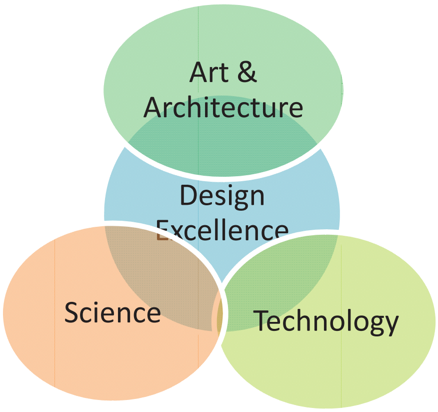
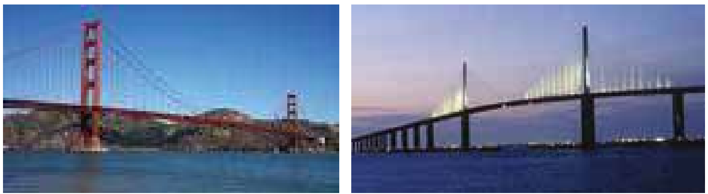
[1] -Frederick Gottemoller & David P.Billington: "Bridge Aesthetics - Structural Art." Bridge Engineering Handbook-2nd edition-p51

[2] -David P.Billington: "The tower and the bridge- The new art of structural engineering"- Princeton University press- New Jersey-USA- 1985- p 16.

[3] - Andrew W. Charleson : "Structure as architecture"- A source book for architects and structural engineers:- 2005-p 20 -22.

excessive yet structurally harmless deflections that would reduce the driving comfort. It must be wide enough for the traffic to safely pass it at an acceptable speed and should not have sudden changes in alignment. Also according to thesis main goal, Environmental sustainability should be added to the structures requirement as will be discussed.[1] Figure (8-2)





Golden gate bridge[3] The Sunshine Skyway.[4]

Three dimensions of structure[2] Craigellachie Bridge. Arch bridge at New jersey[5]

American bridges examples which achieved the three dimensions of structure(art, science and technology

Figure 8-1: The Three Dimensions of structure

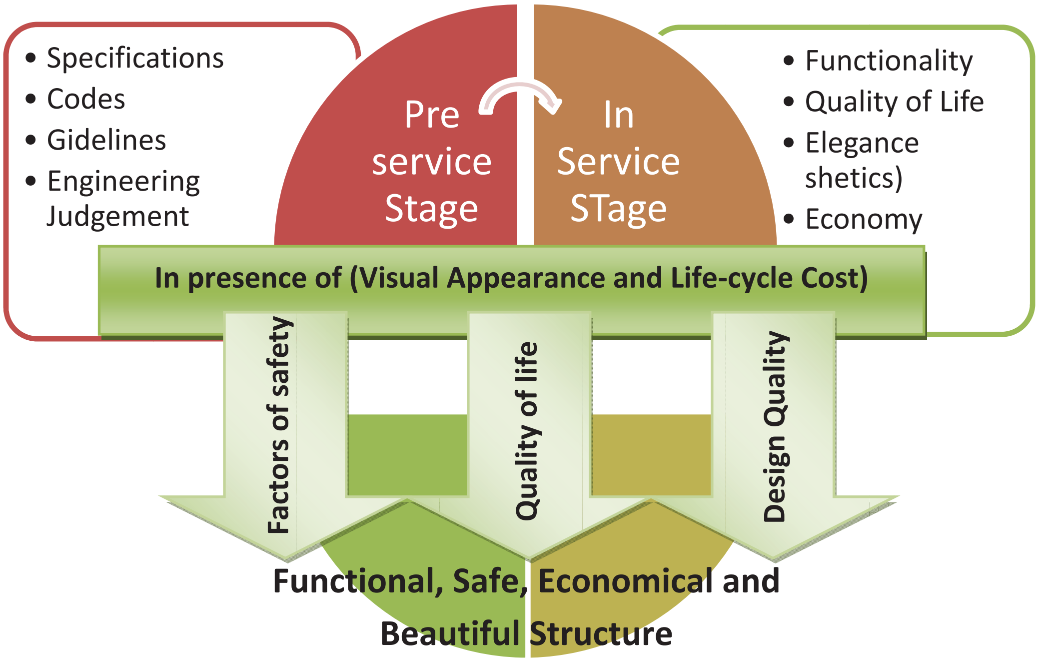


Figure 8-2: Functional Requirements for Structures and Interdependencies[6]

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[1] - O'Connor : "Design of Bridge Superstructures" A Wiley-Interscience Publication- John Wiley and Sons- - USA-1971-p90.

[2] - www.dot.state.mn.us

[3] - http://www.aviewoncities.com/sf/goldengatebridge.htm

[4] - http://www.skywaybridge.com/home.htm

[5] - http://www.panoramio.com/photo/29847487

[6] - Gunnar Lucko: "Means and Methods Analysis of a Cast-In-Place Balanced Cantilever Segmental Bridge"- Master of Science-Civil Engineering-Virginia Polytechnic Institute and State University- USA- 1999- p 99.

8-1-3- The Engineer’s Aesthetical and Structural Art

“Aesthetics” is a mysterious subject to most engineers, not lending itself to the engineer’s usual tools of analysis. Many contemporary engineers are not aware that a long line of engineers have made aesthetics an explicit element in their work, beginning with the British engineer Thomas Telford. In 1812, Telford defined structural art as the personal expression of structure within the disciplines of efficiency and economy. Efficiency here meant reliable performance with minimum materials, and economy implied the construction with competitive costs and restricted maintenance expenses. Within these bounds, structural artists find the means to choose forms and details that express their own vision.

A. Design philosophy

Characterizing for the engineering design process is that it is highly subjective and individual. It is not a predetermined path that is laid out in any professional code, the process is rather similar to the process that artists go through when creating a new piece of art. As there are many ways in which the process can be carried out, there will also be many possible outcomes. One specific optimum solution for a project can hardly exist, as every designer will acknowledge. Designing is a complex process consisting of several steps and consideration of a great amount of information is involved. Environmental, technical, and cultural factors give the frame in which the designer performs his work of structural design. In any case, engineering is always seeking for a good compromise between these many factors.[1]

B. The nature of engineering

Engineering can be placed between the three areas of science, technology, and arts since it incorporates features from all of them. With science it shares analytical and experimental approaches to investigate and better understand material properties and structural behavior, mostly based on models of the real structure. The knowledge extracted hereof is then used on the technological side in finding a practical way of putting the structure in place by technical means and methods.

More requirements than just pure functionality need to be fulfilled by the structure while being under construction and during its service life. An important consideration for highly visible structures as bridges is their appearance.

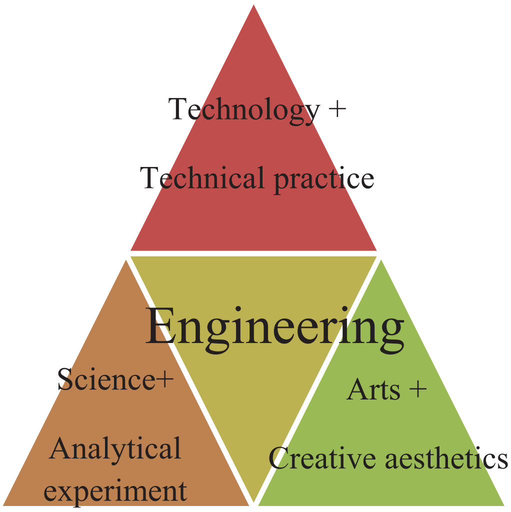

Figure 8-3: Relation of Engineering with Science, Arts, and Technology[2]

To design a truly satisfactory bridge, the engineer needs aesthetic sensibility as an artist does, too. Creativity is of prime importance to comply with the requirements on structures and make the whole project a successful undertaking. [3] Figure (8-3)

As shown in figure (8-4) Factors Influencing Design and Construction of bridges are overviewed.

1-Gunnar Lucko: "Means and Methods Analysis of a Cast-In-Place Balanced Cantilever Segmental Bridge"- Master of Science- Civil Engineering-Virginia Polytechnic Institute and State University- USA- 1999- p 95.

2 - Burke, M. P: "Achieving Excellence in Concrete Bridge Design"- Paper- Concrete International Conference-1995

3 - Same Previous Reference.

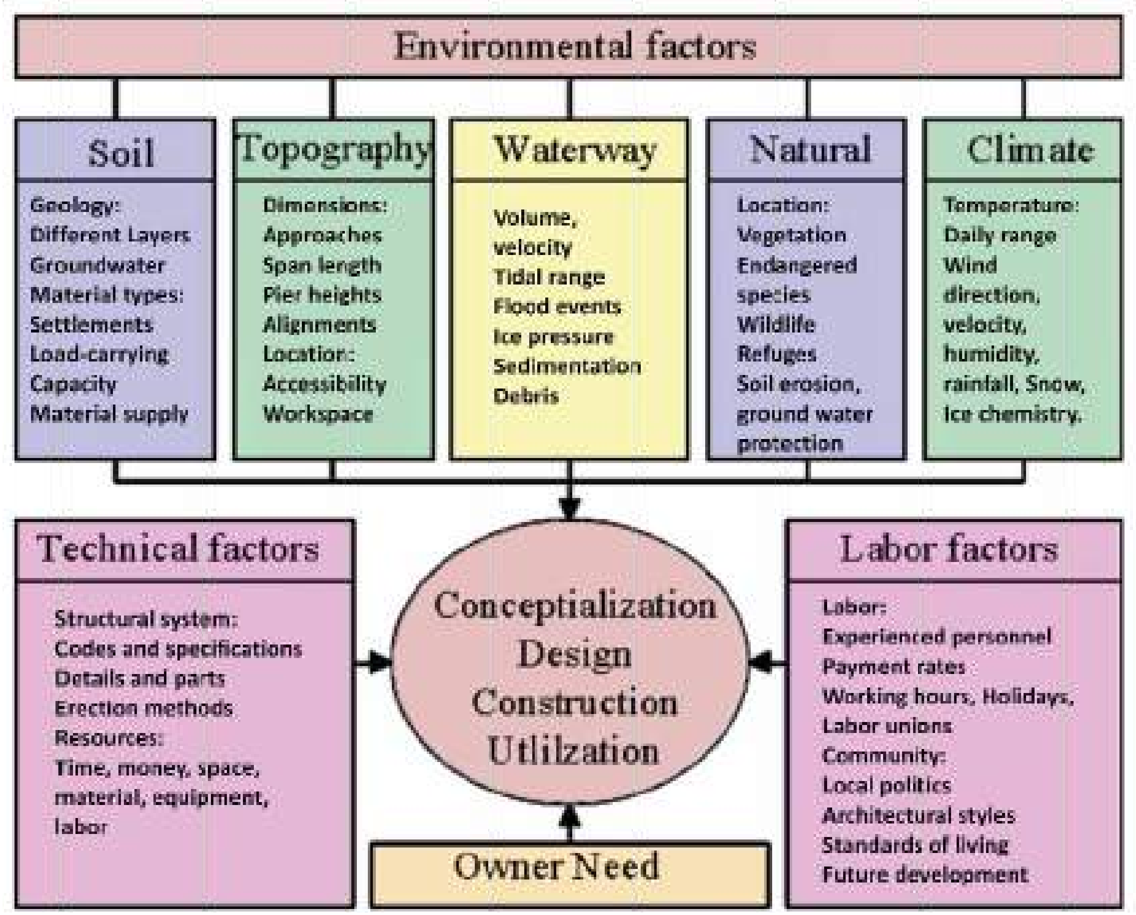

Figure 8-4: Factors Influencing Design and Construction of bridges [1]

8-2- Parties Involved in Bridge Design Process

8-2-1- The Mechanisms of the Design Process

According to the British experience of bridges design there are five mechanisms to design a bridge related to performance and final shape of bridge. these mechanisms proposals depends on how to choose designer, contractor through previous works evaluation or cost which are discussed at table (8-1).[2]

8-2-2-Relation between Bridge Design Process and the Bridge's Owner.

One of major factors on bridge design is the bridge owner, most of Egyptian bridges owner is the Egyptian government, the Government main goal is to construct the most safe bridge with the least cost, so a result is a lot of aesthetically poor prototypes of bridges which do not have any relation with architectural design, heritage or Egyptian culture were constructed.

8-2-3- Architects Role in Bridges Design Process

Bridge design is a very complicated process because of the involvement of a group of parties planners, architects, civil engineers, electrical engineers and contractors to construct the strong structure which achieves a certain goal with a pleasant shape.

There is a big argument about who is responsible of bridge's design architect or structure engineer ? the answer is that both architects and structural engineers have a

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[1] Gunnar Lucko: "Means and Methods Analysis of a Cast-In-Place Balanced Cantilever Segmental Bridge"- Master of Science-Civil Engineering-Virginia Polytechnic Institute and State University- USA- 1999- P120.

٢ - هاني محمد ابو العلا: دراسة تحليلية لعناصر تصميم و تشكيل الكباري - حالة القاهرة الكبري- رسالة ماجستير- قسم عماره- كلية الهندسه- جامعة القاهره- ٢٠٠٢- ص١٩-٢٤.

major rule in bridge's design process. without architects, the result will be aesthetically poor and non-functional bridge and without structural engineer, the result will be Non-safe bridge. So architects and structural engineers should be collaborative from the conceptual design stage of bridge to operation and maintenance stages. [1]

Table 8-1: The five Mechanisms of the Design Process [2]

	Mechanism	Advantages and Disadvantages		Reflection on bridge architecture
1	Design and supervision by the owner or a design consultant has been chosen according to previous work or good reputation. Consultant fees is a percentage from bridge cost. Choosing contractors by tenders presented.	The owner controls the design. The bridge's initial costs defined by proposed tenders.	The bridge's final cost is unknown until the final stage. Designers may be chosen according to financial reasons not excellence.	It was the traditional method in England to the mid of eighties. Not creative at all
2	Tenders presented from consultants. the most expert consultant and the least fees is chosen.	Least consultant fees	Least fees leads to least creativity	No creativity at all
3	According to announced specs brochure, many contractors present their design proposals and tenders by specific fees.	Accurate cost and time schedule more than the previous mechanisms	The owner has no control on design and the chosen design is the most easy to be constructed.	At least the design is acceptable.
4	Many contractors present tenders and proposals without cost, two or three proposals are chosen as acceptable designs, then the contractors present costs, fees and time schedule and the least price offer is accepted.	Accurate cost and time schedule more than the previous mechanisms	The best design is excluded if it was not the least price.	Appropriate solution to achieve good designs and the owner has the right to prevent any changes may effect on the design quality
5	Presented designs by a design competition.	New ideas and the owner may get new and valuable ideas	competitions waste long time	For design quality, the original designer is responsible till the final deliver.

As shown in figure (8-5) Golden gate bridge is considered as an example of the importance of Architects role in bridges design process. Golden gate bridge is a San Francisco landmark.

Sometimes but not always an architect is involved in the process. One-on-one replacements until now are usually done without an architect. At the moment many

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١ - هاني محمد ابو العلا: دراسة تحليليه لعناصر تصميم و تشكيل الكباري - حالة القاهره الكبري- رسالة ماجستير- قسم عماره- كلية الهندسه- جامعة القاهره- ٢٠٠٢- ص١٩-٢٤.

2 - "Bridge Design-" (The royal fine art commission seminar) -1993, p 11-25.

bridges are about to be replaced in clusters. Per cluster there is a design by an architect, this will create a unity in the city. These designs stay available to use for replacements of bridges later on. Only on special occasions an architect is involved for a one-on-one replacement, for example for a one-of-a-kind innovative type of bridge in the city center, which gives charisma to the city.[1]

Architect	Joseph B. Strauss
St. Eng	Leon Moisseiff
Location	San Francisco, California
Date	1933 to 1937
Structure	suspension bridge
Style	Structural Modern with some Art Deco details
note	

One of the longest bridges in the world, a powerful and elegant human structure in an equally beautiful natural location.

Figure 8-5: Example of the importance of Architects role in bridges design process (Golden gate bridge)[2]

8-2-4- The Argument about Architects Role in Bridge's Design Process in Egypt

In Egypt, architects are excluded from bridge design process and this design process is fully authorized to structural engineer. So, as a result most of Egyptian bridges did not achieve their original functions because of the lake of functional studies during design stage. Also, these bridges are aesthetically poor bridges which did not follow any architectural school. Figure (8-6).

Stanly bridge - Alexandria, one of bridges that architect has a major rule in the design process - Constructed by Arab contractors company with length 400 meters and width 21m[3]

El-Azhar bridge - Cairo presents the disappearance of the architect role in design process. The bridge in a historical area but it has no architectural character[4]

Figure 8-6: The Difference between Bridges designed with and without the Architects in Egypt.

8-2-5- International Architects who Designed Bridges:

As shown in table (8 - 2) the most important pieces of work made famous by global architects are overviewed.

8-2-6- Bridge Designs a Competition:

Recently, there are competitions all over the world for bridges designs, these

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[1] - Broek.Meike van den: "Design of a sustainable bridge"- (civil engineers manual)- Delfut university of technology- Netherlands- 2012- p 11-15.

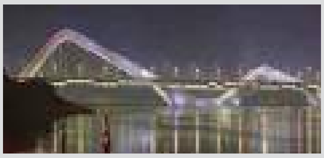
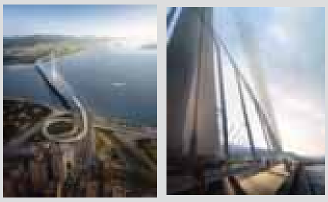
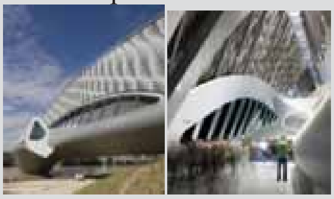
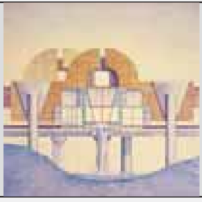
[2] - http://www.greatbuildings.com/buildings/Golden_Gate_Bridge.html

[3] - http://www.arabcont.com/projects/project-126.aspx

[4] - http://www.ahram.org.eg/Archive/2005/1/4/43128_13m.jpg

competitions are calling for architects from across the globe to come forward with exceptional and inspiring designs for a new bridges.[1] Figure (8-7)

Table 8-2: Bridges Examples by Global Architects

Zaha Hadid	The Sheikh Zayed Bridge in Abu Dhabi- UAE 2010 	Danjiang Bridge Competition in Taiwan 	Zaragoza Bridge Pavilion in Spain- 2008 
Frank Lloyd R.	The Butterfly Bay Bridge Frank Lloyd Wright and J.J. Polivka's design for the Bridge on display at SF Museum of Art, 1953.		
Michael Graves		Fargo-Moorhead Cultural Center Bridge- 1978 Michael Graves designed the Fargo-Moorhead Cultural Center and Bridge as a replacement for a vehicular traffic bridge spanning the Red River and physically connecting the states of Minnesota and North Dakota.	
Norman Foster	Millau bridge Millau,France 2004		
Santiago Calatrava	Santiago Calatrava is a structural engineer but he designs very aesthetically rich bridges.	Peace Bridge -Calgary- 2012 	Manrique Footbridge -Murcia- 1999 
	Pont de l'europe-Orléans- 1996 	Margaret Hunt Hill Bridge- Dallas-2012 	Campo Volantín Footbridge Bilbao- 1997 
http://www.dezeen.com/2011/11/03/sheikh-zayed-bridge-by-zaha-hadid-architects/ http://www.archdaily.com/771761/zaha-hadid-architects-win-danjiang-bridge-competition-in-taiwan	http://www.eichlernetwork.com/article/architecture-made-dreams http://www.calatrava.com/projects.html?project_type=bridges http://www.fosterandpartners.com/projects/millau-viaduct/	http://www.moma.org/collection/works/92?locale=en http://www.dezeen.com/2008/06/16/zaragoza-bridge-pavilion-by-zaha-hadid/	

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[1] - http://www.citylab.com/commute/2015/02/its-beginning-to-look-a-lot-like-london-has-a-fancy-bridge-fetish/385946/

bystrup + robin snell office proposal[1] and Other proposals for same competition

Nine Elms to Pimlico pedestrian Bridge Competition[2]

The 2022 Winter Olympics in Beijing. Bridge design[3]

Figure 8-7: Examples of Bridges designed through Competitions

8-3- Conventional Bridge Process

8-3-1- Conventional Bridge's Team Members:

In the conventional bridge process, specialists usually worked in isolation, focusing on their separate area of project expertise and interacting and working together only when absolutely needed. Figure (8-8). As shown in table (8-3) Team Members Responsibilities of Conventional Bridge Projects are discussed.

8-3-2- Conventional Bridge Process (Design, Construction and Operation of a Conventional Bridge).

In the traditional planning and design process, project systems were viewed as separate elements; site, structure, systems, use, and design decisions were each based on budget and/or schedule considerations. Such as design changes in order to meet a certain budget or follow an accelerated schedule did not take into account the final performance of the completed project.[4]

Initiation: A Requirements Plan is made with the requirements for the new bridge. These are technical requirements (length, capacity) but also easy to maintain is an

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1 - http://www.designboom.com/architecture/bystrup-robin-snell-architects-nine-elms-bridge-london-11-25-2015/

2 - http://www.e-architect.co.uk/london/nine-elms-pimlico-bridge-competition

3 - http://www.dezeen.com/2016/07/21/san-shan-bridge-penda-arup-beijing-winter-olympics-2022-china/

4 -"LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014, p13-15.

important requirement and the costs during the whole lifecycle are taken into account. The requirements used to be very restrictive, often even including material already. Nowadays the requirements are based on function and not specifying how this function has to be fulfilled (for example: make it possible for people to go to the other side of the water instead of place a bridge with steel beams, composite deck and wooden railings).[1]

- **Design phases of a conventional bridge**

Design program: This phase involves the development of the program (or brief) for the project. The bridge owner requirements are developed. Ideally, the design team will be involved with this phase, although this information is often developed by a separate specialist consultant

Conceptual Design. An outline of one or more proposed design solutions is developed during conceptual design. The primary purpose of conceptual design is to obtain buy-in from the client and design team on a solution that will be further pursued.

Schematic Design. This phase of design is essentially the proof-of concept phase. The project directions outlined in conceptual design are verified as being technically feasible, within budget, and able to deliver on design intents. Hopes meet reality during schematic design.

Design Development. Design development might be best described as the analysis and production phase of a project. Schematic design decisions are validated, systems are optimized, details are developed, specific equipment selected, and drawings and specifications initiated.[2]

Final design In the final design phase more details are added to the design. not much can be changed anymore to the core properties.

- **Construction Plans:**

Construction Documents. Construction documents are the construction drawings, specifications, and related documents that convey the aspirations of the owner and design team to the contractor. These become a major part of the contract between an owner and a contractor and are the basis for construction.

Statement of work: The writing of the statement of work is an important phase because now the responsibility goes from the design office to the contractor traditionally the procedure of contracting is based on lowest price**.**[3]

- **Construction Phase:**

Bidding process. Construction estimating consists of three parts: Quantity Survey, Price Extension and Bidding.

Construction. During construction, the architect, client, contractor team converts the construction documents to physical reality. Sometimes requests for substitutions occur during bidding and construction. Such requests should be carefully reviewed for their impact on design intent. Construction is not the time to abandon design intent and criteria.

Usage , Occupancy and end-of-life phases.

Usage and occupancy. On most projects, the design team has historically had little (if any) interaction with the occupied building. This, however, is a really bad idea for a green bridge. Many passive (or unconventional active) systems require informed operators (who are often the bridge users). Design team development of User's Manual.[1]

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1 - Broek.Meike van den: "Design of a sustainable bridge"- (civil engineers manual)- Delfut university of technology- Netherlands- 2012- p 11-15.

2 - Kwok. Alison and Grondzik.Walter: " The Green Studio Handbook Environmental strategies for schematic design"- Elsevier Inc publications- USA- 2007- p 2-3.

3 - Broek.Meike van den: "Design of a sustainable bridge"- (civil engineers manual)- Delfut university of technology- Netherlands- 2012- p 11-15.

End-of-life phase In the use phase the bridge is the overseer's responsibility. The overseer decides which maintenance is needed and when the bridge has to be replaced.

There are three main reasons to replace a bridge:

1. Technical value. The technical lifetime has exceeded, the bridge is not safe anymore and maintenance is no longer profitable.[2]
2. Use value. The functional requirements have changed, so the bridge is no longer sufficient, for example: the bridge has to be broader due to in increase in traffic load, or a separate road for bikers is needed. Because technically the bridge is still valuable, it would be desirable to be able to move the bridge to a nother location. The current bridges are not suitable for this.
3. This counts for the now existing wooden bridges. When the bridges were placed, financing was determined for the theoretical technical lifetime. For a wooden bridge this is 25 years. After this 25 years there is no financing for maintenance anymore causing the bridge to degrade fast and a replacement will be needed soon.

Besides these reasons politics play an important role. [3]

Table 8-3- Team Members Responsibilities of Conventional Bridge Projects (by researcher)

A	decision replacement - overseer decision new bridge	• Requirements • building code • low maintenance	• cheap lifecycle • fast building • fitting in environment
B	Design - Architect	• Aesthetics of bridge • Shape of bridge	• Approximately the material
C	preliminary design - Engineers	• Measuring • Environmental inspection • Global construction	• Approximately the size • Material
D	Final design - Engineers	• Exact calculation • Final construction	• Adjust Design to Environment • Costs
E	Statement of work - Engineers	• depends on the detail of the final design • Way of contracting	• Requirements concerning fencing trucks
F	Bridge - contractor	• Details as far as not in the statement of work	• Construction and completion • Check Engineering
G	Use / maintenance - overseer	• Inspection construction • Maintenance	• At end of life instruction for new one
H	End of life - overseer	• Instruction to engineering for replacement including demolition	

8-4- Sustainable Bridge Integrative Process.

To achieve bridge integrated process, there should be an integrative design team.

8-4-1-Integrated Design Definition

is a process that applies the skills and knowledge of different disciplines and the interactions of different building systems to synergistically produce a better, more

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1 - Kwok. Alison and Grondzik.Walter: " The Green Studio Handbook Environmental strategies for schematic design"- Elsevier Inc publications- USA- 2007- p 2-3.

2 - Astúa de Moraes, F: "The Integration of Sustainability in the Fuzzy Front End of Innovation within the context of SMEs- Paper- Transportation Unit Delft - Netherlands- 2010

3- Broek.Meike van den: "Design of a sustainable bridge"- (civil engineers manual)- Delfut university of technology- Netherlands- 2012- p 11-15.

efficient, and more responsible building occasionally for lower first cost, but more typically for lower life-cycle cost. Integrated design considers the relationships between elements that have often been seen as unrelated. The project phases of an integrative process are different than the conventional process, There are many criteria of integrative sustainable process. [1]

An integrative process is an approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, construction, and ongoing operations.

8-4-2-Integrative Project Team Members

During the integrative process team members work together and communicate throughout the process of the building's design and construction. Professions that traditionally may not communicate do so, and the process evaluates how design decisions and components will affect (or be affected by) other site decisions and components. The integrative process results in greater efficiencies, with some estimates showing that single projects employing integrative project teams can achieve savings of 2-10% in the cost of construction.(Figure 6-8) [2]

The integrative process requires collaboration among key stakeholders and design professionals from conception to completion. A stakeholder may be the building owner, a major tenant, or an end user customer, like a college student who uses a building for classes. Decision-making processes and complementary design principles should be established early in the planning, satisfying the goals of multiple stakeholders while still achieving the overall objectives of the project. Stakeholder meetings may be hard to schedule or may include stakeholders opposed to new technologies or green strategies, but even if a project encounters stakeholders who resist this new way of planning a project, they can still be beneficial. Project teams can work to alleviate these concerns, which will lead to a happier stakeholder group at the project's delivery.

The integrative process of a project is what contributes to reaching the sustainability goals established by the project team. Every aspect of building design is considered cohesively, beginning in the pre-design phase, and continuing to the end of the building's lifecycle. A fully integrative process is only possible with an integrative project team. Everyone involved in a building project has to be of like mind and work together to achieve the goals of an integrative process. This includes not only the people who are designing and constructing the building, but also the people that own and manage the building. Figure (8-8)

The success of a project team depends on:

- Setting specific goals that can be measured and validated.
- Developing strategies that will meet the goals and Proper planning.
- Creating processes that foster communication of all team members.
- All team members being on board with the goals and being held accountable for reaching those goals.
- Continuous monitoring of progress throughout the development process and ensuring goals are being achieved.[3]

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[1] - Kwok. Alison and Grondzik.Walter: " The Green Studio Handbook Environmental strategies for schematic design"- Elsevier Inc publications- USA- 2007- p17.

[2] - -"LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014, p 14

[3] - "LEED Refrence Guide for building Design and construction V4"- Accredited Professional (AP)- USA- 2013- p12.

Integrated Team Members

Conventional Team members

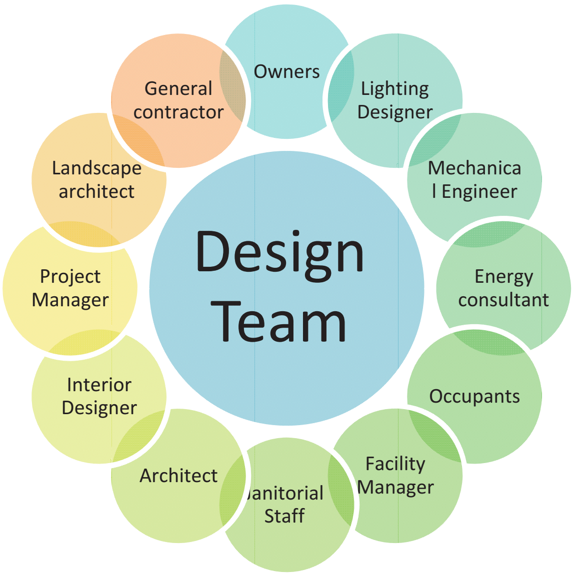

Figure 8-8: Conventional Bridge Team Members (Team Members Working in Isolation) Versus Integrated Team Members (Team members working Together) [1]

8-4-3- Sustainable Bridge Integrative Process

The project phases of an integrative process are different than the conventional process:

A. Pre-Design
B. Design
C. Construction plans
D. Construction phase
E. Commission the building
F. Occupancy and Re-commissioning
G. Building end of life reuse or demolition/recycle

Conventional project practice usually involves a linear project handoff from architect to engineer to contractor to occupant. By contrast, the integrative process front-loads the process, bringing the client, designers, engineers, contractors, occupants and operators together early in the design process to collaboratively establish project goals, strategize innovative approaches and resolve conflicts in advance. These disciplines then continue to work together in an iterative process toward the project's high performance goals. [2]

- **Pre-Design**

Start with a project vision, and then define green building goals while getting input from stakeholders. Next, create a team and identify a budget. Brainstorm about opportunities to gain incentives and cooperation with government organizations. Create a timeline and methodology then decide which measurement tools to be used to identify progress. Finally calculation of the return on investment and identifying risks.[3]

Probably the most critical phase of the integrative process is the pre-design phase. It is in this phase where the groundwork is laid for the entire project. The integrative process increases the level of effort during early design phases, resulting in reduced

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1 - "LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014,p 13

2 -LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014, p 13

3 - Kwok. Alison and Grondzik.Walter: " The Green Studio Handbook Environmental strategies for schematic design"- Elsevier Inc publications- USA- 2007- p18.

documentation time and improved cost control and budget management, all of which increase the likelihood that project goals, including schedule, life cycle costs, quality and sustainability will be achieved.

The pre-design phase will include several new steps:

i. Life Cycle Approach: This approach does not just focus on the delivery of the completed project but goes much further to the life of the project and eventual reuse of the project or its demolition and hopefully recycling.

ii. Developing a Clear Statement of the Project's Vision: Summarize what is trying to be accomplished.

iii. Defining the Green Goals of the Building: Goals should:
  - support the project vision
  - be clear so all team members can relate and understand
  - cover the entire project
  - be measurable (qualitatively or quantitatively)
  - be achievable in the space and time of the project (applicable)

iv. Setting Priorities: The team will need to prioritize the green building goals according to the budget or schedule.

v. Selection of the Project Team: The project team is a collaborative group involved in design and problem solving during all steps of the project. The project team will incorporate people and trades from every aspect of the building process and even the building's end users. Every member of the team will need to be committed to the green building goals and the project's vision. The team has to include some green building experts to help the project along if this is a new process and unchartered territory for a majority of the team members.

i. Assigning Small Task Groups

ii. Defining Green Building Budget Items Green building has a few added expenses compared to traditional building. In addition to the design fees and construction costs, project budget estimation has to include:
  - Life-cycle cost analysis;
  - Design and cost advice from experienced green building professionals;
  - Contingencies for research of unconventional techniques or materials.
  - Green building studies have shown the cost of green project can be the same as that of traditional project. Green projects have hard and soft costs just like traditional projects, but the project team also considers life cycle costs.
  - Reviewing Applicable Laws and Standards.[1]

- **Design**

In the design phase for the integrative process there will be some additional steps:

  - Develop a project budget that covers green building measures
  - Test and select green technologies and strategies
  - Check costs
  - Finalize design decisions

- **Construction plan and construction phase**

After the design phase, the remaining steps look quite similar to traditional design; Construction plans, Bidding process, Construction phase. The main differences is that in each of these steps the project team is always reviewing and verifying that green building goals are being met at every point in the process. Additionally the team is always working together and collaborating. [1]

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[1] - Davis Langdon: "The Cost of Green Revisited"- Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption-London- UK-2007- p12.

Also, construction plans through occupancy is quite different than conventional bridge construction plan during occupancy, as in sustainable bridge all sustainable goals should be taken into consideration to not effect on environment, economic, people social live and time schedule during construction through occupancy.

As shown in table (8-4) Classification of the building Rotation as a sustainable building using the integrated design process are studied according to project phases.

Table 8-4- Classification of the building Rotation addressing phases and transitions as a sustainable building using the integrated design process [2]

Major Phases	Major Categories	Sub Categories
Feasibility study pre-design	Owner and Designer	For Site Bio diversity - Land utilization - Alternate transportation - community development - energy saving For material Low environmental impact materials - reuse - recycle
Design	Site - bridge - Material - Energy	
Construction Management/ Planing	Pre construction	
Construction	Construction comissioning	
Operation and maintenance	Survice and support	
Decomissioning	Source and disposal	

As shown in Figure (8-9) description of each step in the design process, and the text below the pictures describes the main responsible person(s).Those stated in brackets should be available for consultancy, if needed, during the current design step.

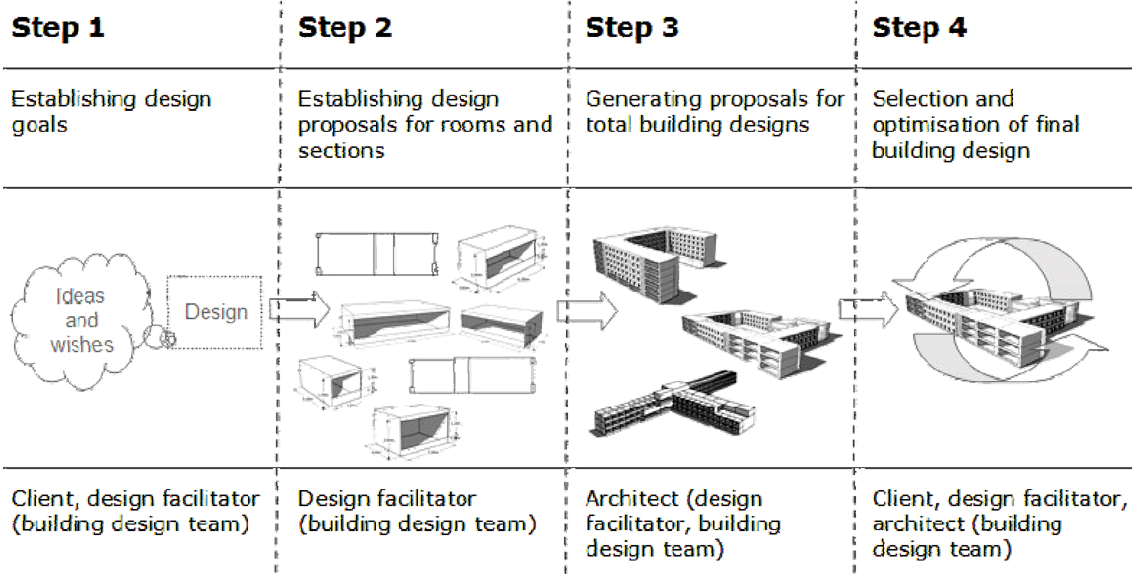

Figure 8-9- A simple description of the total integrated design process[3]

- **<u>Occupancy and commissioning</u>**

These newly added steps to the sustainable bridge is to guarantee the bridge success to achieve its sustainability goals. Also to make sure then the bridge achieved the designed function and accommodate added functions.

- **<u>Building end of life reuse or demolition/recycle</u>**

From bridge design stage, the designer should have an end-of life plan to reduce consumed materials and reuse, recycle the used bridge materials, also the bridge team

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1 - E. Long, R. K. Venables and J. D. Ferguson: "Sustainable Bridge Construction Through Innovative Advances"- paper- Queen's University Belfas- UK-2008

2 - Biswas. Tajin, Wang. Tsung Hsien and Krishnamurti. Ramesh,: " Framework for Sustainable Building Design"- Research Showcase -School of Architecture- College of Fine Arts- Carnegie Mellon University-2009- p 6

3 - Petersen.Steffen: "Method for integrated design of low energy buildings with high quality indoor environment"- paper- Department of Civil Engineering- Technical University of Denmark -Denmark-2007- p 4.

should have a best end of life plan to minimize bad effects on environment and have best economical income. As shown in table (8-5) and (8-6) : Green Construction management versus Conventional construction management are studied.

8-4-4-Systems Thinking

Systems thinking is similar to integrative design in that in systems thinking project teams are supposed to view each part of the project in relationship to other parts of the project.

In a sense a series of small systems are connected to become a more complex system in which the parts all affect each other. These nested systems can represent a building project, a community, or a city. Systems thinking tries to avoid designing a solution to one problem that results in a problem in another system.

To understand systems we must understand the types and how to affect them. There are different types of systems and the difference between them is determined by how the system relates to the world around it.

- Closed Systems - A set of actions/materials with a closed loop. For example, plants growing in a field, grow, produce oxygen, take in water, then die and decay which helps plants grow.

Closed systems can be linked so one system uses the byproducts of another. Closed systems are considered to be the most sustainable because there is no “waste” or final end product. The system continues on and on independently.

- Open Systems - Unlike closed systems, an open system is a system that constantly takes in items from outside the system, uses them and then released them as waste. This system has no feedback loop. Think of a normal home where groceries, products, or water come into the home, are used and then released as waste water or garbage.

Open systems are less sustainable because they require new inputs and create waste. Only if that waste can be used in another system can an open system become closer to a closed system and be more sustainable. An example of two open systems working to be sustainable could be a factory that produces a product, but gives scrap material to another factory to create a different product. Think of a lumber mill that creates 2x4s as one product and uses the wood chips and dust to create paper at another factory.

System thinking requires a project team to access how small systems work together in the larger system to be the most efficient as possible. For example a project team may assume that a recycling program is reducing waste, but if they are not careful to check the recycle removal process, the recycled material could be added to the waste stream. This can happen in office buildings when the cleaning staff is not properly trained on the recycling program. Sometimes recycled materials are sorted in the office but cleaning teams simply treat all recycle material and trash as waste. In this situation teams need feedback to see if the system is working properly.

There are Several Ways to Affect How a System Works.

- Leverage Points - leverage points are a point in a system where a small change can lead to large changes in results. This means small actions that can be free or a small cost might mean large savings or improvements on a project.
- Positive and Negative Feedback Loops - Both positive and negative feedback loops effect a system. Feedback is essentially information or results of the system. [1]

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[1] " Value Engineering: A Guidebook of Best Practices and Tools"- Department of defense- united states of America - p1-5.

Table 8-5: Green Construction management versus Conventional construction management (Feasibility and design stages)

Phase 1: Feasibility [1]		
	Conventional Construction	Sustainable Construction
Project need assessment	Define need based on market conditions, physical needs, or other narrow scopes.	Need definition, in addition to market conditions, physical needs, etc., includes environmental goal, LEED certification level, as well as the amount of capital investment toward green initiatives.
Project manager selection	Select a manager or hire one to serve as the project manager. Selection may or may not happen this early in the project.	Hire an experienced green building consultant/project manager who is familiar with the product type and market and has exposure to all phases of sustainable construction; a LEED accredited professional is optimal and strongly recommended.
Preliminary site analysis and plan	Develop a preliminary budget estimate based on past or benchmarked traditional projects; unit costs are applied to a preliminary scope of work.	Finalize economic and ecological goals based on cost/benefit analysis. Consider site characteristics and weigh building needs against ecological issues. The preliminary budget is aligned with the project's unique goals, and is often accomplished by creating a cost model that aligns resources with program goals to ensure project priorities are not mismatched to resources
Design charrette	Charrettes may or may not be implemented during a conventional project. They are often perceived as economic waste or schedule inhibitors.	Must include all key external stakeholders, including surrounding property owners and other community representatives. Diverse representation from the project team functions design, architecture, building contractor, environmental engineer, real estate consultant, etc. is optimal. The final report serves as one of the guiding documents for the design and construction process
Final site selection	Select site based on traditional pro forma with little stakeholder involvement.	Select site based on stakeholder involvement including community input, At this point, the construction team is in place the owner, the project manager, the architect and the Contractor and all parties have a stake in site selection.
Phase 2: Design[2]		
	Conventional Construction	Sustainable Construction
Initial budget and schedule	Budgets are typically developed by an architect based on a formula or unit costs, which can vary as much as 15% from actual costs. They are often created and expended with little consideration of future operating and maintenance costs	Complete preconstruction estimates with input from the builder, project manager, architect, and real estate consultant. Estimating costs associated with specialized areas like green-building products require experience. The budget may also include an emphasis on life cycle costing, shifting focus from short-term return on investment to long-term gains from operational savings.
Initial budget and schedule	At this point in the project, this is often the first time regulatory agencies have seen design concepts or site plans.	The zoning approval process can often go more smoothly after an inclusive charrette process has been completed because the project will be less likely to face community resistance.
Design team selection	Select the architect or general contractor depending on the type of contract.	Usually, the core design team has already been selected by this time. Additional experts for technical systems may be interviewed and selected.

1- Robichaud, Lauren Bradley and Anantatmula,Vittal: "Greening Project Management Practices for Sustainable Construction"- journal of management in engineering at asce / January 2011- http://ascelibrary.org/journal/jmenea-p52-53.

2 - Matthiessen.Lisa and Morris.Peter: " Costing Green (A Comprehensive Cost Database and Budgeting Methodology)" - Research to USGBC- 2004- at http://www.usgbc.org/Docs/Resources/Cost_of_Green_Full.pdf

Table 8-6: Green Construction management versus Conventional construction management (Construction and Implementation stages)

Phase 3: Construction and Implementation [1]		
	Conventional Construction	Sustainable Construction
Construction document development	Although the design is finalized by this time, often green initiatives are considered, causing rework.	Because the integrated team has participated in the planning and design process, construction documents can be developed more efficiently and with little design modifications.
Government permitting review	Plans are often reviewed for the first time for engineering compliance grading, erosion control, and storm water Standards, building codes, water and sewer systems, etc.	Government stakeholders are involved at earlier stages to ensure compliance with local, state and federal guidelines. The regulation of these important environment systems like wastewater and erosion control are significantly connected to LEED requirements.
Project bidding	“Hard bid” methods are most common, where the lowest bid cost is awarded and subcontracts are negotiated by the contractor on a closed-book basis.	Reed and Gordon 2000 recommend an “overhead/fee bid with an open-book subcontracting process” for green projects. Stipulations for minimum number of bids and cost savings allocations can also be included. “Open book” subcontracting allows the owner to have access to the estimates and pricing submitted by subcontractors.
Contracting	Traditional contracts like cost-plus percentage or cost-plus-fixed fee are applied. Sometimes work is further divided into multiple contracts, depending on uncertainty surrounding the project.	Integrated development requires a different kind of client/ architect and client/contractor. Contracts should include performance agreements, incentives, and bonuses for implementing sustainable practices and exceeding sustainability goals. Contracts should also include specific provisions for LEED points, Energy Star requirements, the use of recyclable materials, on-site recycling requirements, and agreements to return unused materials to vendors, among others.
Construction	Weekly site inspections are typically reported by architect or builder. There is little cross-communication among the site workforce, including subcontractors.	Launch construction with kickoff meeting that includes a sustainable education component for on-site construction personnel; monthly on-site meetings are required by entire site workforce and include periodic education and training sessions on green building. Sustainability requirements are reviewed with each subcontractor prior to commencing work
Inspections	Field changes caused by fragmentation in the owner-architect-builder relationship can require additional government inspections, which create cost and schedule inefficiencies.	At this point, government regulators are working as a partner in the project, as opposed to an outside influence. Less rework and field adjustments decrease the chances of having to request reinsertions.
certification	Typically not applicable. If the project is seeking certification, documentation can be difficult to assemble from multiple sources.	The ongoing efforts of the project manager, coupled with the benefits of an integrated team and specialized technology, can make compiling and submitting documentation more efficient for the project’s schedule and budget.

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1 - Robichaud, Lauren Bradley and Anantatmula,Vittal: "Greening Project Management Practices for Sustainable Construction"- journal of management in engineering at asce / January 2011- http://ascelibrary.org/journal/jmenea- p52-53.

- This feedback can encourage the system or stop it. A feedback loop ca not work unless information or results flow in the system.
- Negative Feedback Loop - a system where the output may signal the system to stop changing, i.e. a thermostat - at a certain point the temperature feedback will tell the system to cut off. The information of temperature must be made available to the thermostat for this system to work.
- Positive Feedback Loop – a system where energy is taken from the output of a system and reapplied to the input, or A produces more of B which in turn produces more of population growth – Adults make children whom in turn make more Adults.

As we see in the positive feedback example, this type of feedback actually increases the speed or encourages the system. Urban sprawl happens because people move to the suburbs, forcing cities to provide utilities and roads for the new communities. Once the new location is urbanized it can encourage people to move even further away since now what used to be far from the city is viewed as being quite close. [1]

8-5- Bridge Economical Evaluation

There are major points to estimate the bridge's cost with reference to value engineering.

A. Estimate the total cost and full consideration from the very first stages of the conceptual design.
B. Accurate estimating is difficult unless it based on considerable experience of similar work. it is reasonably easy to estimate material costs, but plant and man-hour content as well as overheads are often difficult to quantify without previous experience so it is important to use corporations hat previous experience in same projects.
C. It is consequently necessary to update estimates regularly as the design proceeds and details become better defined.
D. During the total period of design and construction, it should be objective to optimize costs in terms of utility. This is naturally part of the design process and requires knowledge, experience proficiency and the ability to innovate.
E. In order to make valid cost comparison between alternative solutions there are two important factors to guide any evaluation:
   - That comparison should be made on a common basis.
   - That significantly varying items should be identified so that they can be examine more closely where necessary.[2]

There are no permanent rules about the comparative costs of differing solutions for construction, because changes take place in the relative cost and availability of labor and materials from one time to another, and developments in constructional techniques or new materials can also make a significant impact. [3]

Cost savings can be achieved by several means, such as optimization of material use in the structure; partial prefabrication if cost for the pre-casting yard, transportation, and placement of the elements are less than cost for cast-in-place facilities on site and schedule optimization with respect to labor allocation.

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1 -" Value Engineering: A Guidebook of Best Practices and Tools"- Department of defense- united states of America- 2011 -p1-5.

٢- جورج صبحي راغب: "جماليات انشاء الكباري - رؤية خاصه من وجهة النظر المعمارية"- رسالة ماجستير- قسم عمارة- كلية الهندسة- جامعة القاهره- ١٩٩٨- ص٤٢٤-٤٣٨.

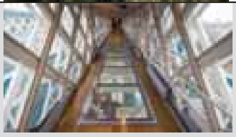
3 - "Value Engineering," -Office of Management and Budget- Circular No. A-131- May 21, 1993 (available at http://www.whitehouse.gov/omb/circulars/a131/a131.htm).

Use of local materials in bridge construction for earthwork, concrete aggregates, and perhaps stone masonry contributes both to aesthetics and cost cutting of the bridge project, as long distances of transportation are avoided.[1]

8-5-1- Beauty versus cost in bridge's design:

Good architect can work under any budget, and good design could be achieved with any budget. Frederick Gottemoeller[2] summarized his opinion concerning beauty versus cost case in some points at his book (Bridgescape - The art of designing bridges). Table (8-7)

Table 8-7: Frederic's opinion concerning beauty versus cost.[3]

Bridge form from its structure	The good design of bridge mostly related to its structure system, and the hierarchy of forces through different parts of bridge will be reflected on bridge's lines smoothing So the beautiful bridges is also economical bridges and not vice versa. [4] Example: Salginatobel Bridge 1929-1930 - Switzerland. Represent that beauty follow good structure[5]	
Cost versus public opinion	Bridge is considered one of the biggest objects affects on the visual image of the bridge's surrounding, especially if the bridge surrounding is a historical place. Bridge design should follow the architectural character of the historic place, also the bridge may have another function instead of carrying people from one place to another , to a land mark. Example: London Tower Bridge 1894 by John Wolfe Barry -and adding London tower bridge exhibition[6]	 
Cost versus Design	One of the ugly bridges designs arguments is the bridge's design process takes big time and this time consumes money but as a defense if the bridge designer provided with good computer skills a man power, the good design will be present with minimal cost and minimal time.	

8-5-2- Green Bridge Costs

Looking down the line to ultimately save dollars impacts the economic bottom line, because of the impact of rising fuel costs and energy costs. In the past when constructing a new building the long term costs were never taken into consideration.

Green building studies have shown the cost of building green can be the same as that of traditional building. Green building projects have hard and soft costs just like traditional building, but the project team also considers life cycle costs.

- life cycle cost (LCC)
- Life Cycle Assessment (LCA)

A life cycle cost differs from life-cycle assessment (LCA), which is the investigation and valuation of the environmental impacts of a given product or service caused or necessitated by its existence. LCA addresses environmental impacts while LCC addresses economic impacts. Used together LCC and LCA can provide the cost of material, environmental and energy analysis of a building, from construction to demolition, needed for decision making.

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1 - Gunnar Lucko: "Means and Methods Analysis of a Cast-In-Place Balanced Cantilever Segmental Bridge"- Master of Science-Civil Engineering-Virginia Polytechnic Institute and State University- USA- 1999- p 109-110.

2 - Frederick Gottemoeller has more than 42 years of experience in bridge and highway design, transportation planning, transportation management, and citizen participation. Using his skills as both an architect and engineer he creates transportation projects that incorporate the goals and aspirations of their communities while integrating both visual and technical criteria. His goal is to work with communities to develop transportation facilities that are as elegant as they are cost effective.(http://bridgescape.net/web/)

3 - Frederick Gottemoller: "Bridgescape – The art of designing bridges"- John Wily and Sons- Hoboken- New Jersey- United States of America- 2004- p30..

4 - David Blockley: "Bridges- The Science and Art of the World's Most Inspiring Structures"- OUP Oxford university press- UK-2010- p57.

5 - http://structurae.net/structures/salginatobel-bridge

6 - http://www.visitlondon.com/things-to-do/place/3901803-tower-bridge-exhibition

A life cycle cost differs from life-cycle analysis (LCA), which is the investigation and valuation of the environmental impacts of a given product or service caused or necessitated by its existence. LCA addresses environmental impacts while LCC addresses economic impacts. [1]

There are some definitions needed to best evaluate LCA and LCC:

Soft construction costs : Are costs not directly related to building, construction, etc. These include architectural, legal, financing, engineering fees and other costs incurred before and after construction. These costs make construction possible but are not directly related to building the project.

Hard costs: deal with fixed assets, They are directly related to improving real property.

Green building also differs from traditional design by considering the operating and maintenance costs of the building over its lifetime, not just the construction costs. A lifecycle cost analysis helps define the long-term operations and maintenance costs. For example, if Carpet A costs $10,000 but only lasts 5 years, and Carpet B costs $20,000 but lasts 20 years, Carpet B is a better choice because it has lower lifecycle costs. During the pre-design phase, project teams should set their goals for life cycle costs rather than "first cost" value-engineering. [2] The use of a well-defined cost-benefit analysis could also be used to demonstrate the benefits of going green.

Table 8-8- The goals and benefits of green construction [3]

Planet/Environmental	Profit/Economic	People/Social
• Reduce energy consumption 50% • Reduce greenhouse gas emissions 50% • Reduce water usage 50% • Reduce waste produced during construction and during operations • Protect biodiversity	• Reduce energy costs 50% • Reduce water costs 50% • Reduce maintenance costs • Increase productivity • Owners payback targets are <10 years • Reduce risk of sick building-related issues	• Be a good corporate citizen • Provide a healthy work environment • Reduce greenhouse gas emissions • Maximize utilization of resources • Reduce overall carbon footprint

In table (8-8), the goals and benefits of green construction is discussed from the planet‘s (environmental), profit (economic), and social point of view with the possible constrains faced by each party.

The main structure of eco-cost as a single indicator of LCA will be shown at figure 8-16

Early in the design process, little is fixed and no big investments are made, therefore there is still a lot of freedom to change the design. A downside of this is that there is not much information available about the design. On the other hand, at the end of the design process the total design is already fixed, a lot of time and money is spend, and to change things is costly. There is however a lot of information available about the design. This dilemma is made visible. Figure (8-10).

To make a full LCA much information is needed about the design. For that reason a LCA is made at the end of the design process, when the design is finished. However, when the design does not score well on the LCA, not much can be improved.

To make really innovative improvements it is needed to take sustainability into account during the whole design process. [1]

---

[1] - Fosu.Richelle: "Investigating the Effect Specific Credits of the LEED Rating System have on the Energy Performance of an Existing Building" -Graduate Thesis-Department of Computer Graphics Technology -Purdue University- India-2013- p11.

[2]- "LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014- p 24.

[3] - Paumgartten, P: " The business case for high-performance green buildings- Sustainability and its financial impact"- Journal of Facilities Management-2003

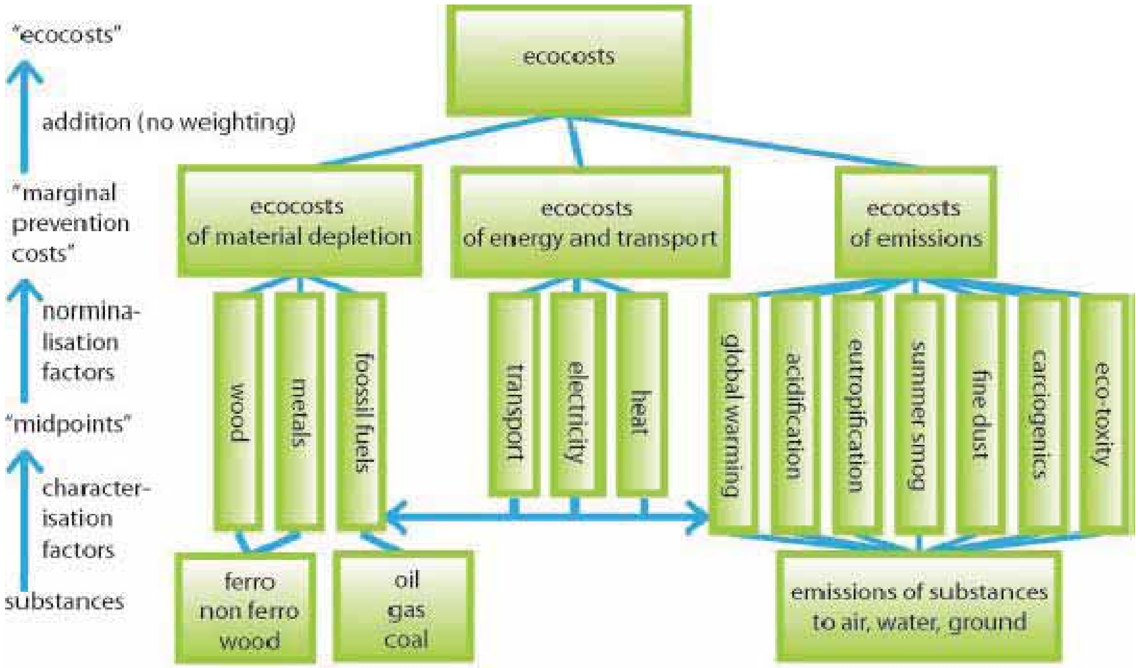

Figure 8-10- The main structure of eco-costs as a single indicator of LCA [2]

8-6- Conclusion

Conventional bridges design process usually involves a linear project handoff from architect to engineer to contractor to users. By contrast, the integrative design process front-loads the process, bringing the client, designers, engineers, contractors, occupants and operators together early in the design process to collaboratively establish project goals, strategies innovative approaches and resolve conflicts in advance.

These disciplines then continue to work together in an integrative process toward the project's high performance goals. As shown in table (8-9) Summary of how process and bridge strategies could be compared. Also, as shown at figure (8-11) Organizational chart of a design team of bridges are illustrated.

---

1 - Vivan Adel Younan: "Developing a green building rating system for Egypt"- Master Thesis- School of Science and Engineering- The American University in Cairo- Egypt- 2011- p 11-12.

2 - Vogtländer, J.G: "A practical guide to LCA for students, designers and business managers- cradle-to-grave and cradle to cradle- - Delft University of Technology - Netherlands- 2010- p 30.

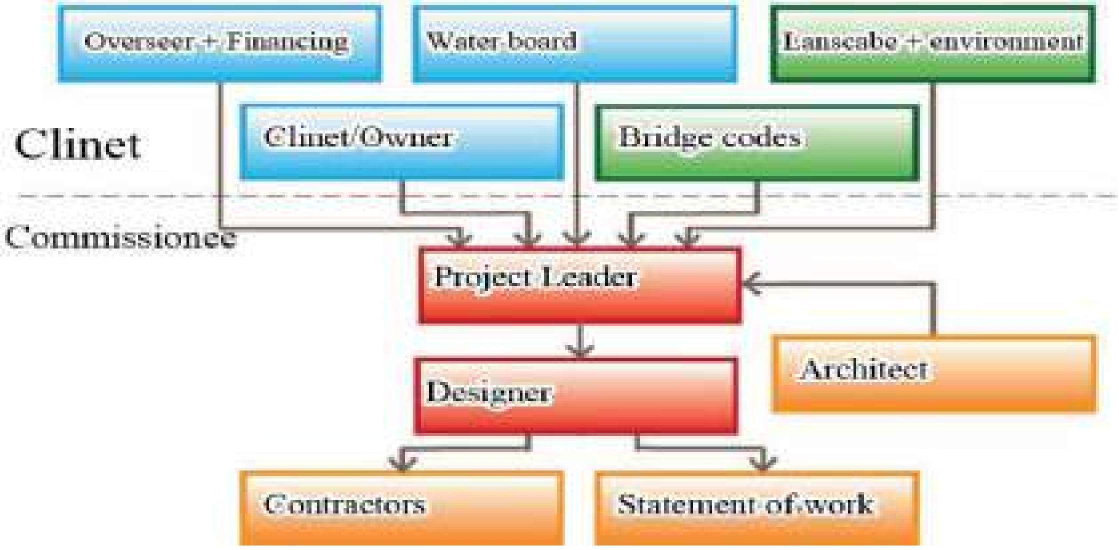

Figure 8-11- Concluded Organizational chart of a design team of bridges [1]

Table 8-9- Summary of how process and bridge or building strategies be compared[2]

	Traditional project delivery	Integrative process
Terms	Hierarchal, working independently only as needed	Collaborative, Integrative, Assembled as early as possible before any designing
Process-schedule	Linear, working in silos	Concurrent, shared information, iterative
Risk	Individual risk	Shared equally
Compensation	Individually based	Based on team success
Communication	Paper based	Digital and virtual, use of computer model
Materials-Strategies	Least expensive to meet code	Life cycle analysis, cost
Project phases	Design -occupancy	Pre design phase, green building goals, review.

8-6-1- Concluded prerequisites

AP: Bridge Design / Construction Proposals
AP: Integrated Team Members and Architect Role
AP: Bridge Integrated Costs

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[1] - Broek.Meike van den: "Design of a sustainable bridge"- (civil engineers manual)- Delfut university of technology- Netherlands- 2012- p 14.

[2] - "LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014- p24

Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

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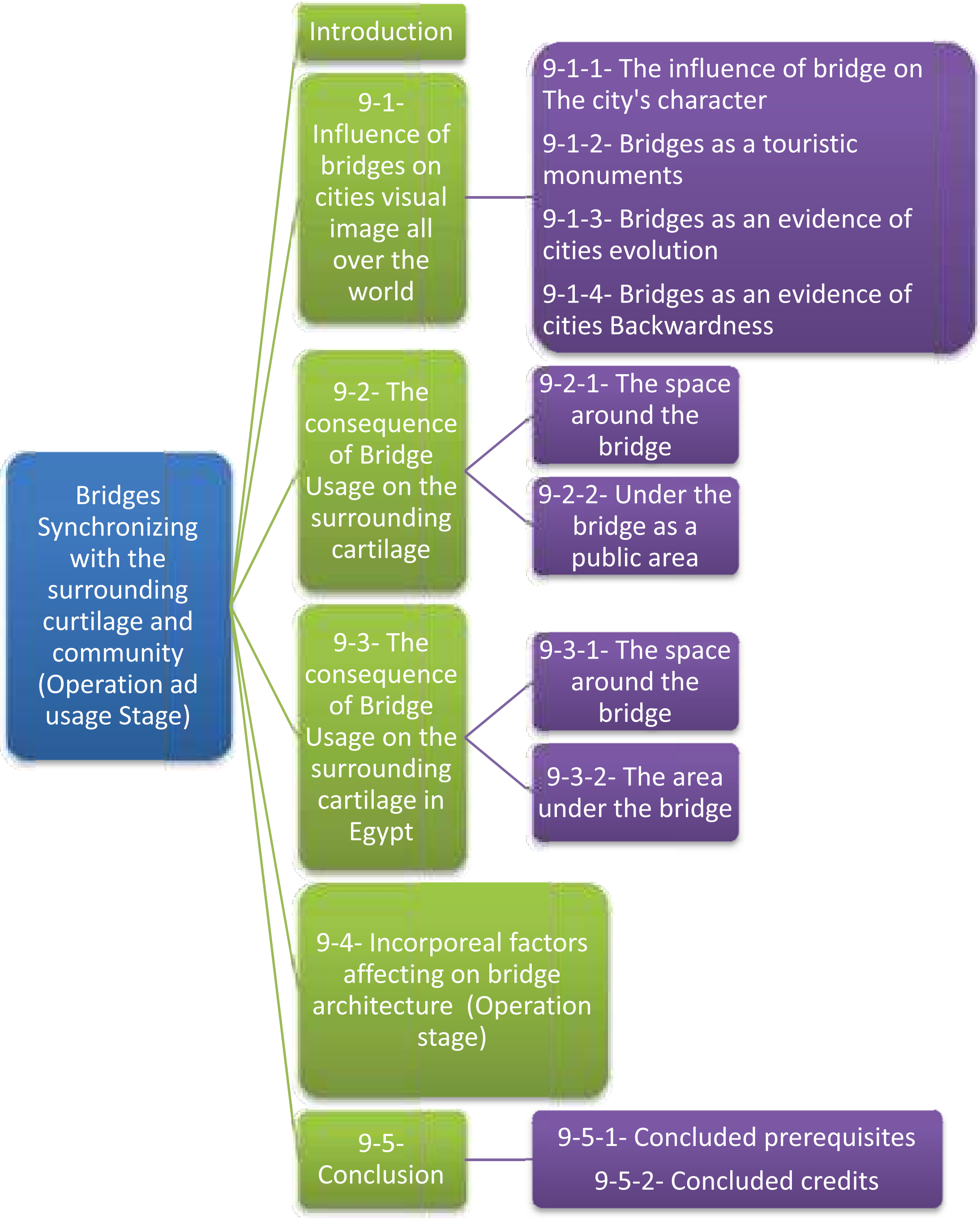
Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

Chapter 9 : Bridges Synchronizing with the Surrounding Curtilage and Community (Operation and Usage Stage)



Chapter 9 structure: Bridges Synchronizing with the Surrounding Curtilage and Community (Operation and Usage Stage)

Chapter 9: Bridges Synchronizing with the Surrounding Curtilage and Community (Operation and Usage Stage)

Introduction

The curtilage of a bridge is the space around and under the bridge. It is integral to the visual success of a structure, just as a garden is integral to a house. It is distinct from the context of the bridge in that it should be considered as part of the project, rather than the existing environment. The design of the bridge curtilage is integral to the success of the bridge as a whole.

9-1- Bridges Influence on Cities Visual Image all Over the World

As shown in table (9-1), Bridges influenced on cities visual image (The influence of bridge on The city's character and Bridges as a touristic monuments). and table (9-2) Bridges influenced on cities visual image (Bridges as an evidence of cities evolution or Backwardness)Positive and negative effects of bridge on the surrounding curtilage and community are discussed.

9-2- The Consequence of Bridge Usage on the Surrounding Cartilage

Bridge curtilage could be divided to:

- The space around the bridge
- The area under the bridge

9-2-1- The Space around the bridge

The space around the bridge, as an interface between the bridge and its context, serves several aesthetic functions.

- It is the setting in views to the bridge.
- It is the foreground in views from the bridge.
- It provides an opportunity to frame and contrast the bridge.

Generally there should be continuity between the existing landscape and the space around the bridge. Where possible the space should be designed so that it complements the adjacent landscape character.[1]

9-2-1- Under the bridge as a public area

Area a bridge must be considered in the concept design phase of the bridge and integrated into the design of the whole structure. Figure (9-1)

If these spaces are not considered then bridge aesthetics will be impaired by the presence of dead or dying plants and ‘eroded rubbish strewn’ surfaces. Also valuable space will be lost. There are range of strategies in dealing with this space which includes the following:

- Consider the surface treatment of the space. These spaces tend to be very dry and if in deep shade plants are unlikely to survive. Where plants are used they should be located to the outside of the space and irrigation may be required. Generally only the most shade and water tolerant plants should be used
- Consider the function of the space. (Footpath and cycle way networks can benefit from the additional connectivity the space under a bridge provides.
- With high urban bridges the potential use of this space for future development should be considered. It may be that the bridge aesthetics would benefit from undercroft development.

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[1] - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 66-69.

Table 9-1: Bridges influenced on cities visual image (The influence of bridge on The city's character and Bridges as a touristic monuments).

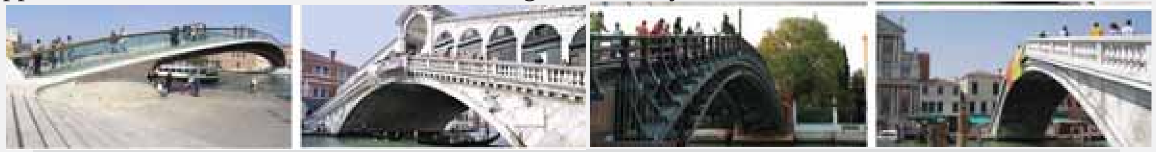
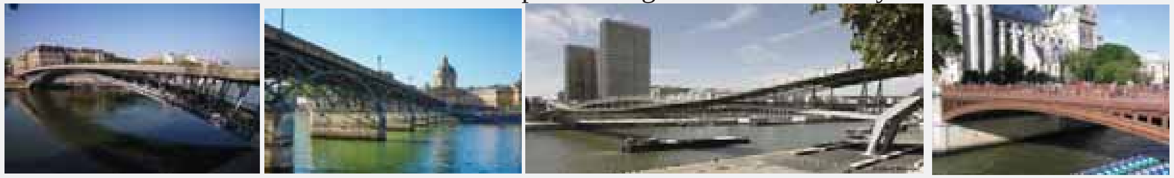
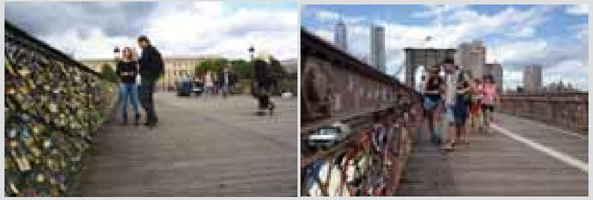
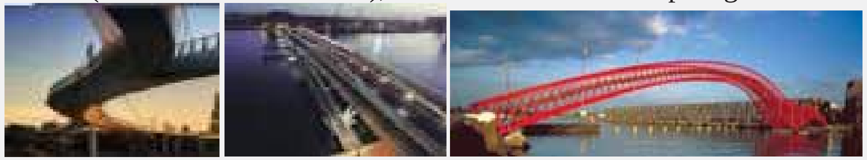
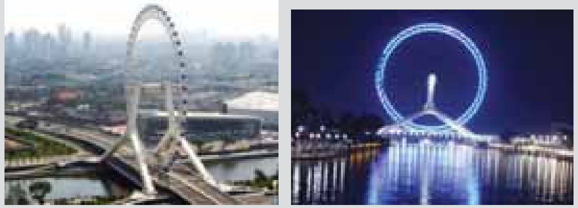
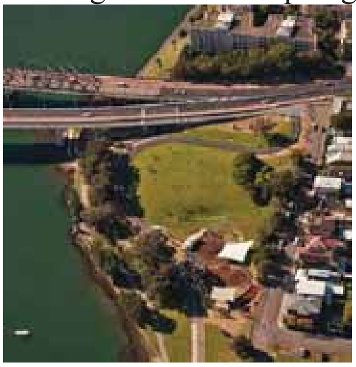
9-1-1-The influence of bridge on The city's character	9-1-2-Bridges as a touristic monuments
Venice Bridges: Venice canal is at in the shape of an ‘s’ in the whole city, there are only four opportunities to cross the Canal Grande throughout the city, which are all worth to be visited.  From left: Ponte di Calatrava, Ponte di Rialto. Ponte dell'Accademia. and Ponte degli Scalzi.	**Galata Bridge:** Galata Bridge is the heart of Istanbul, spanning the Golden Horn from Karaköy on the north to Old Istanbul, built in 1992 The lower level is consists of some restaurants. 
Paris Bridges: Below is a list of some of the bridges that cross the Seine river in central Paris. You can move the mouse over the map on the right to see where they are located.  From left Passerelle Léopold-Sédar-Senghor Bridge, Passerelle des Arts (aka Pont des Arts) bridge, Passerelle Simone de Beauvoir bridge and Pont au Double bridge.	**Love-Lock Bridge:** it has become a tradition of lovers in Paris, France, both French and foreign, to attach metal locks to the bridge to seal their love. 
Amsterdam Bridges: Amsterdam has so many picturesque bridges. With more than 1,200 bridges, Some are historic (the oldest is from 1648), and several are awe-inspiring feats of engineering.  From lift nuncio bridge , jan schaefer bridge and borneo-sporenburg bridge	**Blackfriars Bridge:** Built in 1869 in London, Blackfriars Bridge gained notoriety in 1982 when Vatican bank Chairman Robert Calvi was found hanging from it. 
London Bridges: Many of London’s iconic bridges along Thames river give unique views and access to some of the city’s most popular sights, tours and events. 	**Albert Bridge:** is a road bridge crossing the Thames in West London, It is one of only two road bridges in London to never have been replaced 
http://www.visitlondon.com/things-to-do/sightseeing/london-attraction/bridge http://www.iamsterdam.com/en/visiting/what-to-do/architecture/bridges-of-amsterdam http://www.visitlondon.com/things-to-do/sightseeing/london-attraction/bridge http://blog.smartfares.com/tag/canopy-walk-in-ghana	http://www.reidsitaly.com/destinations/veneto/venice/sights/bridges.html http://www.davestravelcorner.com/journals/destination-europe/the-4-bridges-crossing-the-canal-grande-in-venice/ http://www.aviewoncities.com/paris/bridges.htm

Table 9-2: Bridges influenced on cities visual image (Bridges as an evidence of cities evolution or Backwardness)

9-1-3-Bridges as an evidence of cities evolution	9-1-4-Bridges as an evidence of cities Backwardness	
	Global bridges	**Egyptian bridges**
One of evidence of cities evolution is bridges construction as a symbol of technology and transportation solution, Also because bridges are considered one of the major landmarks in modern cities. **Abu Dhabi : Sheikh Zayed bridge by Zaha Hadid 2010, UAE**  **New bridge to boost Bahrain trade links with Saudi Arabia, KSA**  **Tianjin Eye Bridge, China** 	Students Crossing a damaged suspension bridge, Lebak, Indonesia  Kids traveling through the forest across a tree Root Bridge, India  Crossing a broken bridge on the snow to get to school in Dujiangyan, Sichuan Province, China  People walking on a tightrope 30 feet above a river, Padang, Sumatra, Indonesia 	The Egyptian ring road and Pedestrian bridge), and using it by pedestrians, using the Area under the bridge as Garbage dump and Some Kids are crossing a water way From school Using weak piece of wood (by researcher). 
http://www.zaha-hadid.com/architecture/sheikh-zayed-bridge/ http://www.english.globalarabnetwork.com/2014102213427/Economics/new-bridge-to-boost-bahrain-trade-links-with-saudi-arabia.html		http://www.boredpanda.com/dangerous-journey-to-school/ http://www.listofwonders.com/top-10-worlds-most-beautiful-modern-bridges

- Where the underside of the bridge is visible, consideration should be given to the design of the soffit. Clean uncluttered surfaces, neat connections and simple layout of girders will help to give a suitable appearance.

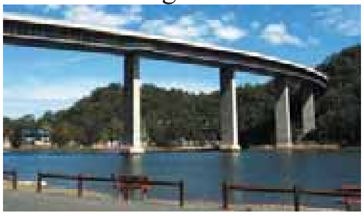


The design of the new Iron Cove Bridge considered the local setting. A bridge curtilage was created that respects King Georges Park in Rozelle and the Bay Run.

The timber boardwalk under the triple bridge over Brunswick River traverses an area of relocated mangroves, preserved sea grasses and rocky outcrops with views towards the ocean and surrounding mountains.

In this example in Canberra the stabbed girder creates a smooth lightly textured surface. LED lighting enhances the effect and also identifies the bridge.

Interchange on the Pacific Highway at Ballina. The bridge design and the setting were a single composition



The curtilage of the bridge over the Woronora River provides a significant public domain, sense creation of local park.

fauna corridors was created and help reconnect habitats. under Bonville Bypass bridge included many fauna connections,

Figure 9-1: Examples of Bridges Curtilage in Australia.[1]

public space definition: A place, in wide definition, for everybody to enjoy their coexistence and represent their collectivity and common interest without drowning or disaggregating their diversity.[2]

"Ashihara" divided the public spaces to positive spaces and Negative spaces according to users ejection and attraction

- Positive spaces: relatively enclosed, outdoor space has a definite and distinctive shape. it is conceivable, can be measured and has a definite boundaries. We could imagine it being filled with water, which subsequently runs out relatively slowly. it is discontinuous (in principle), closed, static but serial in composition. its shape is as important as that of the buildings surrounding it.
- Negative space is shapeless, e.g. the amorphous residue left over around buildings which are generally viewed as positive. It is 'inconceivable' continuous and lacking in perceivable edges or form. It is difficult to imagine such space being filled with water because -quite simply - it is difficult to conceive of the space.[3]

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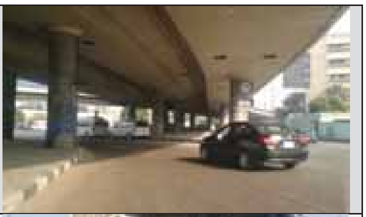
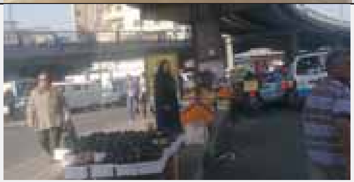
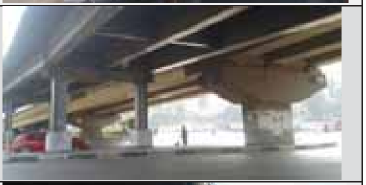
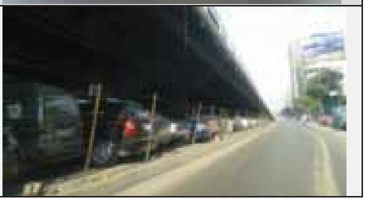
[1] -"Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 66-69.

[2] - http://www.urbandictionary.com/define.php?term=public+space

[3] - Matthew Carmona, Tim Heath,Toner Oc and Steven Tiesdell: "Public places - Urban spaces"- The Dimensions of Urban Design Scribe Design- Gillingham- Kent- UK -2003- p 138.

Conditions to format public spaces: As shown in Table (9-3) Main conditions for formatting public spaces, with examples from Egypt are discussed.

Table 9-3: Main conditions for formatting public spaces, with examples from Egypt.

Available Space	The existance of an outdoor or semi-outdoor space , this space may be rectangular or circle space or has no defined form . Space under the bridge is an available public space, so people illegal using it for different activities	
Flexibility	The space could be converted to contain any new activity or to be connected with an existing activity. The area under the bridge, is a flexible area which could be formed to harmonize the requested activity.	
Connectivit y	A srong relationship between the space and streets or main axes for pedestrians and vehicles. Most of areas under bridges are the perfect connected areas to main axes for pedestrians.	
Activities	The existance of the activity it self, like commerical activities, car parkings or any other activity. The activity is determined by the bridge location and the surrounding activities or by the need of certain activity.	

9-3- The consequence of Bridge Usage on the surrounding cartilage in Egypt

9-3-1- The space around the bridge

Usually, Spaces around Egyptian bridges are previously developed, because most of Egyptian bridges are located to solve traffic problems, so the space around the bridge is mostly another roads, river or any previously mentioned obstacles. figure (9-4)

El-Sayeda Eisha bridge - Cairo was constructed to solve traffic jam at El-Sayeda Eisha square[1]

El-Mosher Tantawy bridge at Fifth settlement - Cairo - Was constructed to solve the traffic conjunction between ring road and ninety road [2]

El-Maledk El-Saleh bridge- Cairo- was constructed to solve the traffic jam between Maadi cornice and El-manyal - Salah Salem directions[3]

Figure 9-2: Egyptian Examples Showing Previously Constructed bridge's surroundings

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[1] - http://media.linkonlineworld.com/img/Large/.jpg

[2] - http://www.n-cairo.com/ar/?p=3244

[3] - http://gallery.egyroom.com/cairo/cairo98.html

9-3-2- The Area under the Bridge

There are some factors affecting the area under the bridge usage, but before studying these factors, some definitions should be studied. Area under the bridge is a public space. Public space is considered one of the major affects on the urban spaces because it considered the small unit which forms the urban spaces. The form of large urban spaces like expressways and downtowns as well as small urban spaces like streets and neighborhoods, plays a key role in how a city works and how it is experienced.[1] Figure (9-3).

Elsaawy Cultural wheel as an example of area under the bridge usage as a public space - Under 15th may bridge - Giza by researcher

The sensitive use of sandstone paving and bollards, at the heritage abutments under the new Iron Cove Bridge in Rozelle, has created a place to view the evolution of harbour crossings at this point – from early ferries to timber truss to Art Deco steel truss to concrete incrementally launched girder.

Figure 9-3- Examples of Under the bridge as a public area[2]

9-4- Incorporeal Factors Affecting on Usage of the Bridge Surrounding Curtilage in Egypt

As shown in table (9-4), The Incorporeal factors affecting on bridge usage on the surrounding curtilage in Egypt are reviewed.

9-5- Conclusion

In this chapter, the effect of bridge on the surrounding curtilage was discussed, Bridge curtilage means area under and around the bridge which is affected by bridge construction and usage. Also the Influence of bridges on cities visual image all over the world, this influence may affect on bridge character, evidence of cities evolution or deterioration, Also bridge may be considered as a touristic attraction.

Bridge curtilage examples from Egypt and all over the world were studied to evaluate Bridges Synchronizing with surrounding curtilage and community.

9-5-1- Concluded Prerequisites

AP: Bridge Curtilage Development Report:

9-5-2- Concluded Credits

CR: Influence of Bridges on Cities Visual Image

CR: The Space around the Bridge

CR: The Area under the Bridge

CR: Bridges Maintenance from Architectural Perspective

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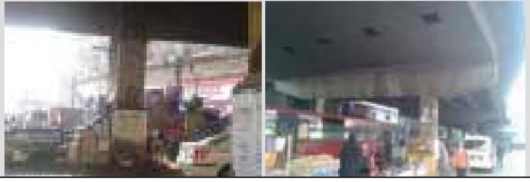
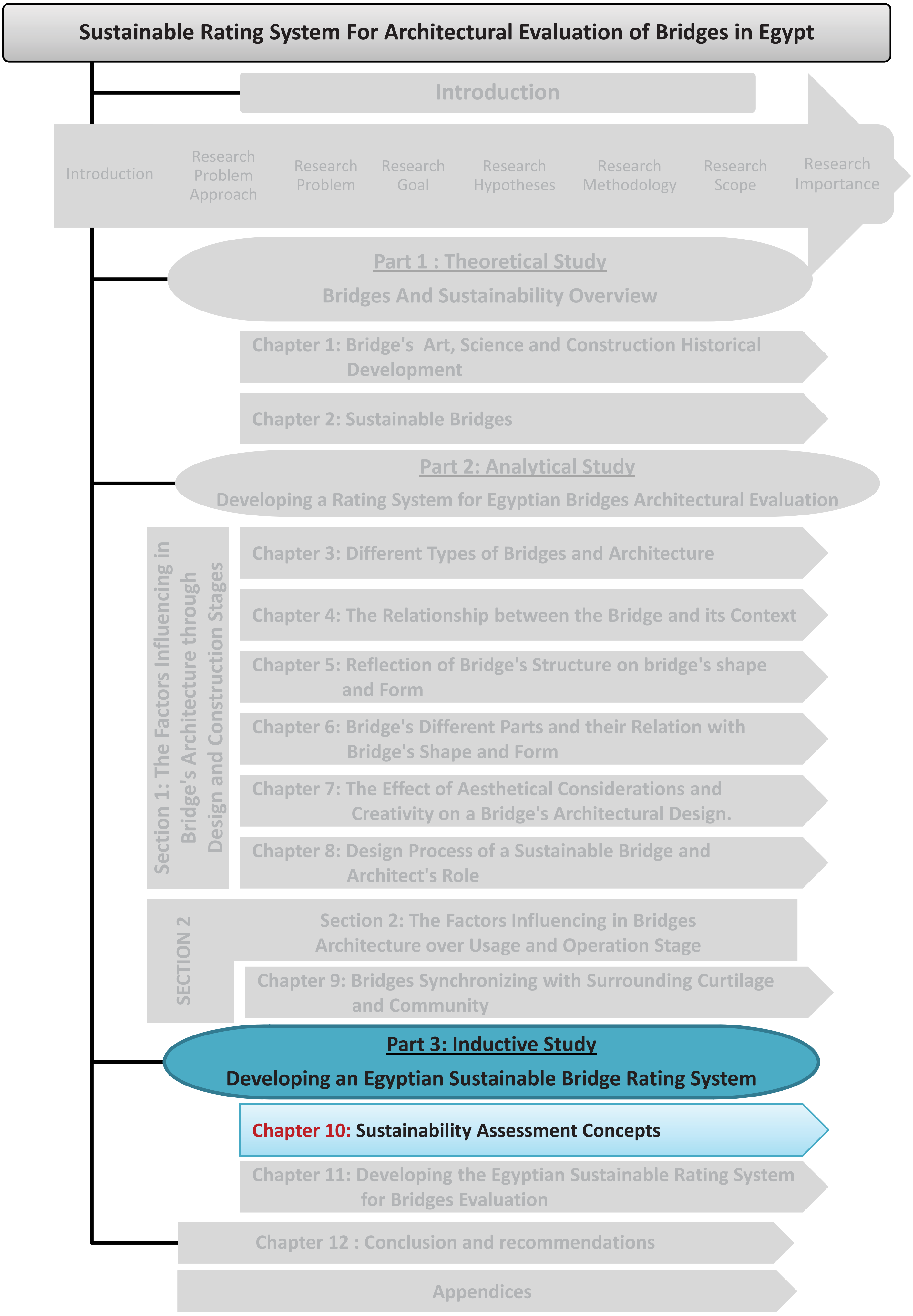
[1] حسام الدين محمد مجدي عبد القوي محمد: تحت الكوبري كفراغ عمراني عام في المدينة المصريه-رسالة ماجستير, قسم عمارة- كلية الهندسه- جامعة القاهره-٢٠١١-ص ٣٠-٤٩.

2 - Same previous reference

Table 9-4: Factors affecting the Bridge Surrounding Curtilage usage in Egypt

	Urban planning Factors A-Bridge Location, B- Bridge relationship with roads and axes, C- The obstacle which bridge crosses, D- City visual image and visual connectivity E- The surrounding neighborhood main activity (industrial, commercial, agricultural areas)
Social Factors	 Homeless and criminals under Egyptians several bridges and at pedestrian bridge. Converting the area under the bridges by homeless to a residence. Using area under the bridge for illegal activities.
Government	 From Lift: Feisal Traffic department - Giza and Orabi bridge in front of Elzeraa college metro station - Commercial activities and Misr bank under the bridge- Cairo
Environmental factors	The negative impacts from using area under the bridge as a garbage dump. The impact from illegal usage of area under bridge for commercial activities.  The illegal usage of the area under El-tunsi bridge at Elsayeda-eisha converts it to slums  Garbage dumps, From lift Qalyob bridge, Ezbet Elnakhl Metro station pedestrian bridge
Economical factors	  From lift: Maarad Bridge - Tanta (shops were built under the bridge), Street vendors under Giza bridge- Giza square and under 6th of October bridge, Ramsis square

http://img.youm7.com/images/NewsPics/gallery/pics/820152711223216hesham-sayed-(15).jpg
http://www.ahram.org.eg/NewsQ/327064.aspx
http://elwadynews.com/news-files-investigations/2014/06/25/41027
http://www.albawabhnews.com/upload/photo/gallery/21/6/700x500/585.jpg
http://www.panoramio.com/photo/60758358?source=wapiandreferrer=kh.google.com
http://1.bp.blogspot.com/_BXyoparxUYM/TCUX2zMGw- and By researcher
http://archive.aawsat.com/details.asp?section=54andarticle=555388andissueno=11389#.Vtqucfl96Uk
http://www.el-balad.com/1292915
https://www.youtube.com/watch?v=dSfJEiAv9TQ
ttp://www.egynews.net/wp-content/uploads/2015/06/IMG-20150607-WA0002.jpg
http://media.rosaelyoussef.com/uploads/image/Untitled-1(10).jpg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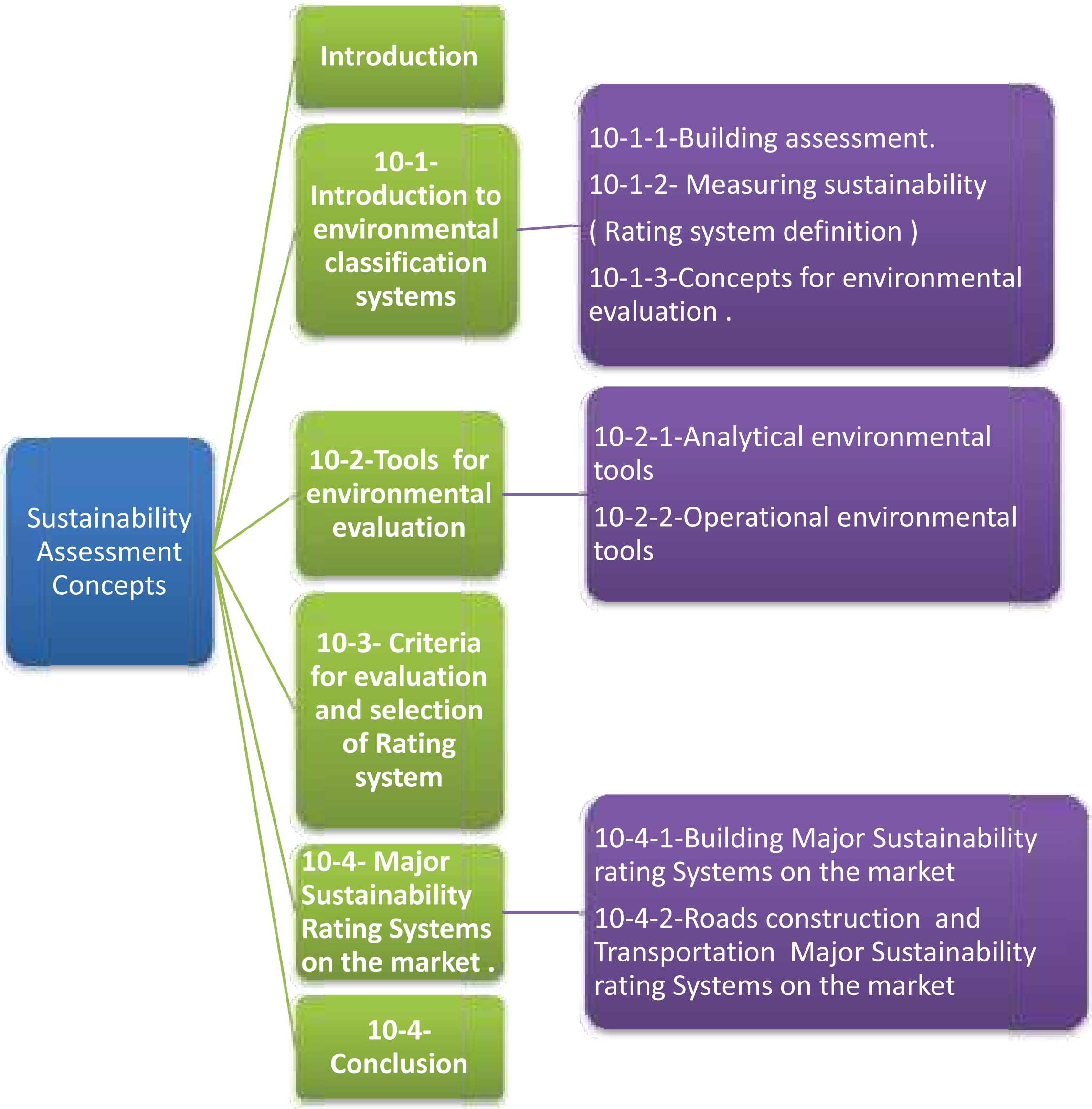
Chapter 10 : Sustainability Assessment Concepts



Chapter 10 Structure: Sustainability Assessment Concepts

Chapter 10: Sustainability Assessment Concepts

Introduction

In 1990, in the United Kingdom, the first comprehensive environmental classification system was introduced: Building Research Establishment Environmental Assessment Method (in short BREEAM). This classification system was an initiative from the construction industry in the U.K.

Today there are many different energy and environmental assessment systems.

An environmental classification is primarily a certification and guarantee that the building constructed should be green. The large number of energy and environmental assessment systems indicate that the awareness in today‘s construction and real estate market has increased. The overall use of environmental systems is to offer an overview of a range of ways to enhance buildings‘ environmental performance.[1]

Sustainable bridge design is still in development, and clear standards and recommendations have not been formalized as they have in building design. So our purpose in this chapter is to overview the main rating systems for sustainable roads and buildings in the market and to select the most convenient rating systems to be well studied to develop the Egyptian sustainable bridges rating system.

10-1- Introduction to Environmental Classifications

In this part, Building assessment, measuring sustainability and concepts for environmental evaluation will be studied.

10-1-1- Building Assessment

Building assessment tools were developed to help with the evaluation of a building’s impact. Ecologically, economically and socially, all aspects of the building need to be eco-friendly, safe and should work harmoniously to promote the health and improve the productivity of its occupants. there are the Green Building tool (GB Tool) and the UK British Research Establishment’s Environmental Assessment Method (BREEAM) model. In addition to those two, the Green Building Initiative (GBI) Green Globes tool, the built green program, the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) method, the VERDE method and the Leadership in Energy and Environmental Design (LEED) method are briefly discussed.[2]

10-1-2- Measuring Sustainability (Rating Systems Definition)

The rating and certification systems can be considered as a way of quantifying the level of sustainability of a building, based on the awards in the form of credits, points and prestigious certifications which are given as per the amount of effort that goes into the construction of the building.

10-1-3- Concepts for Environmental Evaluation

There are two main affecting concepts on environmental evaluation

- Life cycle cost analysis (LCC) - As previously mentioned.
- Life Cycle Assessment (LCA) - As previously mentioned.

Used together LCC and LCA can provide the cost of material, environmental and energy analysis of a building, from construction to demolition, needed for decision making.[3]

1- Pettersson. jonas: " Aiming for sustainability in real estate through using LEED in construction projects"- Master Thesis- Department of Energy and Environment- Division of Environmental Systems Analysis- Chalmers university of technology, Goteborg, Sweden- 2011- p 6.

2- Fosu, Richelle: "Investigating the Effect Specific Credits of the LEED Rating System have on the Energy Performance of an Existing Building" - Master thesis- Department of Computer Graphics Technology- Purdue University-USA- 2013- p 14-15.

3- Same Previous Reference p 12.

Also There are Main Concepts for Environmental Evaluation:

- **Life cycle thinking (LCT) concept**

LCT takes into consideration the impact of any product from cradle-to grave to include environmental impacts along its whole life cycle, process or activity.

- **Life cycle management (LCM)**

LCM‘s goal is to have continuous environmental enhancement from a life-cycle point of view. It can use national or international standards and indicators.

- **Design for environment**

Clean technology cares for the whole life cycle of the product.

- **Cleaner technology**

It is a concept used in the industrial community to refer to preventing pollution and waste at source. Cleaner Production is defined by the UNEP (United Nations Environment Program (UNEP, 2006) as ―the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase eco-efficiency and reduce risks to humans and the environment.[1]

Cleaner production requires: change of attitudes, environmental management and evaluating technology.

- **Dematerialization**

It refers to a considerable decrease in the amount of resources used to meet human needs, while increasing the quality.

- **Eco-efficiency**

The term eco-efficiency was introduced by the World Business Council for Sustainable Development (World Business Council for Sustainable Development (WBCSD, 1993). It is defined as ―the delivery of competitively priced goods and services, which satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle‖. Eco-Efficiency can be used as a practical approach as well as a measurable performance indicator for production because consumption processes can be calculated according to the general formula:

Eco-Efficiency = Environmental impact / cost[2]

- **Industrial ecology**

It is the multidisciplinary study of industrial systems and economic activities and their link to fundamental natural systems.

- **End-of-Life (EOL) management**

It is the management of products at the time their functional life has ended when it enters the waste phase focusing on the environmental aspects of a product.

Tools for environmental evaluation Tools are operational methods based on concepts and supported by technical elements such as models and software‖. Environmental tools may differ in their structure and technical details, but generally target complete environmental assessment. Tools are classified into analytical and operational ones. [3]

10-2- Tools for Environmental Evaluation

Tools are operational methods based on concepts and supported by technical elements such as models and software. Environmental tools may differ in their structure and technical details, but generally target complete environmental assessment. Tools are

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1 - United Nations Environment Program Annual report-2006, http://www.unep.org/pdf/annualreport/UNEP_AR_2006_English.pdf

2 - http://www.wbcsd.org/home.aspx

3- Vivan Adel Younan: "Developing a green building rating system for Egypt"- Master Thesis- School of Science and Engineering- The American University in Cairo- Egypt- 2011- p 13-27.

classified into analytical and operational ones.[1]

10-2-1- Analytical Environmental Tools

Analytical tools study the consequences of a choice. The most popular analytical environmental tools are: Refer to table (10-1)

A. Life-cycle assessment (LCA)
B. Material intensity per service unit (MIPS)
C. Material flow accounting (MFA)
D. Cumulative energy requirements analysis (CERA)
E. Environmental input/output analysis (IOA)
F. Environmental risk assessment (ERA)
G. Checklists for eco-design, life-cycle costing (LCC)
H. Total cost accounting (TCA)
I. Cost-benefit analysis (CBA)

10-2-2- Operational Environmental Tools

Procedural tools focus on measures towards environmental performance. The most popular operational tools are:

A. Environmental management system (EMS)
B. Environmental audits (EA)
C. Environmental performance evaluation (EPE)
D. Environmental labeling (EL)
E. Eco-design (ED)
F. Green procurement (GP)
G. Total quality environmental management (TQEM)
H. Rating systems[2]

10-3- Criteria for Evaluation and Selection of Rating System

As shown in Figure (10-1), Criteria for evaluation and selection of rating system is illustrated.

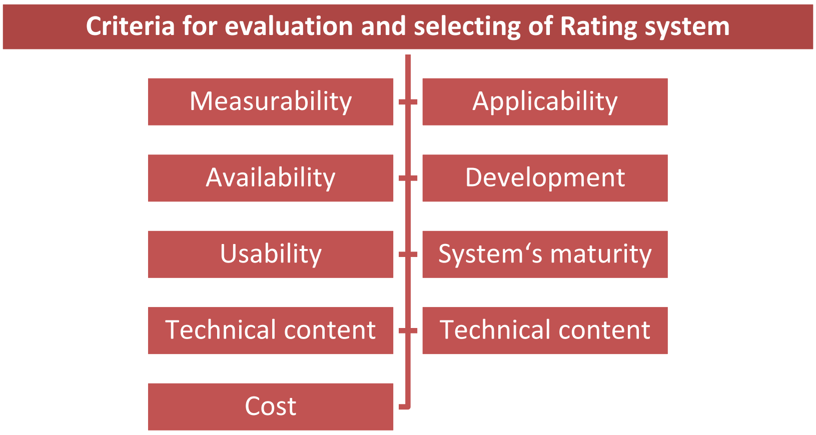

Figure 10-1: Criteria for evaluation and selecting of Rating system

- **Measurability:**

Knowing if the rating system uses measurable characteristics to demonstrate the extent of sustainable design incorporated into the building.

- **Applicability**

It is to know if the rating system can be used for all building types (e.g. commercial,

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1 -A. M. Papadopoulosa and E. Giama: "Rating systems for counting buildings environmental performance"- International Journal of Sustainable Energy- Laboratory of Heat Transfer and Environmental Engineering- Department of Mechanical Engineering- Aristotle University Thessaloniki- Thessaloniki- Greece - 2010

2- Vivan Adel Younan: "Developing a green building rating system for Egypt"- Master Thesis- School of Science and Engineering- The American University in Cairo- Egypt- 2011- p 13-27.

residential, offices, hospitals, etc.).

- **Availability**

It is to understand the possibility of the interchangeable use of different rating systems between countries to rate the same building.

- **Development**

It is to know on which methodology is the rating system based, whether on the requirements of standards and legislation or on life-cycle concept or on EMS philosophy, etc.

- **Usability**

Making sure it is practical and easy to be implemented by the user, by having practical guides with separated implementation information depending on the building's type.

- **System's maturity**

This criterion is related to when the system was developed, its final revision date and the number of buildings' registered and certified.

- **Technical content**

This deals with the environmental aspects examined during the certification process.

- **Communicability**

This ensures that a certified building is well known to outsiders at the end of the evaluation process.

- **Cost**

This criterion is clearly very essential to the user (building developer, owner, inhabitant, etc.) and takes into account all the costs that arise during the buildings' certification process. All systems evaluate buildings environmentally.[1]

10-4- Major Sustainability Rating Systems on the Market.

In this part, major sustainable rating systems for building and roads well be overviewed to select the most convenient rating systems to be well studied to develop the Egyptian sustainable bridges rating system. the rating systems will be discussed through four tables.

10-4-1- Building Major Sustainability Rating Systems on the Market

In this part, most used sustainable buildings rating systems will be summarized. Figure (10-2) and Figure (10-3).

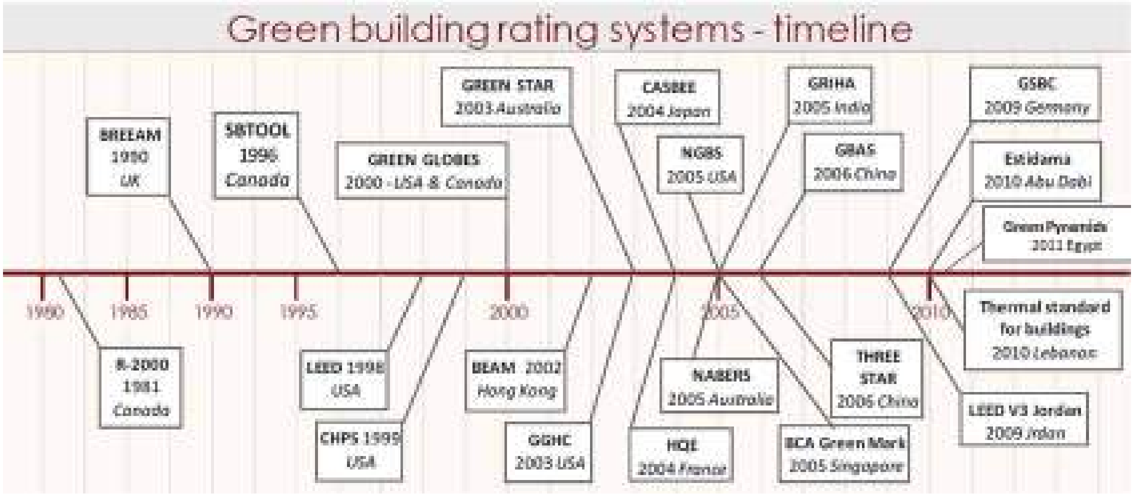

Figure 10-2: Green building rating system timeline[1]

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[1] 1- Vivan Adel Younan: "Developing a green building rating system for Egypt"- Master Thesis- School of Science and Engineering- The American University in Cairo- Egypt- 2011- p 13-27.

Figure 10-3: Current Global Rating Systems[2]

10-4-1-1- BREEAM (Building Research Establishments (Environmental Assessment Method)

BREEAM is the world's foremost environmental assessment method and rating system for buildings.

What does BREEAM do? BREEAM addresses wide-ranging environmental and sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other initial parties, BREEAM uses a straightforward scoring system that is transparent, flexible, easy to understand and supported by evidence-based science and research, has a positive influence on the design, construction and management of buildings, defines and maintains a robust technical standard with rigorous quality assurance and certification.[3]

The scope of BREEAM: It covers all building types, schools, healthcare buildings, offices, industrial units and more. For the housing sector, there are a number of variants: BREEAM Eco Homes for new homes in Scotland. Figure (10-4)

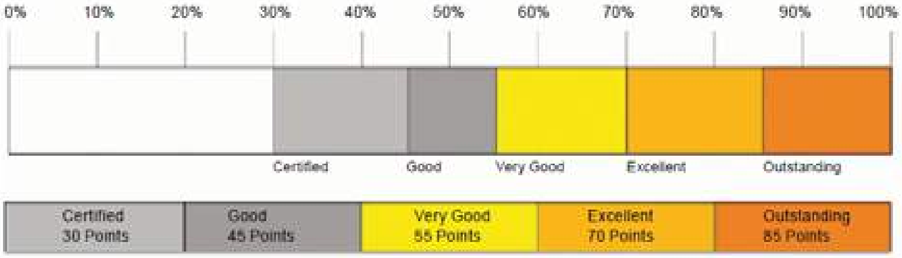

Figure 10-4: BREEAM Certification Weighting[4]

10-4-1-2- LEED (Leadership in Energy and Environmental Design)

LEED stands for Leadership in Energy and Environmental Design. LEED is a leading

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1 - Same Previous Reference, p 29.

[2] - http://www.egypt-gbc.gov.eg/about/global.html

[3]- http://www.breeam.org/about.jsp?id=66

[4] - Michael Bauer, Peter Mosle and Michael Schwarz : " Green Building – Guidebook for Sustainable Architecture"- Springer publications- Geermany-2010 - p17

edge system for certifying high-performance buildings and sustainable neighborhoods.

About LEED: LEED was developed by USGBC, and the LEED Green Building Rating System is the USGBC's primary vehicle for promoting sustainable design and construction. The LEED standard was created through Transform the building market LEED helps to evaluate a building's performance throughout the building's life cycle.[1] Figure (10-5).

Figure 10-5: LEED® Certification Weighting [2]

10-4-1-3- DGNB (German Sustainable Building Council)

The German Sustainable Building Council was founded in 2007 by 16 initiators from various subject areas within the construction and real estate sectors. The aim was to promote sustainable and economically efficient building even more strongly in future.[3]

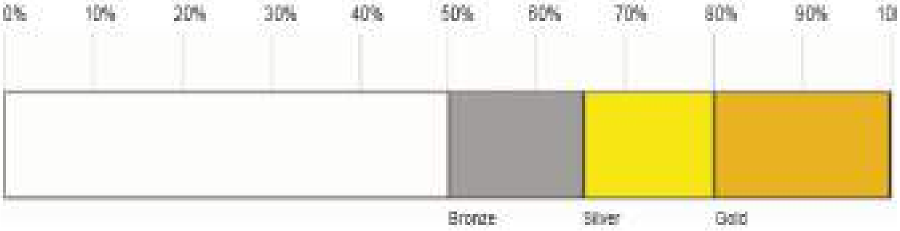

Figure 10-6: DGNB Certification Weighting[4]

10-4-1-4-GRIHA (Green Rating for Integrated Habitat Assessment)

GRIHA is India's National Rating System for Green buildings. It has been developed by TERI (The Energy and Resources Institute) and is endorsed by the MNRE (Ministry of New and Renewable Energy). adopting the five 'R' philosophy of sustainable development, namely

1. Refuse: to blindly adopt international trends, materials, technologies, products, etc. Especially in areas where local substitutes/equivalents are Available.
2. Reduce: the dependence on high energy products, systems, processes, etc.
3. Reuse: materials, products, traditional technologies, so as to reduce the costs incurred in designing buildings as well as in operating them.
4. Recycle: all possible wastes generated from the building site, during construction, operation and demolition.
5. Reinvent: engineering systems, designs, and practices such that India creates global examples that the world can follow rather than us following international examples

Going by the old adage 'What gets measured, gets managed, Project scoring:

- 50-60 points is certified as a 1 star GRIHA rated building,

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[1] "LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014- p 37-40

[2] Michael Bauer, Peter Mosle and Michael Schwarz : " Green Building – Guidebook for Sustainable Architecture"- Springer publications- Geermany-2010 -p16

[3] http://www.dgnb.de/en/council/dgnb/

[4] Michael Bauer, Peter Mosle and Michael Schwarz : " Green Building – Guidebook for Sustainable Architecture"- Springer publications- Geermany-2010 -p18

- 61-70 is a 2 star GRIHA rated building,
- 71-80 is a 3 star GRIHA rating building,
- 81-90 is a 4 star GRIHA rated building and
- 91-100 is a 5 star GRIHA rated building[1]

10-4-1-5-Estidama.

Launched in May 2008, Estidama which means ‘sustainability’ in Arabic is Abu Dhabi’s contribution to the global debate on how to create sustainable communities, cities and enterprises. Based on the four pillars of sustainability (environmental, economic, social and cultural) it aims to pull off the admittedly difficult trick of balancing all these concerns against the simple pursuit of progress and a better life.[2]

<u>The Need for Estidama</u>

- Estidama aims to revive the ecological and cultural sensitivity (traditions) of the people to their environment.
- Estidama arose from the need to properly plan, design, construct and operate sustainable developments with respect to the local traditions and climate.
- In order to achieve the goal of Estidama, developers, design teams and even residents need to rethink the design and planning process, the harsh climatic nature of the region.

10-4-1-6- GRPS (The Green Pyramid Rating system).

The Egyptian sustainability rating system GRPS was completed in 2011. Recognizing the unique ecological, industrial and social challenges of the region, the rating system helps to define what constitutes an “Egyptian Green Building”. To accomplish that goal, the rating system builds upon the Egyptian BEECs and integrate proven methodologies and techniques used in successful programs from the United States, Europe, Asia, South America and the Middle East.[3]

10-4-1-7- CASBEE (Comprehensive Assessment System for Built Environment Efficiency).

The Japanese Green Building Council (JaGBC) has developed a comprehensive family of green building rating tools for many markets and building types. The CASBEE rating systems are designed to analyze building performance at several stages in the building lifecycle. Currently, there are four distinct tools to match building phases from pre-design to renovation for commercial and industrial buildings. All of the rating tools use two general categories of analysis. Q (quality) assessments are taken at the building level, while L (load) assessments look at the building’s impact on the local environment or neighborhood. Buildings are rated using the Built Environment Efficiency (BEE) ratio by taking Q category scores and dividing by L category scores.

<u>Current CASBEE Tools for Commercial, Industrial and Residential Buildings:</u>

- Tool 0 – CASBEE for Pre-Design
- Tool 1 – CASBEE for New Construction
- Tool 2 – CASBEE for Existing Buildings
- Tool 3 – CASBEE for Renovation.[4]

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1 -http://grihaindia.org/
2 - http://estidama.upc.gov.ae/
3 - http://www.egypt-gbc.gov.eg/ratings/
4- http://www.ibec.or.jp/

10-4-1-8-GSBC (German Sustainable Building Certificate)

A certification system developed by (German Sustainability Building Council) and the federal ministry of Transport, Building and Urban Affairs (BMVBS).

GSBC measures how well a building or community performs in ecological, technical, economical, socio cultural and functional quality, as well as quality of process and location. Used as a planning and evaluation tool, the GSBC covers all relevant topics of sustainable construction, awarding outstanding buildings in the categories of Bronze, Silver, and Gold.[1]

10-4-1-9- GBAS (Green Building Assessment System).

In 2006, the Ministry of Science and Technology (MoST) developed the GBAS in China, which is developed from China‘s Green Olympic Building Assessment System (GOBAS,2006), and measures basic environmental performance of buildings such as: electricity, water, and energy consumption.[2]

10-4-1-10- IGBC (Indian Green Building System).

The Indian Green Building Council (IGBC), part of the Confederation of Indian Industry (CII) was formed in the year 2001.

The IGBC is affiliated with the World Green Building Council as a prospective member. This is a network of over 100 national Green Building Councils worldwide with a total membership of over 27,000 of the most progressive international organizations and businesses making it the largest organization globally influencing the green building market. We participate in the European Network of GBCs to influence policy at a European level.[3]

10-4-1-11- R 2000.

In 1981, the Canadian Home Builders' association (CHBA) and the Office of Energy Efficiency (OEE) of Natural Resources Canada (NRCan) developed the R-2000 in Canada (R-2000).[4]

R-2000 is a voluntary standard administered by Natural Resources Canada (NRCan) and is delivered through a network of service organizations and professionals across Canada.

What is the R-2000 Standard? The R-2000 is an industry-endorsed technical performance standard for energy efficiency, indoor air tightness quality, and environmental responsibility in home construction.

Houses built to the R-2000 Standard typically exceed the energy performance requirements of the current Canadian building codes and are recognized by meeting a high standard of environmental responsibility.[5]

10-4-1-12-Green Buildings in China.

China’s Three-Star certification program is an integral part of the national Green Building Evaluation which established by MOHURD (Ministry of Housing and Urban-Rural Development at 2006 Standard (GBES), which defines green buildings as

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1- http://static.victaulic.com/assets/uploads/literature/White%20Paper/WP-09.pdf

2- Vivan Adel Younan: "Developing a green building rating system for Egypt"- Master Thesis- School of Science and Engineering- The American University in Cairo- Egypt- 2011- p 42.

3- http://www.igbc.ie/about/

4- Vivan Adel Younan: "Developing a green building rating system for Egypt"- Master Thesis- School of Science and Engineering- The American University in Cairo- Egypt- 2011- p 29

5- http://www.nrcan.gc.ca/energy/efficiency/housing/new-homes/5051 “buildings that save a maximum amount of resources (including energy, land, water, and materials), protect the environment, reduce pollution, provide healthy, comfortable and efficient space for people, and exist harmoniously with nature” throughout their lifecycle.

The GBES sets the official definition of green buildings in China, but, there are dozens of other definitions in the country that fall into three broad categories: local, project-based, and international.[1]

10-4-1-13-CHPS (Collaborative for High Performance Schools).

The Collaborative for High-Performance Schools (CHPS) began in November 1999 in California. Interest in high-performance design grew and CHPS expanded its focus, developing a national version of the standards. CHPS criteria is available for use by any state that does not have their own version[2]

<u>The goals of CHPS are to fundamentally change the design, construction and operation of schools to: </u>Protect student and staff health, and enhance the learning environments of school children everywhere Conserve energy, water, and other natural resources, Reduce waste, pollution, and environmental degradation. [3]

10-4-1-14-GREEN GLOBES

Green Globes is an online green building rating and certification tool that is used primarily in Canada and the USA. Green Globes is licensed for use by BOMA Canada (Existing Buildings) and the Green Building Initiative in the USA (New and Existing Buildings). There are Green Globes modules for New Construction/Significant Renovations Commercial Interiors and Existing Buildings (offices, multi-residential, retail, health care, light industrial)

Green Globes for Existing Buildings was developed in 2000 by ECD Energy and Environmental Canada. are needed to reply to the questions. An online manual is also available. Users can see how points are being awarded and how they are scoring.[4]

10-4-1-15-BEAM (Building Environmental Assessment Method)

BEAM was created by The Hong Kong Green Building Council. The Hong Kong Green Building Council Limited (HKGBC) is a nonprofit, member led organization established in 2009 which strives to promote the standards and developments of sustainable buildings in Hong Kong. The HKGBC aims to raise green building awareness by engaging the public, the industry and the government, and to develop practical solutions for Hong Kong’s unique, subtropical built environment of high-rise, high density urban area, leading Hong Kong to become a world’s exemplar of green building development.[5]

BEAM provides building users with a single performance label that demonstrates the overall qualities of a building, be it a new or refurbished building, or one that is already in use. A BEAM assessed building will be safer, healthier, more comfortable, more functional and more efficient that a similar building which has not achieved the prescribed levels of performance.[6]

1- Brief.Issue, Li.Yifei and Currie.Julia: "Green Buildings in China: Conception, Codes and Certification, Institute For Building Efficiency" -2011- http://www.institutebe.com/- p3.

2- Nancy Johns: "Guidelines for School Districts: High-Performance School Buildings Program "-Program superintend Of Public instruction Washington- USA- 2015- p7.

3- http://www.chps.net/dev/Drupal/node

4- http://www.greenglobes.com/about.asp

5- https://www.hkgbc.org.hk/eng/Abouthkgbc.aspx

6-"BEAM Plus Existing Buildings"- Version 1.1- 2011- p1 http://www.beamsociety.org.hk/

10-4-1-16-GGHC (Green Guide for Healthcare)

The Green Guide is the health care sector's first quantifiable sustainable design toolkit integrating enhanced environmental and health principles and practices into the planning, design, construction, operations and maintenance of their facilities. This Guide provides the health care sector with a voluntary, self-certifying metric toolkit of best practices that designers, owners, and operators can use to guide and evaluate their progress towards high performance healing environments.

The Green Guide is divided into a Construction section and an Operations section. The Construction section is relevant for new construction, renovations, and additions. Existing facilities are encouraged to track their ongoing performance using the Operations section, while making a commitment to utilize the Construction section on future projects.[1]

10-4-1-17- Green Star (Australia)

Green Star is an internationally recognized sustainability rating system. From individual buildings to entire communities, Green Star is transforming the way our built environment is designed, constructed and operated.

Launched by the Green Building Council of Australia in 2003, Green Star is Australia's only national, voluntary, rating system for buildings and communities.

Your built environment is currently the world's single largest contributor to greenhouse gas emissions, and also consumes around a third of our water and generates 40 per cent of our waste. Green Star is helping to improve environmental efficiencies in our buildings, while boosting productivity, creating jobs and improving the health and wellbeing of our communities.

Whether you're a building owner, operator or occupant, creating a green community or looking to live more sustainably, Green Star offers a framework of best practice benchmarks for sustainability that you - and the marketplace can trust.[2]

10-4-1-18 -NABERS (The National Australian Built Environment Rating system).

NABERS can be used to rate commercial offices, shopping centers, hotels and homes.

NABERS ratings for offices can be used to measure the performance of a tenancy, the base building or the whole building. The tenancy rating includes only the energy or resources that the tenant controls. A base building rating covers the performance of the building's central services and common areas, which are usually managed by the building owner.

A whole building rating covers both the tenanted spaces and the base building, and is typically used in an owner occupied building, or where there is inadequate metering to obtain a base building or tenancy rating. [3]

10-4-2- Road Construction and Transportation major sustainability rating systems on the market

According to AASHTO, the transportation sector worldwide is responsible for 22% of global energy consumption, 25% of fossil fuel use, and 30% of global air pollution along with greenhouse gases. It also accounts for 10% of the world's gross domestic product (GDP).

1- http://www.gghc.org/about.history.php

2 - https://www.gbca.org.au/green-star/green-star-overview/

3 - http://www.nabers.gov.au/

With such significant shares in energy use, and both natural and economic resources, small adjustments to reduce each of these impacts from the transportation sector could lead to important benefits.[1]

As mentioned previously, transportation sustainability should at the very least consider environmental integrity, impacts on economic development, and the social quality of life. System effectiveness can be considered as a fourth attribute necessary for transportation system sustainability, since a less effective system would not be an acceptable alternative.

10-4-2-1- GHP (The Green Highways Partnership)

(GHP) is dedicated to transforming the relationship between the environment and transportation infrastructure. In its nationwide review of green transportation infrastructure, the U.S. House Subcommittee on Technology and Innovation found the GHP to be “the primary federal vehicle for encouraging the use of green transportation infrastructure by state and local governments and private industry.” Such a finding says that this effort is not only unique to the nation, but is the only one of its type serving this critical purpose recognized by Congress. [2]

The GHP goal is to promote market-driven innovation, stewardship, streamlining, and regulatory consistency. GHP activities are rooted in stewardship, safety, and sustainability, with targeted activities to address its mission and primary benefit of “meeting transportation requirements and applying environmental stewardship so that both are better than before”. The GHP promotes a voluntary, not regulatory approach, and continues to grow as a collaborative effort, through an extensive public-private partnering network of industry, trade, and environmental organizations, private sector (consultants and contractors), and government (local, state, and federal). The benefits of building a Green for communities, it means economic stimulation and re-vitalization of community assets. For ecosystems, it means minimal encroachment and optimal storm water management.[3]

10-4-2-2-INVEST (Infrastructure Voluntary Evaluation Sustainability Tool)

The Federal Highway Administration (FHWA) launched INVEST 1.0 in October 2012 with a national webcast, including remarks from the Deputy Administrator and video footage of INVEST in action.

INVEST is a practical, web-based, collection of voluntary best practices, called criteria, designed to help transportation agencies integrate sustainability into their programs (policies, processes, procedures and practices) and projects.[4]

Criteria under the INVEST rating system are defined according to sustainable best practices. They fall under one of three headings: project delivery and system planning and processes (17 criteria), project development (20 or 29 criteria depending on whether basic or extended scorecard is used), and operations and maintenance (14 criteria).[5]

1- FHWA. Transportation Planning for Sustainability Guidebook. Federal Highway Administration. Atlanta: Federal Highway Administration - 2011

2- http://www.greenhighwayspartnership.org/index.php

3- http://www.greenhighwayspartnership.org/index.php?option=com_contentandview=articleandid=2

4- https://www.sustainablehighways.dot.gov/overview.aspx

5- Clevenger.Caroline M, Ozbek.Mehmet E., and Simpson.Sherona: "Review of Sustainability Rating Systems used for Infrastructure Projects" -49th ASC Annual International Conference Proceedings- Associated Schools of Construction-2013- p 5.

10-4-2-3- GREENLITES (Green Leadership In Transportation Environmental Sustainability)

Transportation sustainability at NYSDOT who developed GREENLITES rating system to ensure following their philosophies. These philosophies are:

- Protect and enhance the environment.
- Conserve energy and natural resources.
- Preserve or enhance the historic, scenic, and aesthetic project setting characteristics.
- Encourage public involvement in the transportation planning process.
- Integrate smart growth and other sound land-use practices.
- Encourage new and innovative approaches to sustainable design, and how we operate and maintain our facilities.[1]

10-4-2-4- Envision™ Sustainable Infrastructure Rating System

Envision™ Rating System by Institute of Sustainable Infrastructures to evaluate sustainable infrastructure projects. This rating system evaluates the sustainability for a wide range of infrastructure, including bridges. ISI was formally launched in 2011 and introduced a rating system that was developed by a working group from the American Council of Engineering Companies (ACEC), American Public Works Association (APWA), and American Society of Civil Engineers (ASCE). [2]

Envision™ provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects. It evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle.[3]

Under Envision there are 60 credits distributed under five categories Quality of Life, Leadership, Resource Allocation, Natural World and Climate and Risk. Quality of Life embodies social aspects of sustainability such as appropriateness of project, its holistically effect on the community, and whether it improves the community’s mobility or access to facilities. Leadership measures actual performance of stakeholders in areas such as collaboration, management and planning.[4]

10-4-2-5- Programs with Academic Origins

There are many programs with academics origins, but these most used programs are studied in this chapter.

- **10-4-2-5-A- Greenroads**

The Greenroads sustainability rating system was developed by CH2M HILL and the University of Washington in 2009. Greenroads stimulates sustainability in highway construction by awarding credits to projects that have successfully incorporated sustainable best practices. It provides a holistic means of considering and evaluating roadway sustainability for new construction, reconstruction and rehabilitation through a quantitative method that informs decision making. It also addresses operations and

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1- NYSDOT (The New York State Department of Transportation): "GreenLITES Project Design Certification Program"-2015, from https://www.dot.ny.gov/programs/greenlites

2- Clevenger. Caroline M., Ozbek. Mehmet E. and Simpson.Sherona: "Review of Sustainability Rating Systems used for Infrastructure Projects"- paper- 49th ASC Annual International Conference Proceedings, the Associated Schools of Construction- 2013- p 2.

3- http://www.sustainableinfrastructure.org/rating/index.cfm

4- Institute for Sustainable Infrastructure: (2015), Envision Rating System, http://www.sustainableinfrastructure.org/index.cfm maintenance through an Operations and Maintenance Plan, which is evaluated when the project is scored.[1]

10-3-2-5- B- BE2ST-In-Highways

Developed by the Recycled Materials Resource Center (RMRC) based at the College of Engineering at the University of Wisconsin, Building Environmentally and Economically Sustainable Transportation-Infrastructure-Highways (BE2ST-In-Highways) is a sustainability rating system whose main focus is to quantify the sustainability impact of using recycled materials in pavements.

Projects are analyzed by comparing a reference design (base design) that has no sustainable features, but fulfills statutory and social requirements to proposed designs that satisfy statutory and social requirements, and incorporate sustainable design features . By comparing reference to proposed designs, an accurate, transparent, and replicable measurement, which takes into account tradeoffs, can be implemented to evaluate proposed project performance.[2]

Score percentages are presented in comparison to the reference design and prorated to an equivalent score in accordance with the weight for each sub-criterion. A percentage is calculated by dividing the actual score by maximum possible score according to the following levels: Bronze (50%), Silver (75%) and Gold (90%). The system is applicable to highway projects during the design phase, is entirely web based, and offers third party verification as well as voluntary participation alternatives.[3]

Using recycled materials in the base course is thus more advantageous and has higher value because larger material quantities are involved in the base course with greater potential for cost savings, as shown in this case study.[4]

In scoring projects, the rating system utilizes Pavement Life-Cycle Assessment Tool for Environmental and Economic Effects PaLATE and the Life Cycle Cost Analysis (LCCA) Real Cost software program. In addition, it uses Mechanistic-Empirical Pavement Design Guide (MEPDG) to measure service life, Traffic Noise Model Look up (TNM-Look) to assess traffic noise, and International Roughness Index (IRI) simulation to determine life of pavement.[5]

10-4-2-5-C- Illinois (Livable and Sustainable Transportation Rating System and Guide)

In January 2010, the Illinois Department of Transportation, the American Consulting Engineers Council Illinois Chapter, and the Illinois Road and Transportation Builders Association released a sustainability guide and rating system entitled I-LAST, Illinois was developed by volunteers from these organizations over a two-year period. This paper reviews the reasons for undertaking this project, the contents of the resulting document, and the decisions made during its development.[6]

1- Clevenger. Caroline M., Ozbek. Mehmet E. and Simpson.Sherona: "Review of Sustainability Rating Systems used for Infrastructure Projects"- paper- 49th ASC Annual International Conference Proceedings, the Associated Schools of Construction-2013- p 4.

2- Lee, J., Edil, T., Benson, C., and Tinjum, J: "Use if BEST In-Highways for Green Highway Construction Rating in Wisconsin. Green Streets and Highways"- Report- 2010- p480.

3- RMRC (Recycled material resources center) Report- BE2ST-in-Highways™ at RMAUPG Annual Meeting-2012- http://rmrc.wisc.edu/be2st-in-highways/

4- http://trrjournalonline.trb.org/doi/pdf/10.3141/2233-21

5- Edil, T. B: "Building Environmentally and Economically Sustainable Transportation-Infrastructure-Highways"- Lecture- Recycling Materials Resource Center- University of Wisconsin-Madison- USA- 2012.

6- I-LAST™ Illinois -" Livable and Sustainable Transportation Rating System and Guide" -Department of transportation-2012- p 5.

• 10-4-2-5-D- University of Waterloo Rating system

A recent master's thesis from the University of Waterloo by Peter Cheuk Pan Chan is a preliminary investigation that demonstrates Ontario's initiative to provide a green performance rating system for roads. Pan Chan focuses strongly on pavement materials, management, and design, but also considers land use planning, public transit, walkways and bikeways, and alignment – The report additionally utilizes cost as a strong metric with scaling factors.

Pan Chan focused much of his literature review on pavement materials, maintenance, and rehabilitation. He additionally reviewed design and construction practices, as well as several green initiatives such as LEED, Greenroads, and GreenLITES. 1

Necessary Considerations for the Core Elements of Sustainability[2]

Considering just the materials aspect of sustainability for a moment, there have been initiatives worldwide to improve road materials and standards to better accommodate changes in energy availability and to improve the impact of roads on the environment., the use of improved and recycled materials is one of many methods that can improve construction and maintenance impacts on the environment. The impact of choosing to use a pavement mix that contains recycled content can positively impact the project in many ways. Recycled content may be less costly than purchasing new content it also may reduce costs to both the environment and agency by reducing material transport necessary to arrive at the project site, if it can be utilized from on-site (previously considered) construction waste or come from a local facility. Of course recycling can help construction-related waste from going straight to a landfill, and can aid the reduction in mining natural resources that may or may not be renewable.[3]

10-4- Conclusion

In this chapter, An introduction to sustainability assessment concepts was studied throughout introduction of the tools for environmental evaluation, criteria for evaluation and having an introduction to environmental classification systems.

An overview of most used sustainable rating systems for building and sustainable transportation all over the world was done to select the most appropriate rating systems in order to be developed to conclude our own Sustainable Rating System For Architectural Evaluation of Bridges in Egypt (Sustainability prerequisites and credits) .

Also, As shown in table (10-1) scoring criteria at most important sustainability rating systems are overviewed also, Also, as shown in table (10-2) Summary of Attributes Considered by Major roads Rating Systems are studied.

1- Pan Chan, P. C: "Quantifying Pavement Sustainability for Ontario"- Paper- University of Waterloo- Canada-2010

2- Jeon, C. M. : "Incorporating Sustainability into Transportation Planning and Decision Making"- Definitions, Performance Measures, and Evaluation Report- Civil and Environmental Engineering- Atlanta-Georgia Institute of Technology- 2007

3- Eisenman.Ana AthaliaPlaut: "Sustainable streets and highways: an analysis of green roads rating systems"- Master Thesis- Faculty of Civil Engineering- Georgia Institute of Technology-2012- p 8

Table 10-1- Comparison of different Rating Systems for Sustainable Buildings (by researcher)

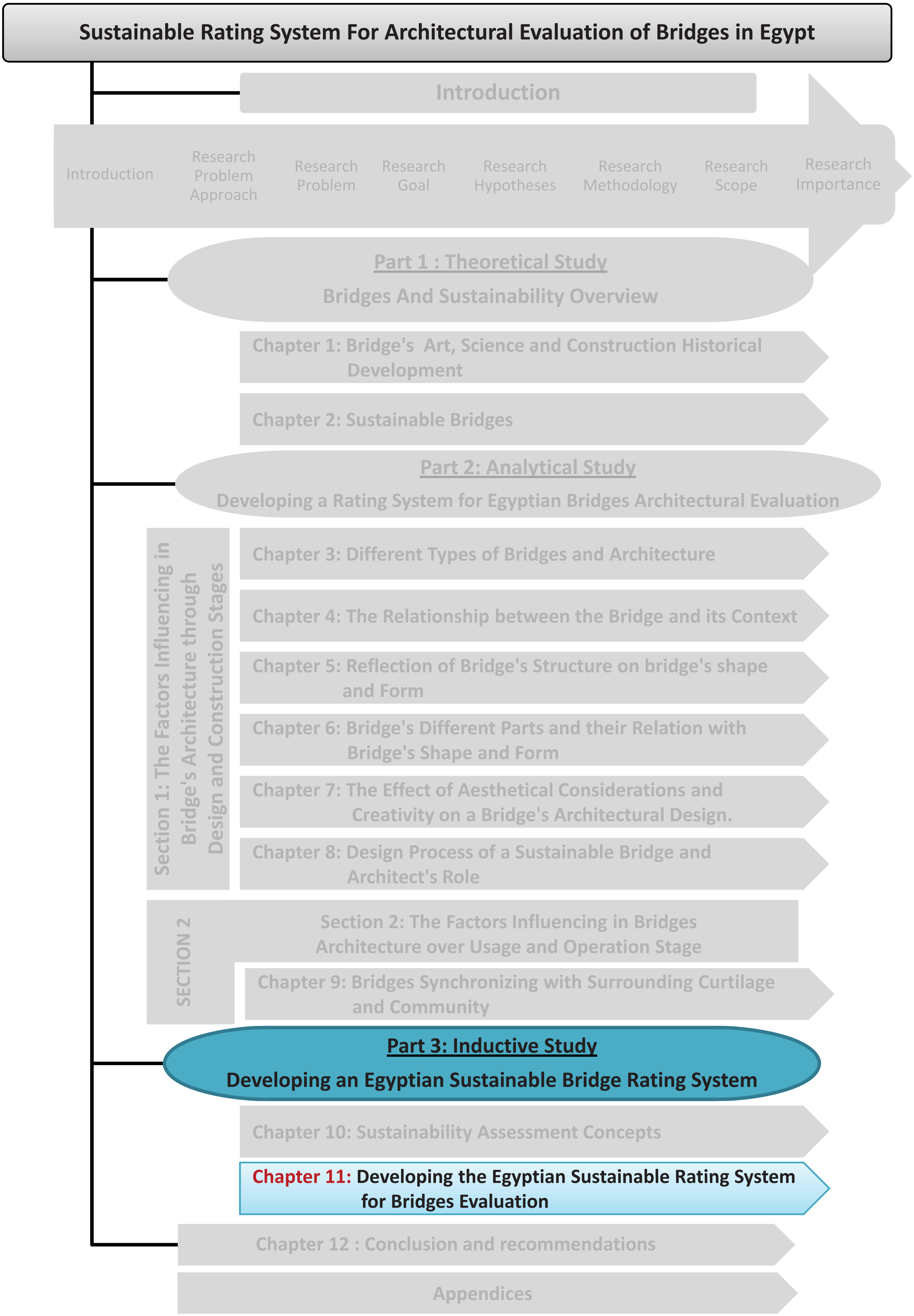
	DGNB (Germany)	**BREEAM (Great Britain)**	**LEED (USA)**	**Green Star (Australia)**	**CASBEE (Japan)**
	2001	1990	1998	2003	2001
Key Aspects of Assessment & Versions	- Ecological Quality - Economical Quality - Social Quality - Technical Quality - Process Quality - Site Quality Purpose of the DGNB Certificate: Application for buildings of any kind (Office high-rises, detached residential homes, infrastructure buildings etc.) DGNB for: - Offices - Existing Buildings - Retail - Industrial - Portfolios - Schools	- Management - Health & Well-being - Energy - Water - Material - Site Ecology - Pollution - Transport - Land consumption BREEAM for: Courts, Eco Homes, Education, Industrial, Healthcare, Multi-Residential, Offices, Prisons, Retail	- Sustainable Sites - Water Efficiency - Energy & Atmosphere - Material & Resources - Indoor Air Quality - Innovation & Design LEED for: New Construction, Existing Buildings, Commercial Interiors, Core and Shell, Homes, Neighborhood Development, School, Retail	- Management - Indoor Comfort - Energy - Transport - Water - Material - Land Consumption & Ecology - Emissions - Innovations Green Star for: - Office – Existing Buildings - Office – Interior Design - Office – Design	Certification on the basis of "building environment efficiency factor" BEE=Q/L Q … Quality (Ecological Quality of buildings) Q1 - Interior space Q2 - Operation Q3 - Environment L … Loadings Ecological effects on buildings L1 - Energy L2 - Resources L3 - Material Main Criteria: (1) Energy Efficiency (2) Resource Consumption Efficiency (3) Building Environment (4) Building Interior
Level Of Citification	Bronze Silver Gold	Pass Good Very good Excellent Outstanding	LEED Certified LEED Silver LEED Gold LEED Platinum	4 Stars: ‚Best Practice' 5 Stars: ‚Australian Excellence' 6 Stars: ‚World Leadership'	C (poor) B B+ A S (excellent)
	http://www.dgnb.de/en/	http://www.breeam.com/	http://www.usgbc.org/leed	https://www.mygreenstarenergy.com/	http://www.ibec.or.jp/CASBEE/english/

Table 10-2- Summary of Attributes Considered by Major roads Rating Systems (by researcher)

	FHWA	Greenroads	BE^2ST	SIPRS	STEED	LITES	I-LAST	STARS
WATER	√	√	√	√	√	√	√	√
Runoff Quantity	√	√	X	√	√	√	√	√
Runoff quality	√	√	X	√	√	X	√	√
Aquatic habitat	√	√	X	√	√	X	X	X
Air	√	√	√	X	√	√	√	X
Light	X	√	X	√	√	√	√	X
Noise	√	√	√	√	√	√	√	X
Carbon	√	X	√	√	X	X	X	√
Materials	√	√	√	X	√	√	√	√
Regional materials	X	√	X	√	√	√	X	X
Recycling	√	√	√	√	√	√	X	X
Waste	√	√	√	√	X	X	X	X
Electricity	√	√	√	√	√	√	√	√
Fuel	√	X	X	X	X	√	X	√
Ecology	√	√	X	√	√	√	√	√
Community	√	X	√	√	√	√	√	√
History	X	√	X	X	√	X	X	X
Lifecyclye cost	√	√	√	√	√	X	X	√

http://www.dot.ga.gov/BuildSmart/research/Documents/10-13.pdf
http://chbenson.engr.wisc.edu/images/stories/pdfs/Sustainability/039.pdf
https://www.fhwa.dot.gov/
https://www.greenroads.org/files/236.pdf

https://www.dot.ny.gov/programs/greenlites
http://rmrc.wisc.edu/be2st-in-highways/
http://www.irap.net/en/about-irap-2/star-ratings



Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

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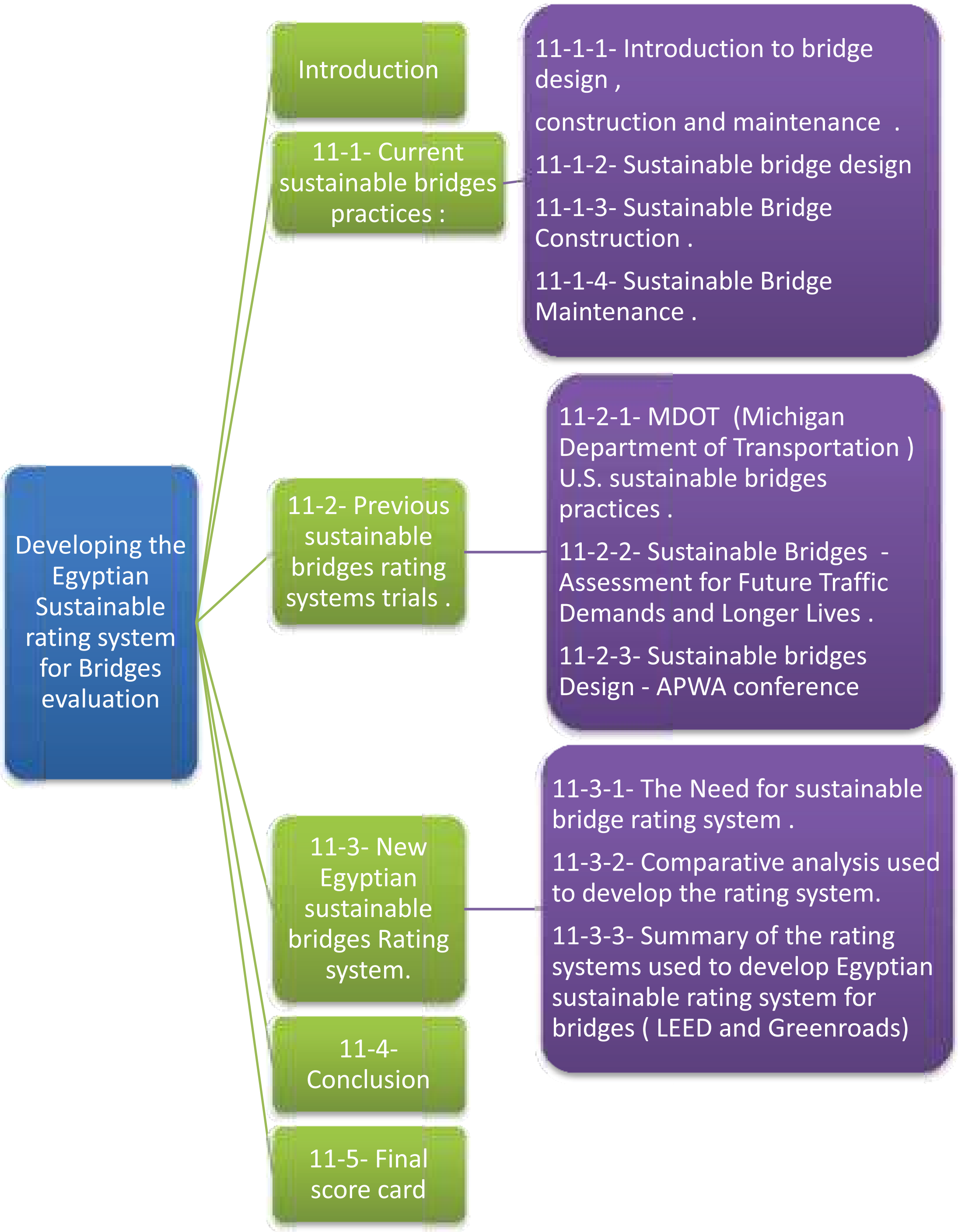
Chapter 11 : Developing the Egyptian Sustainable Rating System for Bridges Evaluation



Chapter 11 structure: Developing the Egyptian Sustainable Rating system for Bridges Evaluation

Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Introduction

During the last twenty years, environmental considerations have become more important and are designed into new projects. Sustainable development is now demanded as a natural part of everyday life. Infrastructure Managers have to fulfill these demands.

A minimal amount of research has been completed to the sustainability rating for bridge designs. The theories and programs available for sustainable buildings and sustainable transportations simply need to be modified to be applicable for bridge design or at least serve as inspiration for a unique rating system.

11-1- Current Sustainable Bridges Practices:

A number of articles, theses, journals, books, and magazines were studied to review current methodologies and approaches used to assess bridges sustainability will be described. The current sustainable practices are concluded in three categories, which are

A. Sustainable Bridge Design.
B. Sustainable Bridge Construction.
C. Sustainable Bridge Maintenance.

11-1-1- Introduction to Bridge's Design, Construction and Maintenance

Building a bridge mainly involves three stages, design, construction, and maintenance. These stages are all related to each other: design practices affect the construction stage and design consequently and construction stages affect maintenance over the lifetime of a bridge. The design stage of a bridge commences with the selection of materials, span arrangements, girder spacing, bearing types, substructure type and geometry, and foundation types. Design of the deck slab, interior and exterior girders, bearing, abutments, piers and foundations are the main steps in design. The bridge design should consider construction and long-term maintenance costs.[1]

All these design parameters coupled with environmental conditions, such as location and site, lead to various procurement and construction applications in the next stage. In the long run, maintenance processes to keep bridges operational and safe also are affected by all the decisions made in the design and construction stages. When considering bridge maintenance, preservation techniques should also be considered. Over time preservation treatments can reduce the overall cost of bridge maintenance. All decisions made in the life cycle of a bridge, especially those that are made early in the process, impact consequent stages. They all need to be critically analyzed for environmental and economic effects during the life cycle of a bridge.[2]

11-1-2- Sustainable Bridge Design

The design of a bridge is an important phase where most decisions can impact later stages. Incorporating sustainability approaches and methods in the design stage is important for achieving sustainability. For example, site selection, material selection for design, service life design, span arrangement, substructure type, geometry, and

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[1] - AASHTO- (American Association of State Highway and Transportation Officials Committee Corresponded)- paper-Submitted by the AASHTO TIG Lead States Team for the following technology- USA-2003.

[2] - MDOT (Michigan Department of Transportation) A Citizen's Guide to MDOT- Michigan- USA- 2011. http://www.maine.gov/mdot/pdf/kobs2014.pdf

foundation types are some of the factors that should be taken into consideration during the design stage; alternative ways are usually considered to achieve sustainability.[1]

High service life design requires the designer to explore outside the current codes, evaluate environmental loading, and establish material performance over a long period; this calls for extrapolation of current knowledge of climate and material properties as well as the extrapolation of material deterioration models.

Sustainability objectives for bridges can also be best accomplished by ensuring durable bridges with a long service life and low maintenance inputs that, on a whole-of-life basis, minimize material consumption over the long term. It is likely that such a bridge also has the lowest whole of- life economic cost.[2]

The durability design process for extended life requires the specific analysis of the environmental conditions in which the structure is placed, the strategic use of a range of materials and an understanding of the means by which they deteriorate and the rate of that deterioration. <u>The process involves</u>:

- Definition of the characteristics of the environment.
- Identification of the potential deterioration mechanisms in that environment.
- Determination of the likely rate of deterioration.
- Assessment of the material life.
- Definition of the required material performance.
- Consideration of a probabilistic approach to the variability of the relevant parameters.
- Assessment and definition of the need for further protection,

Finally, Sustainability objectives for bridges are best accomplished by ensuring durable bridges with long service life and low maintenance inputs, that, on a whole of life basis, minimize material consumption over the long term. It is likely that such a bridge also has the lowest whole-of-life economic cost.[3]

A. Economics of Service Life

definition of service life as the period of time that the structure is expected to be in operation, Design live is the expected service life in design stage.

It could be expected that a structure designed for a very long service life might be more durable than a structure designed for a very short service life.

On the other hand perhaps a structure with a short life would be neglected in the expectation that it will be replaced quicker. Either way it is likely that the structure designed for a very long service life will have a lower annual maintenance cost.[4]

B. Service Life and Design Life

Targeting a service life performance for a structure, the asset owner needs to be aware not only of the initial cost of creating the structure, but its service life and the long term cost of maintaining and repairing it over that service life, and finally its replacement cost. This can be done on a net present value basis, but requires knowledge of the impact of the durability performance on initial and long term costs.[5]

A service life performance must be formulated into specific design criteria to provide the designer with objectives for the design which are then encapsulated in specification

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1- Kasim Armagan Korkmaz, Matt Syal, Ronald S. Harichandran and Sinem Korkmaz : "Implementation of Sustainability in Bridge Design, Construction and Maintenance"- Michigan State University- School of Planning- Annual Report- USA-2012-p 7

2 - John Connal and Marita Berndt: " Sustainable Bridges – 300 Year Design Life for Second Gateway Bridge"- paper- Melbourne-Australia- 2009- p1-2

3 - Collings, D: "An Environmental Comparison of Bridge Forms"- Paper - Institution of Civil Engineers- Bridge Engineering- Vol 159- 2006- p 163-168

4 - Fenwick, J.M., and Rotolone, P: "Risk Management to Ensure Long Term Performance in Civil Infrastructure"- Paper-21st Biennial Conference of the Concrete Institute of Australia- Brisbane- Australia- 2003- P647-656.

5- John Connal and Marita Berndt: " Sustainable Bridges – 300 Year Design Life for Second Gateway Bridge"- paper- Melbourne-Australia- 2009- p 4 requirements that must be met by the builder during the construction. The codes usually define a design life that implies a particular service life regarded by society as acceptable. [1]

11-1-3- Sustainable Bridge Construction

- There are two main processes during construction the stage, which are responsible for energy consumption and emissions. These are a) Transportation and b) Operation. In a normal life cycle, main transportation operations occur ‘‘to site’’, ‘‘from site’’ and “on site”. An evaluation of energy released during transportation, the average distance traveled, and the fuel efficiency of vehicles that travel to and from the site are considered in this life cycle.
- Energy consumed during construction operations is another important factor. Energy consumption is calculated using the weight of equipment, energy it consumes per hour of operation, and the construction duration of a typical bridge deck.
- Different road equipment such as trucks and other vehicles are used during construction operations to transport materials to and from site, which consumes fuel and release wastes to atmosphere. Non-efficient fuel vehicles can increase fuel consumption and also releases GHG (Green-House Gases) emissions. Similarly, various non-road construction equipment such as excavators, bulldozers, compactors, pressure washers, cement and mortar mixers, pumps, trenchers, rollers and other construction equipment used during operation consumes fuel and releases energy. Air emissions from construction equipment contribute significantly to the degradation of the environment.

Therefore, it is imperative to use equipment that produces fewer emissions than conventional ones. “Non-road engines are all internal combustion engines except motor vehicle (highway) engines, stationary engines (or engines that remain at one location for more than 12 months), engines used solely for competition, or engines used in aircraft. The non-road standards cover mobile non-road diesel engines of all sizes used in a wide range of construction, agricultural and industrial equipment” So, non-road equipment is used in construction and not on roads like cars, buses, etc. Accelerated construction is used to achieve the construction of structures in the shortest possible time while decreasing delays and traffic disruption. It is not merely building structures rapidly but also entails a variety of techniques, processes, and technologies to reduce congestion due to construction while improving quality. These techniques are used for the construction of new bridges and also the replacement of existing bridges.

Using precast bent caps, precast columns, precast deck panels, precast barriers, prefabricated trusses, precast abutments, retaining walls and footings allow manufacturing to take place in a controlled environment, thereby reducing impacts to traffic and environmental impacts. [2]

11-1-4- Sustainable Bridge Maintenance

Bridge maintenance is a major part of a bridge life cycle. There are a number of activities involved in bridge maintenance that may have significant impacts on the environment. Bridge maintenance usually includes short-term fixes, medium-term fixes, and long-term fixes.

Short term fixes: include capital preventive maintenance (CPM). It applies lower-cost treatments to slow the deterioration rate, maintain or improve the functional condition, and extend the pavement's service life.

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1 - Kasim Armagan Korkmaz, Matt Syal, Ronald S. Harichandran and Sinem Korkmaz : "Implementation of Sustainability in Bridge Design, Construction and Maintenance"- Michigan State University- School of Planning- Annual Report- USA-2012p 12

2 - EPA: "Non-Road Diesel Engines" from Environmental Protection Agency-USA-2012 : www.dieselnet.com/standards/us/non-road.php

Medium term fixes: includes rehabilitation. Rehabilitation is the application of structural enhancements, such as multiple course resurfacing or concrete pavement repairs, that improve the roadway or overlaying of a bridge deck and superstructure repair.

Long term fixes: include reconstruction/replacement. Replacement refers to the replacement of the bridge deck, super structure, or the entire bridge. [1]

- Many attempts have been made to reduce the number of maintenance activities, which in turn reduce environmental impacts. The use of durable materials extends the service life of bridge components, thus decreasing the need for future maintenance activities. High performance structural materials and FRP can be used to design bridges for more . Figure (11-1)

Figure 11-1: Examples on Bridge Maintenance Techniques [2]

Efficient inspection technologies should be used to properly assess the condition of bridges in a timely manner so that necessary maintenance actions can be taken. Use of efficient inspection technologies can ensure improved data quality while simultaneously controlling the cost of data collection. Further development and evaluation of improved visual inspection procedures, innovative nondestructive testing methods, and automated methods to gather and manage data should be encouraged. The focus should be more on quantitative assessment of bridge performance rather than visual inspections and condition ratings. A variety of permanent sensors can be installed on bridges that can automatically detect the data with the change in chemical and electrical properties of materials related to deterioration, aging in coatings, and changes in service environment or exposure. Sensors report to wireless networks and data can be analyzed; deterioration can be detected automatically by computer workstations. [3]

11-2- Previous Sustainable Bridges Rating Systems Trials.

While there is no official sustainability rating system for bridge designs, some researches were done which began to examine the possibility of a rating system for sustainable bridges.

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[1] - MDOT (Michigan Department of Transportation) A Citizen's Guide to MDOT- Michigan- USA- 2011. http://www.maine.gov/mdot/pdf/kobs2014.pdf

[2] - http://www.aeol.com.au/databases/news/vic_inspections_on_west_gate_bridge.htm http://www.e-nexco.co.jp/english/technology/operation_and_maintenance.html

[3] - George Hearn: "Bridge Maintenance and Management- A Look to the Future"- Paper- Committee on Structures Maintenance and Management- USA- 2008.

11-2-1- MDOT (Michigan Department of Transportation) U.S. Sustainable Bridges Practices.

About MDOT: The Michigan Department of Transportation (MDOT) is responsible for Michigan's 9,669-mile state highway system, comprised of all US routes. MDOT also administers other state and federal transportation programs for aviation, intercity passenger services, rail freight, local public transit services, the Transportation Economic Development Fund (TEDF), and others. [1]

MDOT has recently expressed their interest in developing a frame work that can be used to categorize sustainable bridges and involve the application of sustainable materials, Standards that aim to reduce environmental pollution and other concepts that contribute toward sustainability.

A: MDOT Design Practices

The following design practices of MDOT were studied in detail:

- General Information Site Condition: Temporary support systems and construction methods, clear zone considerations, concrete QA/QC.
- Preliminary design calculations: Design specifications, design methods, and design stress.
- Design: In design practices bridge materials, span arrangements; girder spacing, bearing types, substructure type and geometry, and foundation type were examined.[2]

B: MDOT Construction Practices.

- Erosion and Sedimentation Control.
- Maintenance Activities and Projects.
- MDOT Storm-Water Management.

C: MDOT Bridge Maintenance Practices

MDOT uses a mix of fixes strategy for bridge maintenance. This strategy uses the combination of long-term fixes, medium term fixes, and short term fixes..[3]

11-2-2- Sustainable Bridges Assessment for Future Traffic Demands and Longer Lives.

The European Commission within the 6th Framework Program has developed a project called Sustainable Bridges Assessment for Future Traffic Demands and Longer Lives (2008). The sustainable definition for this group is more focused on longevity. The Sustainable Bridge program targets the enhancement of railway bridges in Europe. Their three main goals are to:

- Increase the transport capacity
- Extend the residual service life
- Enhance management, strengthening and repair systems

These concentrations of interest are very different from the categories on any sustainable rating system, but the underlying theme of specifically improving bridges to help enhance a sustainability driven mindset through infrastructure improvements is fundamentally similar.

this program discusses the importance of R and D (Research and Development) for existing structures. Today and tomorrow existing structures are dominating. Only a small part of the bridge stock is replaced every year. At the same time the society

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1 - http://www.michigan.gov/mdot/0,4616,7-151-9623---,00.html

2 - MDOT (Michigan Department of Transportation) A Citizen's Guide to MDOT- Michigan- USA- 2011. http://www.maine.gov/mdot/pdf/kobs2014.pdf.

3 - Kasim Armagan Korkmaz, Matt Syal, Ronald S. Harichandran and Sinem Korkmaz : "Implementation of Sustainability in Bridge Design, Construction and Maintenance"- Michigan State University- School of Planning- Annual Report- USA-2012., p 21

expects that the Infrastructure Managers shall meet new demands. These demands are for higher speeds, higher axle loads, increased availability, less disturbance and reduced maintenance costs. Also environmental and aesthetic considerations have to be considered. Therefore R and D for existing structures is of great importance for the society and the Infrastructure Managers to meet future needs.

some of the different aspects of maintaining the existing railway bridge heritage.

- Preservation and Conservation
- Materials Technology
- Prefabrication and Assembly
- Connections and welding
- Protective systems
- Dynamic load
- Accidental impact[1]

11-2-3- Sustainable Bridge Design – APWA Conference

At an American Public Works Association (APWA) conference, a presentation was given by Kelly Burnell (2009) titled “Sustainable Bridge Design.” The focus of the presentation was on the bridge engineer’s impact on a bridge project over its lifespan which helps to demonstrate when engineers have the most influence on the sustainability of a bridge. They examined the life of the bridge to be made up of six components. Those components are:

- transportation system
- determining the bridge function
- design
- construction
- operation
- maintenance
- rehabilitation-demolition-replacement

The potential for sustainable improvements according to Burnell (2009) is the highest in the first stage and decreases exponentially through the other phases before it briefly begins to rise again during the rehabilitation-demolition-replacement. The other element of interest during this presentation was the bridge engineer’s influence during the project life.

This information helped to solidify the notion that this research would be for planned and major rehabilitation bridge projects only. At this stage of the project, the engineer has the most control and therefore can have the most impact available to them over the span of the bridge’s life. The rest of the presentation discusses specific designs and materials that can be used to be more sustainable in terms of lowering the energy input in the bridge, increasing the durability and simplifying the deconstruction. While these are important factors to consider, they are beyond the scope of this research.[2]

As a conclusion from studying these trials, every trial focused on the most appropriate sustainability practices to their needs which achieve sustainability from their point of view, So in Egypt we need to develop our own sustainable rating system which is appropriate for Egyptian Economical, environmental and social sustainability needs. As shown in figure (11-2) the engineer influence in bridge life cycle.

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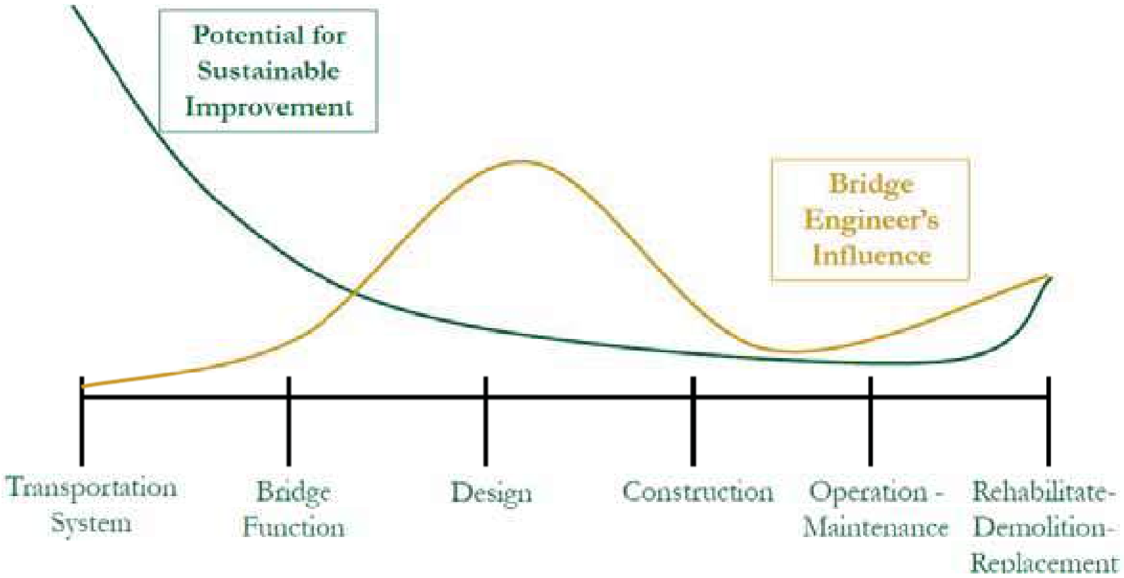
1 - Bieñ.Jan, Elfgren, Lennart and Olofsson:" Sustainable bridges: assessment for future traffic demands and longer lives"- Paper-2008-P15-16.

2 - http://www.apwa.net/Resources/Reporter/2009



This variable in the project started off very low in stage one, transportation system, and peaked during the design phase. Right after construction, the influence of the bridge engineer began to slowly rise again to about half of the peak influence during the final stage. Figure 8 depicts a graphic that demonstrates the bridge engineer's influence and the overall potential for sustainable improvements in the project.

Figure 11-2: Sustainability and the bridge live with Engineer's Influence.[1]

11-3- The Egyptian Sustainable Bridges Rating System

In this part, The Need for Developing the Egyptian Sustainable Bridges Rating System , Comparative Analysis Used to Develop the Egyptian Sustainable Bridges Rating System and Summary of the Rating Systems Used to develop the Egyptian Sustainable Bridges Rating System are studied.

11-3-1- The Need for Developing the Egyptian Sustainable Bridges Rating System

Translating sustainability ideas into definable design and construction practices that are likely to result in a more sustainable Bridge.

- Bridges can be more sustainable than they currently are.
- Needing for a rating system suitable for Egyptian resources and conditions
- Current Egyptian standards and decision tools do not fully address sustainability.

A. The goal of this sustainable rating system are:-

- To provide a common standard of measurement for sustainable bridges
- To promote integrated bridge design practices
- To promote sustainable bridge design
- To provide strategies for achieving sustainable bridge design.
- To recognize environmental leadership in the bridge industry

Also the rating systems must have these benefits: (Ecological benefits, Reduce road and non-road emissions, Reduce air emissions, Reduce wastewater emissions, Reduce soil/solid waste emissions, Reduce consumption, Reduce water use, Reduce fossil energy use, Reduce raw materials use, Create renewable energy, Optimize habitat and land use, Human-centric benefits, User improvement, Improve human health and safety, Improve access and mobility, Performance improvement, Improve business practice,

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[1] - Louis. Rachel Annette: "Sustainable Bridges: Green Links to the Future"- Master Thesis- Graduate School of The Ohio State University-Civil Engineering Department- USA- 2010- p 19-20.

Increase lifecycle savings, Increase lifecycle service, Interaction improvement, Increase awareness, Improve aesthetics and Create new information).
As shown in figure (11-3) Aspects of the sustainable roadway are introduced.

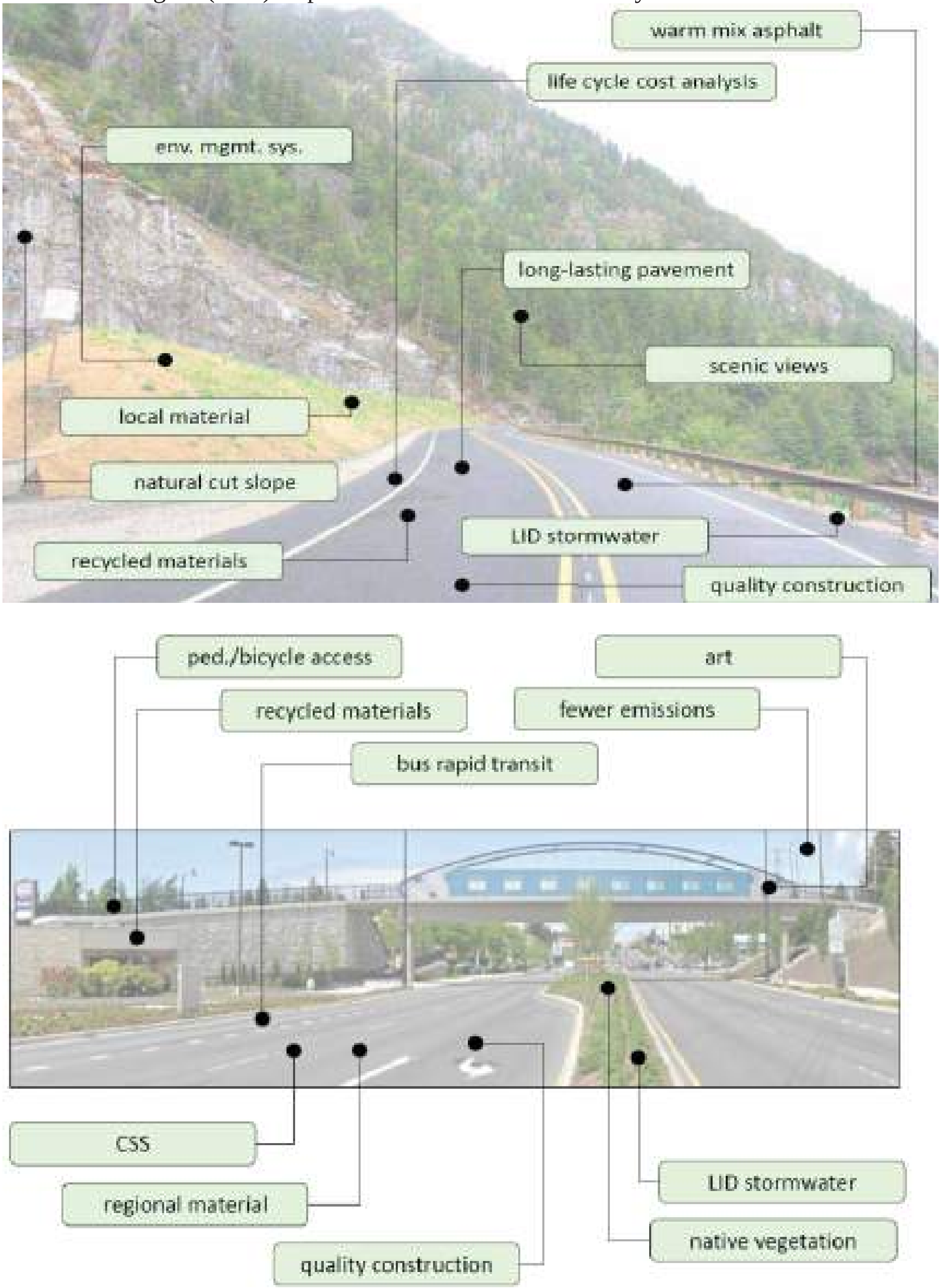

Figure 11-3: Aspects of the Sustainable Roadway[1]

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[1] - Johnson-Bednar: " An overview on GreenRoads"- Research- University of Washington and CH2M HILL-USA-2010 https://www.dot.state.oh.us/engineering/OTEC/2010%20Presentations/34A-Johnson-Bednar.pdf

B. The principles used to determining the criteria for a sustainable bridge are:

- Minimize location impacts (choosing sites tie directly into existing routes, Not using virgin sites and not affecting historical sites).
- Minimize material impacts (reducing materials needed, using recycled material and waste, allowing for future expansion, Embodied energy during construction for various structural forms and materials).
- Minimize traffic by (provide HOV "High occupancy vehicle". pedestrian, bike lanes and reduce time cars are idling).
- Minimize energy consumption: (using material with low embodied energy, minimize energy consumption during bridge construction and operation)

C. All criteria must be

- Meaningful

The rating criteria should have a direct positive environmental impact. A large part of successful sustainable design is demonstrating the advantages to the owner of the project and getting them to endorse the ides.

- Measurable

The rating criteria must be quantifiable. once of the difficulties in developing a rating system such as this is developing quantitative criteria from qualitative concepts.

- Cost effective

The rating criteria should be relatively cost effective. the criteria with high economic costs should also have high environmental impacts to offset the expenses. there may also be additional finding available for sustainable design. [1]

<u>11-3-2- The 3 Comparative Analysis Used to Develop the Egyptian Sustainable Bridges Rating System</u>

1- The focus was on trying to develop a bridges rating system, We can consider the bridge as a building because it has structure, usage, height and finishing. Also the bridge may be considered as a road with pavement, lighting and lanes.

2- The second stage was selecting a best rating systems to be compared, So the most appropriate Building's rating system is LEED for new constructions as we discussed before, And the most appropriate Rating system for roads is Greenroads. Also some credits and prerequisites were taken from another resources (Thesis's, papers and researches) which have a better effect on the rating system and makes it more efficient.

3- This stage is to studying the two previously selected rating systems, some categories are compatible with bridges and some are not, so the methodology will be Select the most compatible prerequisites and credits from both rating systems and study it.

- Define main categories for the Bridges rating system and under every category there will be the credits related to this category from both rating systems (LEED for NC and Green Roads).
- There are similar categories between two rating systems, In this case the most applicable credit is taken and studied.
- The non compatible categories and credits to be removed or calculated as a exemplary performance credits (Example: Indoor environmental Quality
- category in LEED is not applicable to bridges).

4- During the study of every credit, the credit weight should be studied to the total credits weight at the selected rating system and as a percentage.

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[1] Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p 12.

5 - New credits to be added to be compatible with Egyptian culture, rules and practice.
6- After developing the preliminary score card, Credit's weight percentage is determined as a percentage from it's original weight in LEED or GREEN Roads, If the credit is in the two rating systems a percentage average is taken in the final score card.

11-3-3- Summary of the Rating Systems Used to develop the Egyptian Sustainable Bridges Rating System

It was important to study the points beneath on the selected rating systems (LEED and GreenRoads) to develop our rating system,

- A summary of these rating systems.
- Score card of these rating systems.
- credits and prerequisites.
- scoring criteria.

This study is done as a comparison between LEED and GreenRoads as shown in table (11-1) to conclude reasons for selection of these rating systems to be developed or it could be said Why these rating systems were selected ?

Why LEED ?

- A consensus process that has a balanced and transparent committee structure.
- Technical advisory groups to ensure scientific consistency and rigor.
- Opportunities for stakeholder comment and review.
- Member ballot of new rating systems and certain changes to existing rating systems.
- A fair and open appeals process.
- LEED isn’t driven by product manufacturer’s trying to sell the latest technologies, politicians, or the finance industry. LEED comes from everyone that is involved.

Why Greenroads ?

- 100% online third-party rating done by independent experts
- 100% owner support from all clients or executive level policy support for their agent organization to participate.
- More than 500 pages of original research that were wrote and tested before its launch on real projects. (Many rating tools may be original creations or variations, but none are comprehensively tested or calibrated like Greenroads).
- Experts that have been in the rating system development business for a decade.
- Saving Money So far, all Certified Greenroads projects have come in at or below budget and no project's costs have increased specifically because of choices made to participate in Greenroads.

Also as shown in table (11-2) Greenroads rating system scorecards are introduced and table (11-3) LEED BD+C rating system scorecards are introduced.

11-4- The Final Score Card

Sustainability is now recognized as a key issue which much be addressed in the Design, construction and lifelong maintenance of civil engineering structures specially bridges.
A bridge constitutes a large investment of capital, materials, and energy and is associated with significant social, economic, and environmental impacts. Applying sustainable practices to bridge design, construction, and maintenance can enable an environmentally responsible and effective use of resources for this large investment. The focus of this Unit is to develop a framework that assists engineers and managers in developing more sustainable design and construction processes for new bridges, and sustainable maintenance practices. This framework is a developed criteria from existing rating systems (LEED for new construction rating system) and (Greenroads rating

system) and previous researches Also there are invented credits and prerequisites by the researcher which helps to upgrade bridge's sustainability and architecture .

The final score card is developed containing all these prerequisites and credits which are demonstrated in the Appendices attached to the research "page 221".

This Appendices consists of (Appendix A: Architectural Evaluation Prerequisites, Appendix B: Sustainability Evaluation Prerequisites, Appendix C: Architectural Evaluation Credits and Appendix D: Sustainability Evaluation Credits)

11-5- Conclusion

After studying the two rating systems, some prerequisites and credits were selected and others were neglected, also some credits were added by the researcher or from previous researches to reach to the final appropriate score card for Egyptian sustainable bridges which will be demonstrated at the appendices. Also, here is a conclusion about why LEED and Greenroads were selected to be developed:

- Greenroads was selected because it is a research by professors and engineers which is updated and concluded from most used rating systems for roadways also it is not profitable rating system.
- LEED was selected because it is one of the most famous and used all over the world and almost the only rating system used in Egypt.

Table 11-1: Comparison between LEED BD+C and Greenroads

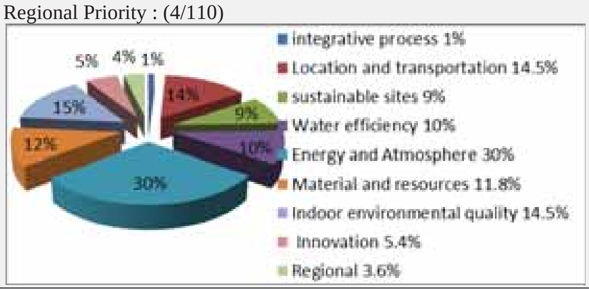
	Greenroads	**LEED BD+c**
Define	Is a roadway project that has been designed and constructed to a level of sustainability that is substantially higher than current common practice**?**	Leadership in Energy and Environmental Design. LEED is a leading-edge system for certifying high-performance buildings and sustainable neighborhoods.
The Need for a Rating System	Roadways can be more sustainable than they currently are. Current standards and decision tools do not fully address sustainability. For instance, while pavements are heavy users of recycled material, their design and construction do not consider life cycle emissions or energy use and ecological considerations can be limited to regulatory compliance. Most roadway sustainability efforts to date have not applied a consistent standard by which the relative importance of efforts are judged. Therefore, comparisons between projects or assessments of improvement are difficult. The science and engineering underlying roadway sustainability can be complex. Decisions by non-experts that often drive project direction or funding can therefore be problematic. Different aspects of roadway sustainability are difficult to compare because they are not normalized to a common value set.	LEED BD+C aims to promote a transformation of the construction industry through strategies designed to achieve these goals: To reverse contribution to global climate change, To enhance individual human health and well-being, To protect and restore water resources and enhance/ restore biodiversity and ecosystem services, To promote sustainable and regenerative material resources cycles and build a greener economy and To enhance social equity, environmental justice, community health, and quality of life <u>LEED was created to accomplish the following:</u> • Define "green building" by establishing a common standard of measurement and Stimulate green competition. • Promote integrative, whole-building design practices. • Recognize environmental leadership in the building industry. • Raise consumer awareness of green building benefits. • Transform the building market.
General Philosophy	Greenroads is designed to influence decisions regarding sustainability options where they are not precluded by regulation or where regulation allows a choice between options that could have sustainability impacts. It is also meant to encourage organizations to include sustainable practices in their company-wide strategy and daily work practices.	1. Promoting the Triple Bottom Line and Establishing leadership 2. Creating and restoring harmony between humans and nature 3. Maintaining integrity by using technical and scientific data to help guide decision making 4. Exhibit transparency by having open standards.
Prerequisites and credits	**<u>Prerequisites:</u>** do not earn your project any points because they are required for the project to be considered. The term "prerequisite" refers to a mandatory project characteristic, measurement, quality, value or function as identified within LEED or Greenroads rating systems. Also it represents the key criteria that define green building performance. Each project must satisfy all specified prerequisites outlined in the LEED or Greenroads rating systems under which it is registered. Failure to meet any prerequisite will render a project ineligible for certification. **<u>Credits:</u>** Each sustainable category has a group of credits that defines a particular sustainability goal. The sustainability goal is referred to as the 'intent' of the credit. In fact, in the reference guide just below every prerequisite/credit name is a section titled 'intent' where the credit intent is defined.	
Categories weighting	<u>11 Project Requirements and 37 Voluntary Credits</u>. Each Voluntary Credit is assigned a point value (1 to 5 points) that corresponds to its impact on sustainability, Higher point values indicate larger impacts. There is also a Custom Credits section where project teams can propose their own Voluntary Credits. • Pavement technologies: 19% • Materials and resources: 21% • Construction activities: 13% • Environmental and water: 19% • Access and equity: 28%. 	<u>13 prerequisite and 110 points for credits.</u> • Integrative process (1/110) • Location and Transportation: (16/110) • Sustainable Sites: (10/110) • Water Efficiency: (11/110) • Energy and Atmosphere: (33/110) • Materials and Resources: (13/110) • Indoor Environmental Quality : (16/110) • Innovation : (6/110) • Regional Priority : (4/110) 
System boundaries	Greenroads is applicable to the design and construction of new or rehabilitated roadways including expansion or redesign. This means that some typical items associated with roadways are considered in specific ways that merit explanation: 1. Roadway Planning, Paths and Trails 2. Supply-Chain Processes 3. Structures (Bridges, tunnels, walls and other structures) 4. Future Maintenance & Preservation	There are rating systems that address multiple project types: • Building Design + Construction (BD+C) Building Design + Construction applies to buildings that are being newly constructed or going through a major renovation. (this rating system will be studied) • Interior Design + Construction (ID+C) • Building Operations + Maintenance (O+M) • Neighborhood Development (ND)
Benefits	• More sustainable roadways. Provide a credibly accounting system for sustainable roadway projects. • Allow sustainability tradeoffs and decisions to be made in a systematic manner. • Define basic roadway sustainability attributes and Confer marketable recognition on sustainable roadway projects	• Lower operating costs and increased asset value • Reduced waste sent to landfills • Energy and water conservation • More healthful and productive environments for occupants • Reductions in greenhouse gas emissions
Certification Levels	Certification levels are provisionally used: • Certified: 32-42 points (30-40% of Credit points), • Silver: 43-53 points (40-50% of Credit points), • Gold: 54-63 points (50-60% of Credit points), • Evergreen: 64+ points (>60% of Credit points).	LEED has four levels of certification, depending on the point thresholds achieved: • Certified, 40–49 points • Silver, 50–59 points • Gold, 60–79 points • Platinum, 80 points and above
References	-----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- p 1-40. -----: "LEED Principles and Green Associate Study Guide"- Green Building Education Services- USGBC -USA- 2014- p 18-47 Federal Highway Administration (FHWA), (2009). Environmental Review Toolkit, FHWA, US Department of Transportation, Accessed March 1, 2010, http://www.environment.fhwa.dot.gov. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 2-14. https://www.greenroads.org/2899/why-greenroads.html	

Table 11-2: Greenroads Scorecard

GREENROADS RATING SYSTEM

LIST OF CREDITS (v1.5)

No.	Title	Pts.	Description
Project Requirements (PR) – Mandatory for all projects			
PR-1	Environmental Review Process	Req	Complete a comprehensive environmental review
PR-2	Lifecycle Cost Analysis (LCCA)	Req	Perform LCCA for pavement section
PR-3	Lifecycle Inventory (LCI)	Req	Perform LCI of pavement section
PR-4	Quality Control Plan	Req	Have a formal contractor quality control plan
PR-5	Noise Mitigation Plan	Req	Have a construction noise mitigation plan
PR-6	Waste Management Plan	Req	Have a plan to divert C&D waste from landfill
PR-7	Pollution Prevention Plan	Req	Have a TESC/SWPPP
PR-8	Low Impact Development (LID)	Req	Complete a LID feasibility study
PR-9	Pavement Management System	Req	Have a pavement management system
PR-10	Site Maintenance Plan	Req	Have a roadside maintenance plan
PR-11	Educational Outreach	Req	Publicize sustainability information for project
Environment & Water (EW) – Up to 21 Points			
EW-1	Environmental Management System	2	ISO 14001 certification for general contractor
EW-2	Runoff Flow Control	1-3	Reduce runoff quantity
EW-3	Runoff Quality	1-3	Treat stormwater to a higher level of quality
EW-4	Stormwater Cost Analysis	1	Conduct an LCCA for stormwater elements
EW-5	Site Vegetation	1-3	Use native low/no water vegetation
EW-6	Habitat Restoration	3	Restore habitat beyond what is required
EW-7	Ecological Connectivity	1-3	Connect habitat across roadways
EW-8	Light Pollution	3	Discourage light pollution
Access & Equity (AE) – Up to 30 Points			
AE-1	Safety Audit	1-2	Perform roadway safety audit
AE-2	Intelligent Transportation Systems (ITS)	2-5	Implement ITS solutions
AE-3	Context Sensitive Solutions	5	Plan for context sensitive solutions
AE-4	Traffic Emissions Reduction	5	Reduce emissions with quantifiable methods
AE-5	Pedestrian Access	1-2	Provide/improve pedestrian accessibility
AE-6	Bicycle Access	1-2	Provide/improve bicycle accessibility
AE-7	Transit Access	1-5	Provide/improve transit accessibility
AE-8	Scenic Views	1-2	Provide views of scenery or vistas
AE-9	Cultural Outreach	1-2	Promote art/culture/community values
Construction Activities (CA) – Up to 14 Points			
CA-1	Quality Management System	2	ISO 9001 certification for general contractor
CA-2	Environmental Training	1	Provide environmental training
CA-3	Site Recycling Plan	1	Have a plan to divert waste from landfill
CA-4	Fossil Fuel Reduction	1-2	Use alternative fuels in construction equipment
CA-5	Equipment Emissions Reduction	1-2	Meet EPA Tier 4 standards for non-road equip.
CA-6	Paving Emissions Reduction	1	Use pavers that meet NIOSH requirements
CA-7	Water Tracking	2	Develop data on water use in construction
CA-8	Contractor Warranty	3	Warranty on the constructed pavement
Materials & Resources (MR) – Up to 23 Points			
MR-1	Life Cycle Assessment (LCA)	2	Conduct a detailed LCA of the entire project
MR-2	Pavement Reuse	1-5	Reuse existing pavement sections
MR-3	Earthwork Balance	1	Use native soil rather than import fill
MR-4	Recycled Materials	1-5	Use recycled materials for new pavement
MR-5	Regional Materials	1-5	Use regional materials to reduce transportation
MR-6	Energy Efficiency	1-5	Improve energy efficiency of operational systems
Pavement Technologies (PT) – Up to 20 Points			
PT-1	Long-Life Pavement	5	Design pavements for long-life
PT-2	Permeable Pavement	3	Use permeable pavement as a LID technique
PT-3	Warm Mix Asphalt (WMA)	3	Use WMA in place of HMA
PT-4	Cool Pavement	5	Contribute less to urban heat island effect (UHI)
PT-5	Quiet Pavement	2-3	Use a quiet pavement to reduce noise
PT-6	Pavement Performance Tracking	1	Relate construction to performance data
Custom Credits (CC) – Available for all projects based on context and innovation, subject to approval			
CC-1	Custom Credit 1	1-5	Design a new voluntary credit
CC-2	Custom Credit 2	1-5	Design a new voluntary credit
	Greenroads Total Points:	**118**	

Table 11-3: LEED BD+C Scorecard

LEED v4 for BD+C: New Construction and Major Renovation

Project Checklist

Project Name:
Date:

Y	?	N			
			Credit	Integrative Process	**1**
0	**0**	**0**		**Location and Transportation**	**16**
			Credit	LEED for Neighborhood Development Location	16
			Credit	Sensitive Land Protection	1
			Credit	High Priority Site	2
			Credit	Surrounding Density and Diverse Uses	5
			Credit	Access to Quality Transit	5
			Credit	Bicycle Facilities	1
			Credit	Reduced Parking Footprint	1
			Credit	Green Vehicles	1
0	**0**	**0**		**Sustainable Sites**	**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Site Assessment	1
			Credit	Site Development - Protect or Restore Habitat	2
			Credit	Open Space	1
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1
0	**0**	**0**		**Water Efficiency**	**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	2
			Credit	Water Metering	1
0	**0**	**0**		**Energy and Atmosphere**	**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
			Credit	Optimize Energy Performance	18
			Credit	Advanced Energy Metering	1
			Credit	Demand Response	2
			Credit	Renewable Energy Production	3
			Credit	Enhanced Refrigerant Management	1
			Credit	Green Power and Carbon Offsets	2
0	**0**	**0**		**Materials and Resources**	**13**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
			Credit	Building Life-Cycle Impact Reduction	5
			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
			Credit	Construction and Demolition Waste Management	2
0	**0**	**0**		**Indoor Environmental Quality**	**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
			Credit	Indoor Air Quality Assessment	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight	3
			Credit	Quality Views	1
			Credit	Acoustic Performance	1
0	**0**	**0**		**Innovation**	**6**
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1
0	**0**	**0**		**Regional Priority**	**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	**0**	**0**		**TOTALS** Possible Points:	**110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

Final Score Card

Prerequisites

Appendix A: Architectural Evaluation Prerequisites (AP)

	Prerequisite	Category	Reference rating system
AP1	Bridge Goals Analysis	Design process	Researcher
AP2	Bridge Design / Construction Proposals	Design process	Researcher
AP3	Integrated Team Members and Architect Role	Design process	Researcher
AP4	Bridge Integrated Costs	Design process	Researcher
AP5	Bridge Main Functions	Bridge function	Researcher
AP6	Bridge Expected Future Functions	Bridge function	Researcher
AP7	Bridge Functions Achievement	Bridge function	Researcher
AP8	Taken Considerations to Achieve Functions	Bridge function	Researcher
AP9	Safety Codes	Bridge function	Researcher
AP10	Bridge Site Background and Analysis	Bridge site	Researcher
AP11	Relationship Between Bridges and Road Networks	Bridge site	Researcher
AP12	Site Natural Delimiters	Bridge site	Researcher
AP13	Site Constructed Delimiters	Bridge site	Researcher
AP14	Context Sensitive Design and Solutions	Bridge site	Researcher
AP15	Historical Site/ Bridge Treatment	Bridge site	Researcher
AP16	Bridge Surroundings Character	Bridge site	Researcher
AP17	Expected bridge effect on the Curtilage	Bridge site	Researcher
AP18	Construction Materials Selection	Bridge structure	Researcher
AP19	Structure Systems Selection	Bridge structure	Researcher
AP20	Construction Methods Selection	Bridge structure	Researcher
AP21	Bridge Parts Architectural Integration	Bridge parts	Researcher
AP22	Bridge Aesthetical Considerations	Bridge aesthetics	Researcher
AP23	Bridge Fundamentals of Aesthetical Design/Qualities	Bridge aesthetics	Researcher
AP24	Aesthetical Design Objectives	Bridge aesthetics	Researcher
AP25	Bridge Visual Design Elements	Bridge aesthetics	Researcher
AP26	Bridge Aesthetical Considerations Integration	Bridge aesthetics	Researcher
AP27	Bridge Curtilage Development Report	Bridge curtilage	Researcher
AP28	Synchronizing with the Surroundings	Bridge curtilage	Researcher

Appendix B: Sustainability Evaluation Prerequisites (PR)

PR1	Environmental Review Process	-	Greenroads
PR2	Lifecycle Cost Analysis	Material and Resources	Greenroads
PR3	Lifecycle Inventory	Material and Resources	Greenroads
PR4	Quality Control Plan	Sustainable Construction Activities	Greenroads
PR5	Noise Mitigation Plan	Sustainable Construction Activities	Greenroads
PR6	Waste (Construction Demolition) Management Plan	Sustainable Construction Activities	LEED - Greenroads
PR7	Pollution Prevention Plan / Construction Activity Pollution Prevention	Sustainable Construction Activities	LEED - Greenroads
PR8	Low Impact Development	Sustainable Construction Activities	Greenroads
PR9	Pavement Management System	Pavement Technologies	Greenroads
PR10	Site Maintenance Plan	Bridge Maintenance	Greenroads

PR11	Educational Outreach	Social aspect	Greenroads
PR12	Increasing Bridge Durability	Bridge Maintenance	Researcher
PR13	Fundamental Commissioning and Verification	Bridge Maintenance	LEED
PR14	Minimum Energy Performance	Energy Efficiency	LEED
PR15	Bridge Level Energy Metering	Energy Efficiency	LEED
PR16	Efficient Water Use	Water Efficiency	Researcher
PR17	Outdoor Water Use Reduction	Water Efficiency	LEED
PR18	Bridge Level Water Metering	Water Efficiency	LEED

Credits

Appendix C: (AC)Architectural Evaluation Credits

Category 1 : Bridge Function (BF)

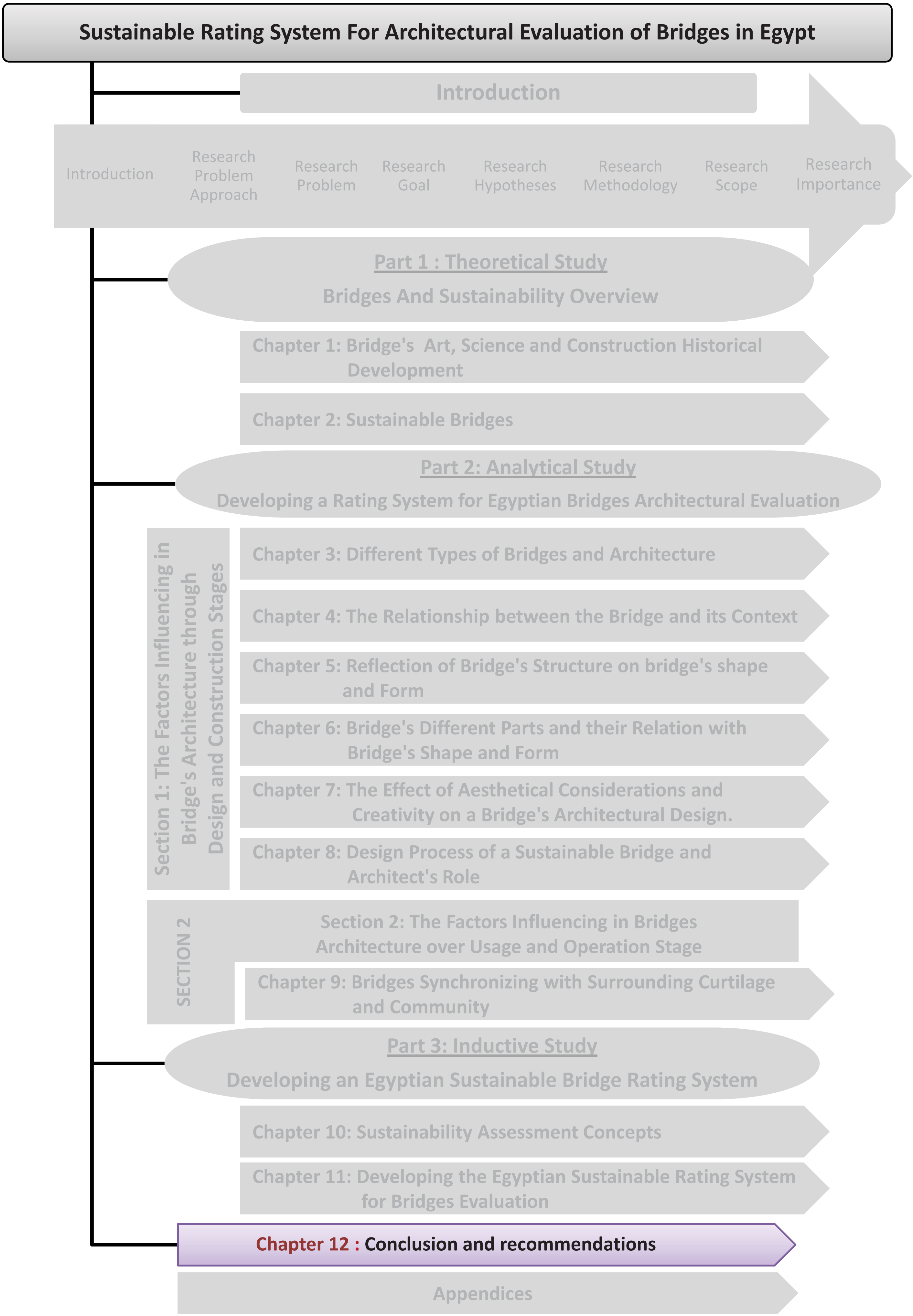
	Credit	LEED weight	G.R. Weight	Research Weight	Final Weight	Reference Rating Sy.
AC1	Bridge Movement and Constancy	-	-	-	1	Researcher
AC2	Creating a Global Bridge	-	-	-	1	Researcher
	Category 2 : Bridge Site (BS)					
AC3	Site Investigation	-	-	-	2	Researcher
AC4	A Living Bridge Plan	-	-	-	2	Researcher
AC5	Bridge viability for Expansion	-	-	-	3	Researcher
AC6	Bridge as a Whole Aesthetical Design	-	-	-	3	Researcher
	Category 3 : Bridge Structure (BST)					
AC7	The influence of Site/Context/Concept on Bridge Structure Systems Selection.	-	-	-	2	Researcher
AC8	The Influence of Site/Context/Concept on Bridge Construction Materials Selection.	-	-	-	2	Researcher
AC9	The Influence of Site/Context/Concept on Bridge Construction Methods Selection.	-	-	-	2	Researcher
	Category 4 : Bridge Parts (BP)					
AC10	Superstructure Types Selection	-	-	-	1	Researcher
AC11	Superstructure Parts Aesthetic Considerations	-	-	-	3	Researcher
AC12	Substructure Types Selection	-	-	-	1	Researcher
AC13	Substructure Parts Aesthetical Considerations	-	-	-	3	Researcher
AC14	Non Structural Parts Aesthetical considerations	-	-	-	3	Researcher
AC15	Whole Bridge Structure Integrity	-	-	-	1	Researcher
	Category 5: Bridge Aesthetics (BA)					
AC16	Bridge Architectural Development	-	-	-	1	Researcher
AC17	Following an Architectural School	-	-	-	1	Researcher
AC18	Bridge Fundamentals of Aesthetical Design/Qualities	-	-	-	3	Researcher
	Category 6 : Bridge Curtilage (BC)					
AC19	Influence of Bridges on Cities Visual Image	-	-	-	2	Researcher
AC20	The Space Around the Bridge	-	-	-	3	Researcher
AC21	The Area Under the Bridge	-	-	-	3	Researcher
AC22	Bridges Maintenance From Architectural Perspective	-	-	-	3	Researcher

Appendix D: (SC) Sustainability Evaluation Credits

Category 1 : Location and Transportation (LT)						
CR1	Site Selection	1/110	-	6/100	2	Researcher
CR2	Historical Site Improvement	-	-	3/100 1/25	2	Researcher
CR3	Surrounding Density and Diverse Uses	5/110	-	-	2	LEED
CR4	Footing Pier Location	-	-	1/25	1	Researcher
CR5	Brown Field Redevelopment (High Priority Sites)	2/110	-	2/100 2/25	1	LEED-Researcher
CR6	Sensitive Land Protection	1/110	-	-	1	LEED
CR7	LEED For Neighborhood	8-16/110	-	-	1	LEED
CR8	Context Sensitive Solution	-	5/118	-	3	Greenroads
CR9	Scenic View	-	1-2/118	-	2	Greenroads
CR10	Safety Audit	-	1-2/118	-	1	Greenroads
CR11	Cultural Outreach	-	1-2/118	-	2	Greenroads
1-2- Encourage Environmental Friendly Transportation Solution (Traffic Efficiency)						
CR12	Bicycle Lane	1/110	1-2/118	1/100 1/25	1	LEED- Gr Research
CR13	Walk able Lane "Pedestrian Lanes"	1/110	1-2/118	1/100 1/25	2	GR-LEED neighborhood Research
CR14	Green Vehicles & HOV lane "	1/110	-	2/25	1	LEED-Research
CR15	Transit Lane (Access to Quality Transit)	1-6/110	1-5/118	2/25	2	LEED-Gr
CR16	Lane Adaptability	-	-	1/100 3/25	2	Research
CR17	Tollbooth Transponders on Bridge Entrance	-	-	1-2/25	1	Researcher
CR18	Sponsors , Advertisements & Signs	-	-	-	2	Researcher
CR19	Traffic Emission Reduction	-	5/118	-	1	Greenroads
CR20	Intelligent Transportation System	-	2-5/118	-	1	Greenroads
Category 2 : Sustainable Sites & Construction Activities (SC)						
2-1- Sustainable Sites						
CR21	Site Assessment	1/110	-	-	1	LEED
CR22	Site Development - Habitat Restoration	2/110	3/118	-	1	LEED-Gr
CR23	Site Recycling Plan	-	1/118	-	1	Greenroads
CR24	Open Space	1/110	-	-	1	LEED
CR25	Heat Island Reduction	2/110	-	-	1	LEED
CR26	Light Pollution Reduction	1/110	3/118	-	2	LEED-Gr
2-2- Sustainable Construction Activities .						
CR27	Quality Management System	-	2/118	-	1	Greenroads
CR28	Fossil Fuel Reduction	-	1-2/118	-	1	Greenroads
CR29	Non Road Equipment Emission Reduction	2/100	1-2/118	2/100	1	GR-Researcher
CR30	Contractor Warranty	-	3/118	-	1	Greenroads
CR31	Accelerated Bridge Construction Techniques	-	14/100	-	4	Greenroads
CR32	Construction and Demolition Waste Management	1-2/110	-	4/100 1/25	2	LEED-Researcher

CR33	Soil Erosion and Sedimentation Control Plan	-	1/25	6/100	2	Researcher
Category 3 : Material , Resources & Pavement Technologies (MRPT)						
3-1- Material and Resources						
CR34	Life Cycle Cost Analysis	-	-	5/100	1	Researcher
CR35	Life Cycle Assessment (Bridge Life Cycle Impact Reduction)	2-5/110	2/118	-	1	LEED-Gr Researcher-
CR36	Bridge Product Disclosure and Optimization Product Declarations and Certified Wood	2/110	-	1/25 1/100	1	LEED-Researcher
CR37	Bridge Product Disclosure and Sourcing Of Raw Material	1-2/110	-	-	1	LEED
CR38	Bridge product disclosure and Optimization Material Ingredients	1-2/110	-	-	1	LEED
CR39	Earthwork Balance	-	1/118	-	1	Greenroads
CR40	Recycled Materials	-	1-5/118	5/100	1	GR-Researcher
CR41	Regional Materials	1-2/110	1-5/118	3/100 1/25	1	LEED-GR researcher
CR42	Reduction in Quantity of Materials	-	1/25	3/100	1	Researcher
CR43	Material Reuse (Salvaged Materials)	-	-	2/100	1	Researcher
CR44	Corrosion Resistant Steel Reinforcement	-	-	4-8/100	1	Researcher
CR45	Cement Replacement - Supplement Cementations Material	-	-	3/100 1/25	1	Researcher
3-2- Paving Credits						
CR46	Paving Emission Reduction	-	1/118	-	1	Greenroads
CR47	Pavement Reuse	-	1-5/118	-	1	Greenroads
CR48	Long-Life pavement	-	5/118	-	2	Greenroads
CR49	Permeable Pavement	-	3/118	-	1	Greenroads
CR50	Warm mix asphalt	-	3/118	-	1	Greenroads
CR51	Cool Pavement	-	5/118	-	1	Greenroads
CR52	Quit Pavement	-	2-3/118	-	1	Greenroads
CR53	Pavement Performance Tracking	-	1/118	-	2	Greenroads
Category 4 : Energy and Atmosphere (EA)						
CR54	Enhanced Commissioning	2-6/110	-	-	2	LEED
CR55	Optimize Energy Performance	1-18/110	-	-	4	LEED
CR56	Advanced Energy Metering	1/110	-	-	1	LEED
CR57	Renewable Energy Production	1-3/110	-	1/100	2	LEED-Research
CR58	Green power and carbon offset	1-2/110	-	1/25	1	LEED-Research
CR59	Environmental Management System	-	2/118	-	1	Greenroads
CR60	Energy efficiency	-	1-5/118	-	1	Greenroads
Category 5 : Water Efficiency (WE)						
CR61	Runoff Flow Control	2/3/100	1-3/118	1/25	1	LEED-Gr
CR62	Runoff Quality	-	1-3/118	2-5/100	1	GR-Research
CR63	Storm Water Cost Analysis	-	1/118	-	1	Greenroads
CR64	Site Vegetation (Water Use	2/110	1-3/118	-	1	LEED-Gr

	Reduction)					
CR65	Ecological Connectivity (Avoiding and Minimizing Impacts to Fish and Wildlife)	-	1-3/118	1/100	1	Greenroads -Researcher
CR66	Water Use Tracking (Water Metering)	1/110	2/118	2/100	1	LEED-Greenroads
Category 6 : Bridge Maintenance (BM)						
CR67	Efficient Inspection Technologies	-	-	3/100	2	Researcher
CR68	Bridge Painting and Coating	-	-	3-6/100	2	Researcher
CR69	Corrosion Resistant Steel Reinforcement	-	-	4-8/100	1	Researcher
CR70	Corrosion Control Materials	-	-	2-3/100	1	Researcher
CR71	Bridge Cleaning	-	-	1-2/100	1	Researcher
CR72	Bridge Deck Drainage	-	-	1-3/100	1	Researcher
CR73	Bridge Deck Joints and Deck Joint Seals	-	-	1-4/100	1	Researcher
ICC: Innovation & Custom credits						
ICC1	LEED AP	1/110	-	-	1	LEED
ICC2	Innovation (Custom Credits)	5-110	1-10/118	3/25	4	Greenroads
ICC3	Environmental Training	-	1/118	-	1	Researcher
ICC4	Building Under the Bridge	-	-	-	3	Researcher
ICC5	Bridge Rentable Spaces		-	-	2	Researcher
ICC6	Governmental Rules Monitoring of the Bridge's surface			-	2	Researcher
ICC7	Governmental Rules Monitoring of the Bridge's surrounding areas				2	Researcher
ICC8	Regional Priority	1-4/110	-	-	1	LEED
ICC9	Architectural Creativity	-	-	-	2	Researcher
ICC10	Structural Innovative Solutions	-	-	-	2	Researcher
					165	



Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

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Introduction

Throughout this study, bridges history, site selection, context, bridges types, structure systems, construction materials, design process and aesthetical considerations are studied. All these factors form the bridge's architecture. Also bridge sustainability is studied through over viewing sustainability assessment concepts and bridges sustainability previous trials and practices.

After studying bridge architecture and sustainability, the researcher developed a Sustainable Rating System for Architectural Evaluation of Bridges in Egypt in addition to some conclusions and recommendations which should be taken into consideration in the new construction bridges projects.

12-1-Conclusion

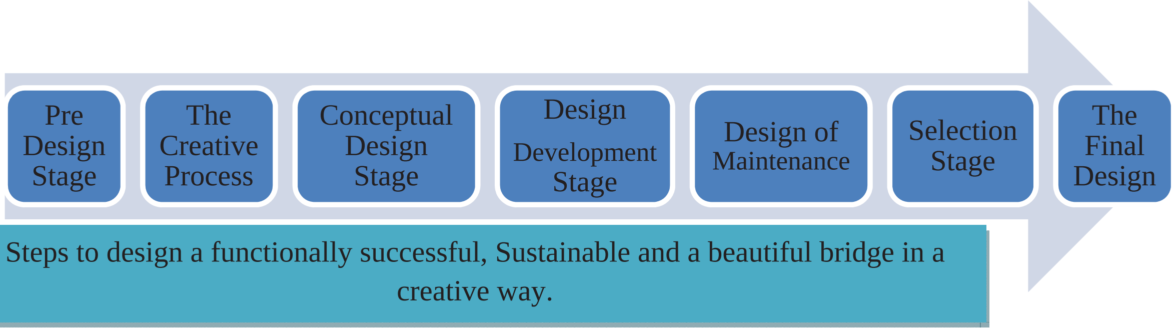
Many solutions to research's problems are introduced through the research. These solutions will be achieved throughout following the concluded and developed rating systems "Sustainable Rating System for Architectural Evaluation of Bridges in Egypt". Also some results are concluded as shown below :

1. Adhering to the developed rating system which is the first step to create a beautiful and sustainable bridge which well achieve its desired function, This rating system is considered a guideline to lead the design team to reach its goals.
2. The importance of architect role in bridge design, construction and operation process to dominant these process and coordinate between all other team members including civil, structural, mechanical, electrical engineers, bridge owner and users.
3. Bridge architectural design is not only depends on its appearance, but also it depends on the degree of its function performance.
4. Several design solutions are often available for most situations. Therefore, a selection of a design solution has to be the optimum solution not only a possible solution.
5. In mega projects like bridges which consume money, time and resources, decisions are impossible to be taken throughout one person due to the large volume of work and different specialists. Hence the integrated design team plays a very critical role in discussing every single decision taken by specialists to reach to the optimum solutions.
6. Before design phase, all basic information should be available, Functional, aesthetical, sustainable goals and priorities should be defined to guide the design team to take the best solutions and achieve the bridge's desired function. This phase is called "Pre-design phase", which is very important to guarantee creating the most beautiful and sustainable bridge and well achieve desired functions with the lowest price in less time.
7. To achieve bridge sustainability, sustainable sites, sustainable transportations and sustainable construction activities must be integrated. Also materials, energy, water efficiency and bridge maintenance should be formulated through an integrated design, construction and operation process by the integrated design/construction teams.
8. Economics is a fundamental consideration in design/construction process, structure type selection, construction materials/methods and all design decisions but it shouldn't be the only consideration to avoid creating ugly or useless bridges.

9. "Sustainable bridge" doesn't necessarily mean expensive bridge. Sustainability may need extra costs in the beginning, but more costs will be paid back during bridge life through its operation, low cost maintenance and end of life usage solutions.
10. Bridge location is considered as one of the main factors affecting bridge function and form, therefore studying the bridge site, context, surrounding area and natural or constructed delimiters is very important to guarantee a successful bridge.
11. In case of constructing a new bridge next to an existing/ historical bridge or creating a bridge in a historical district, a careful study should be developed to respect and preserve the history.
12. Bridge architectural character should be defined as of the beginning of design stage, This character should consider bridge site, architecture character and any other design, function or budget limitations.
13. Bridge original function should be well defined and respected in the pre-design stage. Also bridge further functions by community should be expected and considered in the bridge design.
14. Any bridge is considered a road extension to cross any obstacle, so bridge context sensitive design and solutions should be proposed through respecting the surrounding roads hierarchy, capacity, width, etc.. to well achieve its desired function without having adverse impacts on the surrounding road's functions.
15. Bridge is considered a civilian facility which consists of many components. The most important component is its structure. That is why structure system, construction materials, methods and structural parts are very important to bridge architecture.
16. The available construction techniques have significant influence on the selection of the most suitable class of bridge for a particular site so it is important that the designer should at an early stage be aware of the various construction techniques that are economically viable, as well as their advantages and disadvantages.
17. Although feasible configurations of bridge structure are largely dictated by forces and actions on bridge and properties of construction materials, there are usually almost unlimited possible variations in structure systems types, proportions and forms. The designer should select a safely optimum structure system, identify structure parts proportion and form through considering aesthetic improvement within a specific budget.
18. Bridge parts are divided into structural and non structural parts, each of them has different character, function and design considerations which should be considered and coordinated against each other to create a compatible entity which is regard as an addition to the bridge surroundings.
19. Beauty could not be derived from some simple shortcuts but it depends on a large number of aesthetical values and qualities. Therefore the aesthetical considerations have a major effect on bridge shape and form, Aesthetic design objectives should be defined, Fundamentals of aesthetical design and aesthetical qualities should be met in a creative way to design a pleasant bridge.
20. The four "Rs" (reuse, reduce, recycle and regional materials) are the main factors of sustainable materials, which should be used in sustainable bridges due to their easy maintenance and replacement, low transportations cost. They decrease energy consumption in material's manufacturing and transportation.
21. Bridge monitoring during construction and operation stages is highly important to observe bridge success or failure in achieving its function, deal with new further functions, sustain bridge safety and aesthetics and decrease bridge maintenance or replacement costs.

12-2- Recommendations

The main purpose of this research is to design a pleasant and sustainable bridge which successfully achieves a desired function in a creative way. To reach this purpose an Egyptian Sustainable Rating System to Evaluate Bridges Architecture is developed. Several steps should be followed to design a successful bridge in a creative way:



Steps to design a functionally successful, Sustainable and a beautiful bridge in a creative way.

A.Pre-Design Stage

The architect role is very important in this stage. In this stage, design team should :

- Define bridge functional, aesthetical and sustainable goals.
- A preliminary data is needed at the beginning of the bridge pre-design process.
- A plan of site showing all obstacles (streets, rivers, roads, etc..)
- Bridge required number of lanes, bridge width, future expansions, etc.. should be determined.
- Soil conditions data for foundations, local regulations, weather, environment and topography should be considered.
- The expected cost is compared to the specified budget.
- Design team should be well selected in this stage

B. The Creative Process :

After studying the design data, designer should imagine the first shape of bridge then convert the imagination to a preliminary sketch. This sketch is to be developed several times to reach the most acceptable sketch ready to be blown up to add details. It is better to make several proposals to choose the perfect proposal after seeking the consulting of the design team. Most of bridges design developed in section not plan and after some trials 3D modeling would be preferable.

C. Conceptual Design Stage:

In this stage, co-operation between architect, civil engineer and the rest of the design team members is significant to decide the perfect structure system and innovative material or innovate new shape of existing structure system.

Also design team should have a combination of innovative mental attribute for deductive and intuitive adapting of proposed several concepts.

D. Design Development Stage:

This stage is the calculation stage, designers and engineers verify safety, function, beauty, cost, sustainability, etc. This includes the following:

- Design stage that gives rise to structure and durability problems.
- Design details that cause difficulties for inspection.
- Aspects of durability that satisfy rules in stimulated design codes.
- Applying all developed rating system categories will be commenced in this stage to

be resumed in later stages.

E. Design of Maintenance Stage:

The designed bridge should be maintainable and a maintenance plan should be approved.

F. Selection Stage:

It is a very significant stage. It consists of a search for optimal solution through identification of possibilities, followed by evaluation and comparison, make to the final decision. Also most appropriate materials calculating Whole life cost versus initial cost will be used.

G. Final Design Stage

After design approval, the final design work can begin with rigorous calculations of forces, stress, loads, etc.. Also, mechanical equipment, construction methods, maintenance and inspection issues, materials and finishing quality, etc...

After these stages, there are construction, operation and maintenance stages which should comply with the approved construction and maintenance plan, and regular inspection should be conducted to guarantee adherence to the rating system and achieving the desired goal. There are some recommendation to be taken into consideration during the bridge design, construction and maintenance stages which will be discussed below:

❖ **Functional Recommendations**

- Well studying bridge site, bridge characteristics and bridge main and developed functions.
- Bridge parts and details should be compatible with each other. Every part in a bridge should realize its targeted function and all these parts should unified to achieve the bridge designed function.
- Bridge shape and form to suit, serve and express bridge function for example railway bridges, in accommodating the heavy weight of trains should generally appear strong and need to be stiffer than road bridges.
- Bridge width to follow road width at its starting and endings to avoid car rush to facilitate desired function.
- All safety considerations for cars, pedestrians and the bridge itself should be checked and local regulations must be complied with.
- Bridge future expansions should be taken into consideration to assimilate future growth.
- Further functions to the bridge and under the bridge (pedestrians in vehicle bridges, street vendors in pedestrian bridge, etc..) should be considered, and solutions should be provided.

For pedestrian bridges :

- Bridge parts should follow "Anthropometry" human body scale" at all details (bridge and stairs width, handrails, etc..)
- Bridge design should stick to architectural standards at (ventilation and lighting windows, stair's steps numbers, steps dimensions tread and riser, etc..
- Stairs width should be the same as bridge width to avoid people rush.

- Bridge design should consider old people and handicaps, so elevators/escalators must be applied to the bridge design.
- Bridge's handrails should adhere to the safety regulations and the bridge's design concept.
- For pedestrian bridge entrance, good and strong material should be used as marble and granite. The entrance should also be obvious with an attractive design and reflecting the bridge function and architectural character.
- For pedestrian bridge flooring and stairs, strong materials should be used to endure the permanent friction.
- For pedestrian bridges roof, a soft material should be used to be protected from dust sticking.
- The attitude of the bridge's neighborhood population should be studied to be taken into consideration to accomplish the maximum comfort for these population, feeling that the new bridge is an addition to their neighborhood to be carefully use it.
- The area around the bridge is to be thoroughly studied, the major activity of the surrounded community is to be taken into consideration. Strict laws should be applied to protect farmlands around bridges (The Ring Road informal housing surrounding).
- Social and religion considerations are to be well thought-out (as example bad effect of bridges on surrounding houses in Ring Road and 6th of October Bridge).

❖ **Aesthetical Recommendations**

- Architects should be engaged in the starting of the bridge's design process.
- Textures, colors and materials should be coordinated against bridge surroundings either to be in line with or in contrary to the surroundings to make a contrast. They should be appropriate to the color theme of the surrounding site.
- The architectural character for bridge location is to be discussed to make a link between the bridge and the surrounding community.
- The architectural character of the location should be taken into account.
- The bridge should be compatible to the surrounding buildings styles to enhance the visual image of the site. This could be accomplished by avoiding all the visual pollution reasons such as (bad material textures, bad colors, bad maintenance, etc)
- Bridge design should follow rules of aesthetical values such as (ratios, scale, rhythm, etc.) Also The designer should abide by general ratios rules (golden ratio, module, etc)
- Structure elements aesthetical treatment is to be studied to mitigate structure tough relationships.
- Bridge entrances should be obvious. Also forces in structure system should be confirmed by aesthetical treatments.
- Keep the bridge as long and slender as practical. Ramps should also provide a smooth and continuous geometric flow. Sharp breaks and odd angles should be avoided.
- Provide as low a parapet as is possible. The structure is more slender and opportunities for graffiti are reduced.
- Keep the design of the pedestrian screen simple to offer more open appearance

There is no single design parameter that controls the general physical characteristics of a bridge. An attractive bridge is the orchestration of design

parameters employed simultaneously to complement each other. Designers can interpret these design parameters to constitute principal aesthetic design factors.

Principal Aesthetical Design Factors: these factors fashion the visual basis upon which the balance of the appearance is built. Designers should concentrate on developing the best design solutions for these design parameters prior to considering other visual treatments. To find the best design solution, designers must consider the aesthetic objectives outlined previously when making decisions regarding these design parameters.

- Superstructure type and shape.
- Vertical and horizontal geometry and their relationship to the surrounding environment.
- Pier placement and shape.
- Abutment placement and shape.
- Interaction between the bridge and its surroundings/ environment.
- Appearance of strength and stability.
- The users of bridges have to feel safe and consequently it must not only in facet be strong and stable, but it becomes an aesthetic requirement that its visual form must generate a sense of security by appearing to be so.

Secondary Aesthetical Design Factors: these factors can be used to accentuate the positive qualities that have been treated with the principle aesthetic design factors. The texture, color, and shape can be engaged to draw attention to, or to detract from, the role of structural elements. These factors should consider aesthetical design considerations. These secondary factors such as:

- All-non structural parts and details as (railings, noise walls, safety screens, lighting, joints and access hatches, etc..)
- Surface colors, textures, Concrete surface quality, Cladding and architectural embellishments.

❖ Structural Recommendations

- Bridge structure system should be chosen according to many factors (bridge span, architectural design, budget, loads and function)
- Selecting the most appropriate material for both structure system and budget.
- Bridge structure design should be coordinated between civil engineer and architect.
- Using long live structure materials which need minimum maintenance to be suitable for the environment (humidity, rain, dust, etc..)
- Structure system should be coordinated against the bridge design, shape, form and aesthetics.

❖ Bridge Sustainability Recommendations

- To design a sustainable bridge, three major steps should be taken: sustainable design, sustainable construction and sustainable maintenance. Every step should be studied to be connected to the next step.
- Determining sustainability goals for designing a sustainable bridge is very important to determine the appropriate approaches to achieve sustainability.
- Mostly important, sustainable bridge design criteria will include these items (sustainable sites, water and energy efficiency, materials and resources conservation and design innovation), Each of these criteria should be studied to be taken into consideration during bridge design, construction and maintenance.

12-3- Subsequent Studies

This study is considered a start that should be continued and developed to increase bridge design awareness in Egypt. Consequently, many studies should be done in the future. These studies can be concluded as below :

Subsequent studies for architects :

- This research is considered a guideline to the bridge design team to evaluate new construction bridge's function and aesthetics in Egypt. It is also considered just a start in the sustainable bridges field in Egypt. This start needs to be developed to enable the design team to evaluate the Egyptian existing bridges to facilitate renovation and replacement. So next research will be developing a sustainable rating system for architectural evaluation of existing bridges in Egypt.
- Spread awareness between architects about the importance of architect role in bridge design and construction process and bridge design should not be totally dedicated to structural engineer. Since bridge is like any other construction, it needs to achieve its desired function in a safe way and fine shape and form.

Subsequent studies to the government:

- The next step is submitting this rating system to the Egyptian General Authority for Roads and Bridges and The Egyptian Ministry of Transport to include this rating system as a part of any new bridge authorization process in Egypt.
- This study should also be delivered to the responsible entities in Egypt to be developed by expertise from different specialties in order to be applied to the existing construction bridges through Egyptian roads and bridges development plan.

Subsequent studies for public :

- Awareness of bridge aesthetics importance should spread between public users. Because of the proliferation of ugly bridges, people thought that the default bridge is an ugly construction whish has a function to transport passengers between two points over any obstacle. A bridge is a beautiful structure that should be considered an addition to the city's visual image and has other social and economical functions in addition to its basic function of passengers transportation .
- Increase the interest of Egyptian young people and students to learn more about bridge structure systems and aesthetics. For example, there is a "Bridging our future by Intel" experience in USA, Intel computer appliances company offers an experience to students for using technology to collaborate with peers and industry experts to build a bridge model, from the initial design phase through the final structure testing.[1]

  There is also "Bridges: Amazing structures to design, build and test (Kaleidoscope Kids)" book which Describes different kinds of bridges, their history, design, construction, and effects on populations, environmental dilemmas, safety being studied at USA schools.[2]

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1 - https://www.youtube.com/watch?v=BYMd-7Ng9Y8

2 - http://www.scholastic.com/teachers/book/bridges-1#cart/cleanup

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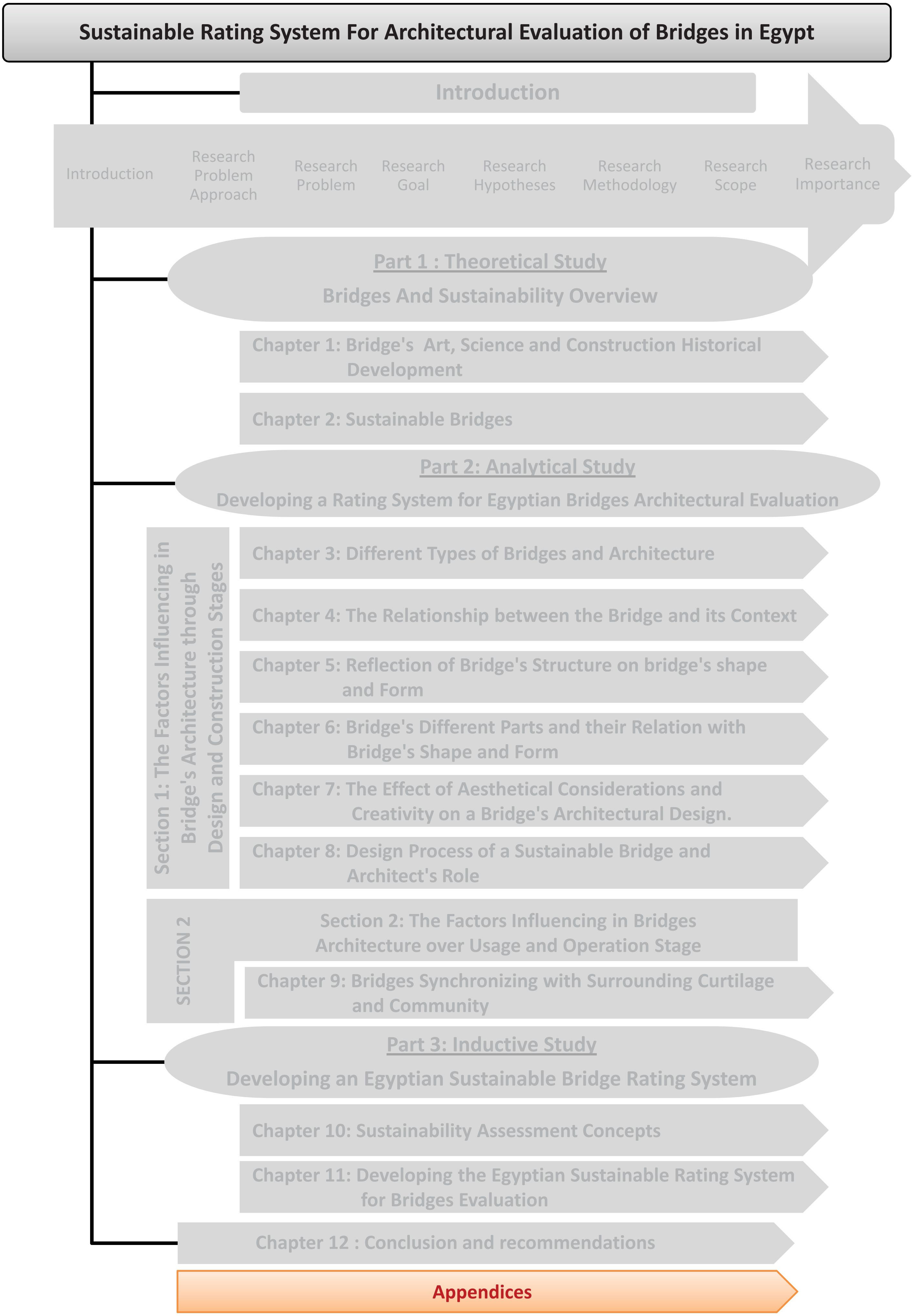
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Introduction

The focus of this section is to demonstrate the previously developed rating system under study to assist bridge engineers, design team, construction team and operation team in developing more sustainable design and construction processes for new bridges and to architecturally evaluate the same.

This section consists of four parts; first part "Appendix A" includes the architectural evaluation prerequisites, the second part "Appendix B" consists of the sustainable evaluation prerequisites, the third part "Appendix C" entails the architectural evaluation credits and the forth part "Appendix D" deals with the sustainable evaluation credits. Architectural prerequisites and credits are developed by the researcher over this study chapters adding a new criteria for bridges aesthetics, function and curtilage evaluation. Sustainability prerequisites and credits are developed based on two existing rating systems LEED V4 for BD+C (sustainable building rating system) and Greenroads V1.5 (sustainable roads rating system). Also some credits are developed in this part to add a new criteria for the evaluation of bridge sustainability.[1]

Rating System Structure:

This rating system could be applied on any new construction bridge “pedestrian, vehicle or railway bridge "to evaluate its architecture and sustainability, it is divided into these main categories:

Architectural evaluation categories:

- **Bridge Site:** Have the design team well studied the site?
- **Bridge structure:** The reflection of the bridge's site, function, design and loads on the selected structure system, construction materials and methods.
- **Bridge parts:** The harmony between bridge parts to achieve function, aesthetics and sustainability goals.
- **Bridge aesthetics:** How to make a good looking bridge?
- **Bridge curtilage**: The reflection of a bridge on the surrounding site after operation and usage.

Sustainability evaluation categories:

- **Location and Transportation:** Does the location preserve environmentally sensitive places and take advantage of existing infrastructure, community resources, and public transit?
- **Sustainable sites and construction activity:** Is the selected site able to maximize sustainability? How to achieve sustainability through site and construction activities?
- **Materials, resources and pavement technologies:** Are the bridge materials and pavement sustainable for the environment, and where does the waste go?
- **Energy and atmosphere**: How to save energy, cut energy costs and encourage green energy development and use?
- **Water efficiency:** What can be done to save on landscaping water use and operation water use?
- **Bridge maintenance:** How to make the bridge operate as long as possible with full capacity?

Innovation and custom credits: what can be discovered to add even further value to the project that is not subject to the rating system?

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[1] Note: For detailed criteria and requirements please refer to the main prerequisite/credit at LEED, Greenroads or mentioned references of every prerequisite/credit reference guide.

Prerequisites and Credits

Prerequisites: Prerequisites do not earn bridge project any points because they are required for the project to be considered. The term “prerequisite" refers to mandatory project characteristic, measurement, quality, value or function as identified within the rating system. Prerequisites represent the key criteria that define successful bridge performance. Each project must satisfy all specified prerequisites outlined in the rating system under which it is registered. Failure to meet any prerequisite will render a project ineligible for certification.

Credits: Each category has a group of credits that defines a particular sustainability, aesthetical or functional goals. The goal is referred to as the ‘intent’ of the credit. In fact, in these appendices just below every prerequisite/credit name is a section titled ‘intent’ where the credit goal is defined and a "requirement" is referred to how to achieve the credit/ prerequisite also the references which source and standards of the credit /prerequisite.

A bridge project does not have to score all credits. Credits are optional elements. A bridge Project only needs to score enough credits for the certification level the project is aiming for (certified, silver, gold, or platinum). The word “Credit" means a non-mandatory project characteristic, measurement, quality, value or function as identified within the rating system.

Scoring Criteria

Project Certification: There are four levels of certification:

- Certified: 50-74 points
- Silver: 75-99 points
- Gold: 100-124 points
- Platinum: 125+ points from 165

A project must satisfy two requirements for certification:

1. Satisfy all prerequisites
2. Satisfy a combination of credits that realize a certain number of points for the desired certification level.

Credit weightings: Points are available in each of the credit categories, and the points are weighted to best address the social, environmental, and economic outcomes identified by the original rating system or from a researcher point of view (in case of credits based on specific or several rating systems, the researcher takes the average weighting from the original rating system and compare it with Egyptian sustainability goals. In case of credits developed by the researcher, their importance are evaluated and given the appropriate weight according to their importance.

Credits have different weightings depending on their ability to impact different environmental, aesthetical, functional, economic, social and human health concerns. More points are awarded for these credits that have a greater impact. The impact categories answer the question: “What should a successful bridge accomplish?”

- Achieve the desired functions and adapt the added ones.
- Evaluate selected structure system, construction materials and construction methods to meet desired goals.
- Understand aesthetical goals, requirements, qualities and values.
- Reverse contribution to global climate change.
- Enhance individual human health and wellbeing.
- Protect and restore water and energy resources.

- Protect, enhance and restore biodiversity and ecosystem services.
- Promote sustainable and regenerative material resources cycles.
- Build a greener economy.
- Enhance social equity, environmental justice, and community quality of Life.

All credits could achieve exemplary performance and earn extra points by exceeding the original requirements to achieve the credit, as an example for renewable energy credit, maximum points are 3 points by creating 10% of the whole bridge energy from a renewable resource. But what if 15% renewable energy is generated, more points will be earned/scored.

General Notes:

- All architectural evaluation credits are created and developed by the researcher, and to best understanding these prerequisites/ credits please refer to the mentioned chapters at every prerequisite/credit.
- Reports are prepared with regard to the credits and prerequisites and final score card achievement to be calculated by bridge design team and be revised and approved by an accredited committee authorized by a certified Egyptian engineering school or any accredited engineering office. This committee job is to double check all achieved prerequisites and credits to certify the bridge project for the final score (Platinum, Gold, Silver or Certified)

Appendix A: Architectural Evaluation Prerequisites

AP1: Bridge Goals Analysis: (Design Process- Chapter 4)

Intent: To determine the main and secondary goals of a new bridge for perfect accomplishment. This goals must contain functional, aesthetical, special and sustainability factors.

Requirements: An integrated report concludes all main and secondary goals of a new bridge. This report help the design team to make priorities according to budget, determinants and circumstances. Also it helps the design team to choose the perfect structure system, construction materials and methods and optimum design solutions.

AP2: Bridge Design/ Construction Proposals: (Design Process- Chapter 8)

Intent: Choosing the best bridge design according to project delimiters

Requirements: At least three design/construction proposals should be offered and reasons for selection or denials of such depend on the project delimiters (aesthetical and functional goals, site, budget, codes and regulations, etc..).

AP3: Integrated team members and architect role: (Design Process- Chapter 8)

Intent: Integrity is one of the most important factors for achieving sustainability in a bridge project.

Requirement: A report to show the integrity between bridge owner, project manager, architects, design team members, project construction team members, project contractors, suppliers, etc. This report should illustrate every member's role, responsibilities and permissions especially project architect.

AP4: Bridge Integrated Costs: (Design Process- Chapter 8)

Intent: Preliminary calculations for bridge costs to be compared with the bridge budget to select the optimum design solutions within the budget.

Requirements: One of the major factors affecting bridge architecture and sustainability is the project budget, so in this prerequisite a report contains all design, construction, sustainability costs to be calculated and compared to the preliminary budget and design goals to set priorities to be submitted in order to achieve the safest, most pleasant and sustainable bridge within budget.

AP 5: Bridge Main Functions (Bridge Function- Chapter 3)

Intent: to reach the main goal of bridge construction and well achieve the desired function

Requirements: Bridge main function/ functions and the expected benefits from these functions to the community to be approved by design the team (Pedestrian, vehicle, railway, etc...).

AP6: Bridge Expected Future Functions: (Bridge Function- Chapter 3)

Intent: To design a flexible bridge which could adapts with new functions without Affecting on main function.

Requirements: future further functions according to the bridge location, bridge users or the surrounded community to be expected and submitted. Also the effect of these functions on the bridge's main function, architecture and curtilage are well studied and solutions are proffered. This prerequisite should be submitted for approval as a report showing main activities at the surrounding areas, bridge user main activities, an example of similar existing bridge case study and further functions.

AP7: Bridge Functions Achievement: (Bridge Function- Chapter 3)

Intent: To evaluate bridge success in achieving its targeted function.

Requirements: After construction, operation and usage, an evaluation should be executed to assess bridge success in achieving the designed function and its ability to contain the further functions, Also solutions are proposed for any functional problems.

AP8: Taken Considerations to Achieve Functions: (Bridge Function- Chapter 3)

Intent: Increment bridge ability to the best functional achievement.

Requirements: Define all added techniques to help a bridge in achieving the targeted function such as elevators, escalators and stairs to pedestrian bridges; walkways, lanes and entrances or exits for vehicle bridges. These techniques shall be in accordance with local codes.

AP9: Safety Codes: (Bridge Function- Chapter 3)

Intent: To preserve bridge user life and bridge itself.

Requirements: The bridge should fulfill all safety requirements of local codes (Fire resistance materials, firefighting procedures, first aid techniques for accidents, etc.) which should be submitted for approval and attached with the applicable local codes..

AP10: Bridge Site Background and Analysis: (Bridge Site- Chapter 1)

Intent: Guarantee creating a compatible bridge with its surroundings.

Requirements: a full study of bridge site history, architectural character and any historical facilities revealing in this study the bridge's relationship with such surroundings. This study contains any factors affecting the bridge's structure, architecture or sustainability.

AP11: Relationship between Bridge and Road Networks: (Bridge Site- Chapter 4)

Intent: To coordinate the interchanges between bridge and the surrounding roads network to avoid traffic jam which affects the bridge's functional success.
Requirements: A full study of road network hierarchy from/to the bridge, also studying road width, from and to the bridge to determine the bridge width to guarantee the best function for both and to avoid traffic jam. In case of pedestrian or vehicle bridges, a report which illustrate the relationship between bridge entrances, stairs, bridge structure, etc.. And the surrounding roads should be submitted for approval.

AP12: Site Natural Delimiters: (Bridge Site- Chapter 4)

Intent: To insure the best harmony between newly constructed bridge and the surrounding natural delimiters.
Requirements: Well understanding the site natural delimiters (rivers, seas, land farms, etc..) and the bridge design according to such delimiters (dimensions, construction materials and methods, foundations, shape and form and sustainability).

AP13: Site Constructed Delimiters: (Bridge Site- Chapter 4)

Intent: To insure the best synchronization between newly constructed bridge and surrounding constructed delimiters.
Requirements: well studying the constructed delimiters such as current bridges, buildings tunnels, etc.. And the design criteria to best accommodate these delimiters.

AP14: Context Sensitive Design and Solutions: (Bridge Site- Chapter 4)

Intent: Reaching to the best traffic solutions and the best function achievement
Requirements: An approach of context sensitive design and solution plans. These plans are to be designed, discussed and approved by the bridge design team.

AP15: Historical Sites/Bridge Treatment: (Bridge Site- Chapter 4)

Intent: To preserve the historical site/ bridge and to consider new bridge as an addition to these historical sites/bridges.
Requirements: An integrated plan to demonstrate the relationship between new bridges and historical or existing bridge or any other historical sites/facilities and the precautions taken to preserve these historical sites/facilities.

AP16: Bridge Surroundings Character: (Bridge Site- Chapter 4)

Intent: Creating a compatible visual image of the bridge and its surroundings
requirements: when designing a bridge in a site with architectural character or local character, a plan to demonstrate the relationship between bridges and this local/ architecture character is be submitted for approval.

AP17: Expected Bridge Effect on the Curtilage: (Bridge Site- Chapter 4)

Intent: guarantee the best relationship of the bridge and the surrounding curtilage
Requirements: The expected problems from constructing a new bridge on an existing Curtilage as (crowdedness, informal usage of area under or around the bridge, bad effects on surrounding buildings, etc...) to be well studied and proposing solutions to such problems for approval.

AP18: Construction Materials Selection: (Bridge Structure- Chapter 5)

Intent: To save material resources and achieve value engineering and to achieve the best aesthetical and functional considerations.

Requirements: A full study of the selected construction material. This study should include the following: Value engineering study, operation and maintenance plan, material specs safety reports, and aesthetical treatment of these materials.

AP19: Structure Systems Selection: (Bridge Structure- Chapter 5)

Intent: Selecting a structure system which best achieve safety and cost requirements within the architectural and sustainable design framework.

Requirements: Different structure systems alternatives should be proposed for the final selection of the structure system accomplished by the approval explanation for this selected system.

AP20: Construction Methods Selection: (Bridge Structure- Chapter 5)

Intent: Selecting a construction method which optimum achieve safety and cost requirements within the architectural and sustainable design framework

Requirements: A comprehensive study of the effect of the selected construction method on bridge architecture, sustainability, site, quality and time schedule should be prepared by bridge design team to be submitted for approval.

Note: To achieve these three prerequisites AP 18 to AP20, A study should be done and revised by the design team, containing the bridge site plans, site pictures, site history from local competent authorities and a survey filled by bridge surrounding residents should be submitted for approval.

AP21: Bridge Parts Architectural Integration: (Bridge Parts- Chapter 6)

Intent: To guarantee the integration between bridge parts.

Requirements: An integrated report defining the bridge structure and nonstructural parts selection, properties and the integration between these parts to reach to the best architecture for the bridge. This report should contain all bridge drawings, and all bridge parts specifications.

AP22: Bridge Aesthetical Considerations: (Bridge Aesthetics- Chapter 7)

Intent: Designing a bridge which follow aesthetical considerations.

Requirements: An integrated report showing the aesthetic design, qualities, visual design elements, visual characteristics, creativity considerations and the integration between these aesthetical considerations to ensure best bridge shape, form and aesthetics.

AP23: Bridge Fundamentals of Aesthetical Design and Aesthetical Qualities: (Bridge Aesthetics- Chapter 7)

Intent: Submit the applied aesthetical design/qualities to guarantee the best bridge shape and form

Requirements: Achievement of aesthetical qualities (proportion, rhythm, order, harmony, balance, contrast, scale, unity, illusion, simplicity and consistency) should be checked. Also the integrity between these qualities should be presented and demonstrated.

AP24: Aesthetical Design Objectives: (Bridge Aesthetics- Chapter 7)

Intent: Decide the aesthetical design objectives and goals to guarantee best bridge shape and form.
Requirements: The applied aesthetical design objectives and goals (functional clarity, scale and proportion, simplicity and continuity, order and balance, site/ environmental integration, refining the form, bridge architecture character, shade and shadow, fulfillment the purpose, reflections, symmetry and asymmetry) should be decided as of design stage and to be tracked through the bridge's design, construction and maintenance stages.

AP25: Bridge Visual Design Elements: (Bridge Aesthetics- Chapter 7)

Intent: Selection of the most appropriate visual design elements for the bridge
Requirements: A study of visual design elements selection reasons (color, concrete quality, texture and patterns, brick, stone and other nonstructural materials and finishes, ornamentations) according to the bridge site, history, surroundings, design goals, etc.. Should be provided.

AP26: Bridge Aesthetical considerations integration: (Bridge Aesthetics- Chapter 7)

Intent: To guarantee the integration between all bridge aesthetical considerations and quality to achieve the best architectural design for the bridge.
Requirements: An integrated report showing all bridge aesthetical considerations and qualities and the integration between them to reach to the best architecture for the bridge. This report should contain all bridge drawings.

Note: To achieve the prerequisites from AP22 to AP25, All bridge drawings attached to the elaborated report which demonstrate the selected aesthetical qualities and how these qualities achieve the previously defined aesthetical design objectives and the aesthetical design goals.

AP27: Bridge Curtilage Development Report: (Bridge Curtilage- Chapter 9)

Intent: Bridge development and deterioration observation
Requirement: A monthly report describing (bridge parts required to be maintained, bridge aesthetics, infringements on bridge curtilage, Infringements on surrounding lands or any other natural or constructed delimiters, etc..) should be submitted, Also solutions for any problem should be proposed and procedures to solve that problem should be taken.

AP28: Synchronizing with the Surroundings (Bridge Curtilage- Chapter 9)

Intent: Newly constructed bridge should be part of the whole site image as a beautiful addition.
Requirements: A full study showing the relationship between the bridge design and the surroundings (Natural and constructed delimiters, context, etc...). This study should highlight the bridge value to the surrounding context and how the designer well use the surrounding site.

Appendix B: Sustainability Evaluation Prerequisites

PR1: Environmental Review Process Greenroads

Intent: Evaluate impacts of bridge projects through an informed decision making process.

Requirements: Perform and document a comprehensive environmental review of the bridge project. This review should clearly and concisely document:

1. Project name and location.
2. Names and contact information of key players in the decision making process, including (but not limited to): the owner agency, agency representatives Responsible for completing the environmental review process, other stakeholders, and relevant professionals involved.
3. Intent and purpose of the bridge project.
4. Descriptions of potential environmental, economic and social impacts of the Intended bridge project.
5. Detailed descriptions of the extent of the significance of these impacts with respect To the decision making process and feasible performance expectations.
6. Description of the public involvement opportunity in the environmental review process; document this opportunity and the results of input in the final decisions.
7. Any jurisdictional requirements for more detailed environmental review documents such as environmental impact statements (EIS) or environmental assessments (EA)to determine the significance of environmental impacts.
8. Description of the final environmental decisions made. Table A-1

Table A-1: Topics Addressed by an Environmental Review Process

Topics Addressed by an Environmental Review Process															
Earthen materials	Air	Water	Plants	Animals	Energy	Human health and safety	Noise	Land and shoreline use	Housing	Aesthetics	Light and glare	Recreational, historic, cultural resources	Transportation	Public services and utilities

Reference:

1. Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R., andSöderlund, M. et al. (2011). Greenroads Rating System v1.5. (J.L. Anderson and S.T. Muench, Eds.). Seattle, WA: University of Washington. p29:38.
2. http://www2.epa.gov/nepa/national:environmental:policy:act:review:process

PR2: Lifecycle Cost Analysis Greenroads

Intent: Determine the lifecycle cost for the bridge project to aid in decision making.

Requirements: Perform a life cycle cost analysis (LCCA) of the bridge project. LCCA must contain at least agency costs and work zone user costs. LCCA can be performed with manual calculations or by using recommended software, do one or more of the following to determine input values for software:

- Justify the use of any default inputs
- Use historical data as representative values where available
- Use engineering estimates
- Use values recommended for select software where noted at main prerequisite in Greenroads reference guide

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA- 2010- p39:46.

2. FIELDS. TIM and Others: Guidance on Life Cycle Thinking and Its Role in Environmental Decision Making, Sustainable Materials Management Coalition, Sustainable Materials Management Coalition, - USA- 2014 https://www.michaeldbaker.com/wp:content/uploads/2014/03/Guidance:on:Life:Cycle:Thinking:031014.pdf
3. National Cooperative Highway Research Program (NCHRP) Report 483- 2003 http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp rpt 483.pdf

PR3: Lifecycle Inventory Greenroads

Intent: Incorporate energy and emissions information into the decision making process for pavement design alternatives.

Requirements: Complete a lifecycle inventory for the final pavement design alternative for the project using the software tool Road print, created by Dr. Yen□Yu Lin at the University of Washington, or approved equivalent software. Report only results for total energy use and global warming potential (GWP) (in carbon dioxide equivalent emissions, CO2e) for the final pavement design alternative.

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- PR3.
2. Lin.Yen:Yu: “Eco:decision Making for Pavement Construction Projects”- Phd Thesis- Department of Civil and Environmental Engineering- University of Washington- USA-2012.

PR4: Quality Control Plan: Greenroads

Intent: Have a process in place to monitor and improve construction quality.

Requirements: The prime contractor shall establish, implement, and maintain a formal construction Quality Control Plan (QCP). The QCP must follow local regulations and address the following quality control elements:

1. Key quality control personnel, their responsibilities and their qualifications (resumes, certifications, etc.).
2. Procedures used to control quality during construction including (as a minimum):
   a. Items to be monitored (including pavement mix designs)
   b. Testing to be done (including testing standards and frequency)
   c. When corrective action is required (action limits)
   d. Procedures to implement corrective action
   e. Procedures to modify QCP if ineffective or when modifications are necessary

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p65:68.
2. http://www.wfl.fhwa.dot.gov/resources/construction/field notes/documents/d 02 15.pdf.
3. http://www.dot.state.fl.us/construction/manuals/cpam/CPAMManual.shtm
4. http://www.highways.gov.sk.ca/standard test

PR5: Noise Mitigation Plan Greenroads

Intent: Reduce or eliminate annoyance or disturbance to surrounding neighborhoods and environments from road construction noise.

Requirements: Establish, implement, and maintain a formal Noise Mitigation Plan (NMP) during construction for the prime contractor.

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p69:78.
2. http://nyc.gov/html/dep/pdf/noise mitigation.pdf.
3. http://nyc.gov/html/dep/pdf/noise alternative mitigation.pdf
4. http://nyc.gov/html/dep/html/noise/index.shtml
5. Barksdale, R. D: “The Aggregate Handbook. Washington”- D.C.: National Stone Association.-USA-1991.

PR6: Waste Management Plan / Construction and Demolition Waste Management Planning: Greenroads / LEED

Intent: To reduce construction and demolition waste disposed of in landfills and

Incineration facilities by recovering, reusing, and recycling materials. Also create an accounting and management plan for road construction waste materials.

Requirements: Develop and implement a construction and demolition waste management plan and Establish, implement and maintain a formal construction and demolition waste management plan (CWMP) during bridge construction. The CWMP should be included in the project contract documents.

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA- 2010- p69:78.
2. Bremner, P. and City of Vancouver Engineering Services. " Road construction waste: to landfill or recycle? There is no question. In proceedings of Transportation Association of Canada 2006 Annual Conference and Exhibition. Session: 2005 TAC Environmental Achievement Award Nominations. Accessed October 22, 2008. Available at http://www.tac□atc.ca/english/resourcecentre/readingroom/conference/conf2006/docs/s007/bremner.pdf
3. (2013), LEED Reference Guide for building Design and construction V4, p479:484
4. (2015), LEED version 4 for building design and construction, p 87
5. King County Solid Waste Division and Seattle Public Utilties.- 2007. Available at: http://your.kingcounty.gov/solidwaste/greenbuilding/documents/ConGuide.pdf

PR7: Pollution Prevention Plan / Construction Activity Pollution Prevention Greenroads / LEED

Intent: Reduce pollution and associated effects from construction activities by controlling soil erosion, waterway sedimentation, and airborne dust.

Requirements: Create and implement a comprehensive Storm water Pollution Prevention Plan (SWPPP) or Temporary Erosion and Sedimentation Control (TESC) plan that conforms to the requirements of the current Environmental Protection Agency (EPA) Construction General Permit OR the local or state Construction General areas that manage their own permitting plan, whichever is more stringent. The SWPPP/TESC must address water quality control and dust control activities used during construction of the bridge project.

Reference:

6. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA- 2010-p91:94.
7. "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 201٥- p 31
8. "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013, p139:145
9. http://cfpub.epa.gov/npdes/Stormwater/swppp.cfm
10. http://www.epa.gov/npdes/pubs/sw swppp template authstates.doc
11. http://water.epa.gov/polwaste/npdes/stormwater/EPA:Multi:Sector:General:Permit:MSGP.cfm

PR8: Low Impact Development Greenroads

Intent: Use low impact development (LID) storm water management solutions where appropriate to better mimic pre development hydrological conditions.

Requirements: Determine the feasibility of LID best management practices (BMPs)for storm water management in the right of way (ROW). Complete a basic LID hydrologic evaluation according to the steps outlined in the original prerequisite at Greenroads reference guide.

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA- 2010- p95:105.
2. http://www.lowimpactdevelopment.org/pubs/LID Hydrology National Manual.pdf.
3. http://www.seattle.gov/util/About SPU/Drainage and Sewer System/GreenStormwaterInfrastructure/NaturalDrainageProjects/HighPointNaturalDrainageSystem/index.htm
4. http://www.seattle.gov/util/About SPU/Drainage and Sewer System/Green Stormwater Infrastructure/Natural Drainage Projects/Street Edge Alternatives/index.htm

PR9: Pavement Management System Greenroads

Intent: Make roadway capital assets last longer and perform better by preserving and maintaining them.

Requirements: Have asset management systems in effect that include the pavement and critical structural features on a project, Asset management system(s) must serve the project and include, at minimum, these activities:

1. Measure conditions of pavement structure and bridge structures at least once every two years.
2. Possess documented decision criteria for timing preservation actions.
3. Record when preservation efforts occur.

Example: A local pavement management system could be followed or any other PMS like, Street Saver or (MTC) for use by local governments.

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p107:115.
2. http://www.chulavistaca.gov/cityServices/DevelopmentServices/engineering/pavementmgmtsystem.asp
3. http://owww.cecer.army.mil/paver/Paver.htm.

PR10: Site Maintenance Plan Greenroads

Intent: Maintain environmental quality and aesthetics of the bridge project during use.

Requirements: Have and implement a comprehensive ongoing site maintenance plan that addresses (at a minimum) responsible parties/organizations, standards, schedule, methods to be used and funding source(s) for the following items (listed by major topics):

- Bridge maintenance
- Pavement patching, repair and crack sealing andShoulder/sidewalk maintenance
- Storm water system cleaning and repair
- Roadside vegetation
- Safety device maintenance and repair
- Traffic signal maintenance and repair
- Bridge lighting maintenance and repair
- Intelligent transportation system maintenance and repair
- Pavement sweeping, cleaning andLitter control and Trash collection

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p107:115.
2. http://www.wsdot.wa.gov/Maintenance/Accountability

PR11: Educational Outreach Greenroads

Intent: Increase public, agency and stakeholder awareness of roadway sustainability activities.

Requirements: Incorporate a comprehensive public educational outreach program into the operational phase of the project. A minimum of three out of the following eight educational elements, to be installed within the project limits or within the purview of the lead agency, must be completed to meet the intent of this project requirement:

1. Install and maintain a permanent project oriented signage program along the bridge right of way. During construction registered projects may use temporary signs to display factual information about the certification level being pursued.
2. Install and maintain at least one off road, permanent point of interest kiosk that displays the certification level pursued, project information, and the certification level actually achieved.
3. Provide a publicly available and maintained informational project website with capacity for submitting feedback and comments.

4. Develop an agency and/or stakeholder guide, specification, or policy that incorporates or otherwise clearly references and reflects the ideals and intents of the developed rating system.
5. Institute an internal agency continuing professional education and training program related to develop rating system.
6. Perform at least two presentations about the project for primary and secondary schools.
7. Perform one professional technical presentation.
8. Document the project experience using (conduct a detailed case study for the bridge project and spread it in national and universities libraries).

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA- 2010- p123:126.
2. http://www.th.gov.bc.ca/kickinghorse/index.htm
3. http://www.th.gov.bc.ca/kickinghorse/updates/KHCP Fact Sheet.pdf

PR12: Increasing Bridge Durability Researcher

Intent: increase the usage of the bridge and make maximum benefit from bridges investments.

Requirements: The new bridge is designed and is being built with a design life target of 100 years. Designing for a very long service life has considerable economic and community benefits and is a means of maximizing the return on community investment in infrastructure. Delaying replacement and minimizing maintenance costs and the disruption caused by maintenance activities is an aim of asset owners. Designing for such a long service life can represent sustainable structural engineering without significant cost premium. The durability design process for extended life requires the specific analysis of the environmental conditions in which the structure is placed, the strategic use of a range of materials and an understanding of the means by which they deteriorate and the rate of that deterioration.

Reference:

1. John Connal and Marita Berndt: "Sustainable Bridges – 300 Year Design Life for Second Gateway Bridge"- paper- Melbourne-Australia- 2009- p1:14.
2. (Bieñ.Jan, Elfgren, Lennart and Olofsson:"Sustainable bridges: assessment for future traffic demands and longer lives"- Paper- 2008.

PR13: Fundamental Commissioning and Verification LEED

Intent: To support the design, construction, and eventual operation of a project that meets the owner‘s project requirements for energy, water and durability.

Requirements: Commissioning Process Scope Complete the following commissioning (Cx) process activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies, in accordance with ASHRAE Guideline 0:2005, as they relate to energy, water and durability. Requirements for exterior enclosures are limited to inclusion in the owner‘s project requirements (OPR) and basis of design (BOD), as well as the review of the OPR, BOD and project design. NIBS Guideline 3: 2012 for Exterior Enclosures provides additional guidance or any other equivalent local code.

Reference:

1. -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- ,p.30
2. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p 64:65
3. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p321:333.
4. Liv.Haselbach: “The engineering guide to LEED- new construction: sustainable construction for engineers”- Mcgraw:Hill Companies- USA- 2008- p 123:126.

PR14: Minimum Energy Performance LEED

Intent: To reduce the environmental and economic harms of excessive energy use by achieving a minimum level of energy efficiency for the bridge.

Requirements: Whole Bridge Energy Simulation Demonstrate an improvement of 5% for new construction bridge, compared with the baseline bridge performance rating. Calculate the baseline bridge performance according to ANSI/ASHRAE/IESNA Standard 90.1–2010, Appendix G, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.), using a simulation model of any similar bridge.

Reference:

3. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p 66:68.
4. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC- USA- 2013- p335:374.
5. Liv.Haselbach: "The engineering guide to LEED- new construction: sustainable construction for engineers"- Mcgraw:Hill Companies- USA- 2008p 126:129.

PR15: Bridge Level Energy Metering LEED

Intent: To support energy management and identify opportunities for additional energy savings by tracking bridge level energy use.

Requirements: Install new or use existing bridge level energy meters, or sub meters that can be aggregated to provide bridge level data representing total bridge energy consumption (electricity, natural gas, chilled water, steam, fuel oil, propane, biomass, etc). Utility-owned meters capable of aggregating bridge-level resource use are acceptable.

Whole-project energy usage data for a five year usage period should be calculated and traced every month to compare the difference between actual and expected consumption.

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 201٥- p 69.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- pp 375: 380.

PR16: Efficient Water Use Researcher

Intent: The objective is to efficiently use water during bridge construction and incorporate water efficiency and conservation in equipment washing. It entails a considerable reduction in potable water use and employs on site resources in order to lessen the municipal water supply demand.

Requirements: Consider using gray water in making ready mix concrete(Standard test method for water ASTM, 2009, Consult Section 911 of the 2012 MDOT Standard Specifications for the standard limits the amount of total solids, total organic content and alkalinity of non-potable water that can be used in concrete mix designs or any other equivalent local standard.

OR Other means to decrease the water usage could be using recycled water in truck washing, Slump adjustment Aggregate sprinklers.

Reference:

1. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012- p 7 0:71.

PR17: Outdoor Water Use Reduction LEED

Intent: To reduce outdoor water consumption.

Requirements: Reduce outdoor water use through one of the following options. No vegetated surfaces, such as permeable or impermeable pavement, should be excluded from the landscape area calculations.

Option 1. No Irrigation Required: Show that the landscape does not require a permanent irrigation system beyond a maximum two years establishment period.
OR Option 2. Reduced Irrigation: Reduce the project‘s landscape water requirement by at least 30% from the calculated baseline for the site‘s peak watering month. Reductions must be achieved through plant species selection and irrigation system efficiency, as calculated by the Environmental Protection Agency (EPA) Water Sense Water Budget Tool.

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p 51.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- pp259:266.
3. http://www3.epa.gov/watersense/outdoor/what to plant.html
4. http://www3.epa.gov/watersense/water budget/

PR18: Bridge Level Water Metering LEED

Intent: To support water management and identify opportunities for additional water savings by tracking water consumption.
Requirements: Install permanent water meters that measure the total potable water use for the bridge and associated grounds. Meter data must be compiled into monthly and annual summaries; meter readings can be manual or automated. Whole project water usage data for a five years usage period should be calculated and traced every month to compare the difference between actual and expected consumption.

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p 55.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- pp283:285.

Appendix C: Architectural Evaluation Credits

Category 1: Bridge Function (BF)

AC1: Bridge Movement and Constancy (Chapter 3)

Intent: Taking the best decision for bridge movement or constancy.
Requirements: Deciding bridge movement or constancy according to social, economic, functional and aesthetical advantages and disadvantages.

AC2: Creating a Global Bridge (Chapter 3)

Intent: To upgrade bridge from local standards to global standards
Retirements: If there is any extra more strength global regulations or considerations which are not stipulated in existing local codes, the designer follows these considerations to upgrade the bridge design from local to global level. These regulations/considerations could be (functional, safety, aesthetical, etc...) considerations that should be submitted to score credit points.

Category 2: Bridge Site (BS)

AC3: Site Investigation: (Chapter 4)

Intent: Best selection of bridge site.
Requirements: Well investigate the unique sites to approach more useful functions from the bridge and to use the scenic views to achieve more financial resources and passenger pleasure. A report containing the site investigation should be submitted to score such credits points.

AC4: A Living Bridge Plan: (Chapter 4)

Intent: Preserve and investigate natural views such as rivers, seas, open spaces, etc..

Requirements: An integrated plan to well exploit the river front, sea front bridges or any bridge with view to protect these bridges from informal usage and to create a landmark for tourism promotion.

AC5: Bridge Viability for Expansion: (Chapter 3)

Intent: Designing a bridge which assimilates future growth to increase bridge durability and minimize the need for new bridges.

Requirements: A study showing considerations for future expansions and the proposed solutions to achieve such expansions.

AC6: Bridge as a Whole Aesthetical Design: (Chapter 4)

Intent: Design a bridge to enhance the visual image

Requirements: Study the value added by the bridge to the surrounding site as a newly added entity. Also any unique aesthetical consideration taken by the design team to suit the nature of the site should be presented and submitted.

Category 3: Bridge Structure (BST)

AC7: The Influence of Site/Context/Concept on Bridge Structure Systems Selection. (Chapter 5)

Intent: Measuring the success of the selected structure system.

Requirements: An evaluation of the selected structure system should be done after bridge operation, usage and maintenance (with reference to the original prerequisite) to record the advantages of the selected structure system and to solve the problems of selection also to avoid these disadvantages in future projects.

AC8: The Influence of Site/Context/Concept on Bridge Construction Materials Selection. (Chapter 5)

Intent: Measuring the success of the selected construction materials

Requirements: An evaluation of aesthetical construction materials should be done after bridge operation, usage and maintenance (with reference to the original prerequisite) to record the advantages of material selection, solve the problems of selection also to avoid these disadvantages in future projects.

AC9: The Influence of Site/Context/Concept on Bridge Construction Methods Selection. (Chapter 5)

Intent: Measuring the success of the selected construction methods.

Requirements: An evaluation of selected construction methods should be done after bridge operation, usage and maintenance (with reference to the original prerequisite)to record the advantages of the selected construction methods, to solve the problems of selection and to avoid these disadvantages in future projects

Category 4: Bridge Parts (BP)

AC10: Superstructure Types Selection: (Chapter 6)

Intent: the best superstructure type selection to achieve safety, architectural and sustainability goals within budget.

Requirements: Design team should provide reasons, benefits and advantages of the selected superstructure, compared to other proposed superstructures alternatives.

AC11: Superstructure Parts Aesthetical Considerations: (Chapter 6)

Intent: Showing the integration between superstructure parts to each other and to other bridges parts.

Requirements: Aesthetical considerations for each of superstructure parts and the relation with the other parts (girder elevations and cross section, bearing, abutment bearing and drainage) should be provided by the bridge design team and to be submitted for approval.

AC12: Substructure Types Selection: (Chapter 6)

Intent: the best substructure type selection to achieve safety, architectural and sustainability goals within budget.

Requirements: Design team should provide reasons, benefits and advantage of the selected substructure compared to other proposed substructure alternatives.

AC13: Substructure Parts Aesthetical Considerations: (Chapter 6)

Intent: Showing the integration between substructure parts to each other and to other bridges parts.

Requirements: Aesthetical considerations for each of the substructure parts and the relation with the other parts (Piers "families, height, shape, form, parts, protection", bridge seats, abutments "height, placement, landscaping, shapes, materials", retaining walls, parapets) should be provided by the bridge design team to be submitted for approval.

AC14: Non Structural Parts Aesthetical Considerations: (Chapter 6)

Intent: Showing the integration between nonstructural parts to each other and to other bridges parts.

Requirements: Aesthetical considerations for each of nonstructural parts and the relation with the other parts (railings, safety screens, protective fencing, noise walls, signings, advertisements, landscaping, slope protection, lighting "roadway and accent, bridge miscellaneous details) should be provided by the bridge design team to be submitted for approval.

AC15: Whole Bridge Structure Integrity (Chapter 5)

Intent: Bridge whole structure selection to guarantee a good architecture

Requirements: whole structure parts shape and form selection to guarantee a good architecture (bridge layout, skewed structure, viaduct structure, structure depth) should be studied Also the relationship and interchanges between the new bridge and other surrounding bridges are to be shown.

Category 5: Bridge Aesthetics (BA)

AC16: Bridge Architectural Development (Chapter 1)

Intent: Designing an updated bridge which is in line with the state of the architectural technologies.

Requirements: A study showing all the updated design technologies and techniques, computer programs, construction materials and techniques, global architectural directions, etc... Used in bridge design and construction.

AC17: Following an Architectural School (Chapter 1)

Intent: Creating a bridge which adopts a specific architectural school.

Requirements: selecting the targeted architectural school and providing the reason for choosing this school, its aspects, its relationship with the bridge surrounding's architectural character and the reflection of adopting this architectural school for bridge architecture and the whole site image.

AC18: Bridge Fundamentals of Aesthetical Design and Aesthetical Qualities: (Bridge aesthetics- Chapter 7)

Intent: Check the applied aesthetical design/qualities to guarantee the best bridge shape and form

Requirements: Achievement and integration of aesthetical qualities (proportion, rhythm, order, harmony, balance, contrast, scale, unity, illusion, simplicity and consistency) should be checked/ verified.

Scoring criteria: As much as achieved qualities as more as obtained points. Therefore an integrated study of the achieved qualities should be developed and discussed by bridge design team to decide the best weighting for the credit.

Category 6: Bridge Curtilage (BC)

AC19: Influence of Bridges on Cities Visual Image (Chapter 9)

Intent: Developing bridges which improve the city's visual image.

Requirements: Take decisions which facilitate the city's visual image improvement, to be provided and discussed by the design team. Answer the question of how the new bridge is considered an addition to the city's visual image.

AC20: The Space around the Bridge (Chapter 9)

Intent: Observe and use the space around the bridge.

Requirement: An integrated plan by bridge design team to manipulate the space around the bridge to improve its architecture. Also the problems of adding further functions by the community to the bridge affecting badly the original functions of the same must be discussed and proposed for solving.

AC21: The Area under the Bridge (Chapter 9)

Intent: Observe/use space under the bridge

Requirement: An integrated plan by bridge design team to exploit the area under the bridge to improve its architecture. Also the problems of adding further functions by the community to the bridge affecting badly the original functions of the same must be discussed and proposed for solving.

AC22: Bridges Maintenance from Architectural Perspective. (Chapter 9)

Intent: Maintain bridge aesthetics and functions and supervise all maintenance work of bridge to avoid bad effects of periodical structure maintenance on bridge architecture (functions, colors, ornaments, shape, form, etc...).

Requirements: periodical maintenance should be executed under an architect supervision to maintain bridge aesthetics, shape and form

Appendix D: Sustainability Evaluation Credits

Category 1: Location and Transportation (LT)

1:1: Site Selection

Site selection plays a vital role towards sustainability. Preference should be given to already develop sites, as further environmental damage is limited due to lesser construction activities. Selecting the site wisely preserves natural habitats and avoids encroachment of sites on water bodies and agricultural lands.

CR1: Site Selection Researcher

Intent: The objective of this criterion is to select sites that do not have impacts on the environment due to the location.

Requirements: Try to avoid sites, which are identified as habitats of any species on the federal or state threatened endangered lists. The criteria can be found in Appendix D of EPA‘s construction general permit or any other local equivalent code. Also avoid building on agriculture lands if the bridge location must be on an agriculture land, another land must be replaced in same state with same area, quality and quantity.

Reconstructing a bridge at the same location of the bridge being replaced, rather than relocating it and having more environmental impacts at a new location might be consideration for points.

Reference:

1. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012- p 40:41.
2. http://www.agr:egypt.gov.eg/

CR2: Historical Site Improvement: Researcher

Intent: This section encourages preserving and conserving sites and structures of any historical significance. The main purpose is to avoid any potential harm or damages to historic sites and/or structures. The objective of this credit is to avoid development on historic sites and reduce the socio-cultural environmental impact from the location of a bridge on a site.

Requirements: Provide documentation showing the project team does not demolish any historical bridge as defined in Egyptian ministry of tourism, If the bridge structure is built on a historic site, improvements should be made to the facilities and/ or access to the site.

An example: Fom-Elkhalig bridge: Cairo, the government destroyed part of Magra-Eloyon fence to cross the metro and the bridge which considered a bad example should be avoided to achieve historic site improvement credit. Figure (A-1)

Figure A-1: Fom Elkhalig bridge destroy The historical Magra Eloyon fence.

Reference:

1. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p 16.
2. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012- p 42.
3. http://www.sis.gov.eg/Ar/Templates/Categories/tmpListArticles.aspx?CatID=576
4. www.almasryalyoum.com/

CR3: Surrounding Density and Diverse Uses: LEED

Intent: To conserve land and protect farmland and wildlife habitat by encouraging Development in areas with existing infrastructure. To promote walk ability, and transportation efficiency and reduce vehicle distance traveled. To improve public health by encouraging daily physical activity.

Requirements: Locate new bridge in previously developed areas to avoid long distance which makes cars consume more energy, also to avoid insert new infrastructure and utilities to non-developed areas and to limit urban sprawl

Reference:

1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p 15:17.

2. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p77:87
3. -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- p 80:82.

CR4: Footing Pier Location Researcher

Intent: Avoid placing footing and piers in waterways and reduce the environmental Impact from the location of a bridge on site. Also avoid affecting on fish and wildlife during bridge maintenance.

Requirements: Try to avoid placing footings and piers in water bodies to minimize environmental impacts. Consider choosing sites where the crossing distance is minimum.

In scenarios where bridges traverse a road, try to avoid placing footings within 50 feet of any water body such as seas, lakes, rivers, and streams that could support aquatic life, recreational or industrial use, consistent with the terminology of the clean water act. Also, with bridges over water, avoid constructing or developing sites within 100 feet of wetlands as defined in Appendix M of construction general permit of the Environmental Protection Agency (EPA) (EPA, 2011).

Try to build more durable bridge which need minimum maintenance, Also schedule maintenance to minimum time spent and minimum effect on sensitive environments.

Reference:

1. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering-Massachusetts institute of technology- USA- 2005- p 16.

CR5: Brown Field Redevelopment (High Priority Sites) Researcher / LEED

Sites that have been abandoned due to contamination from previous activities are called as Brownfield sites. They can be redeveloped or reused once cleaned up. Redeveloping Brownfield sites may avoid environmental and health problems and reduce pressure on undeveloped lands.

Intent: The objective of this credit is to rehabilitate contaminated sites and to reduce pressure on undeveloped land and to encourage project location in areas with development constraints and promote the health of the surrounding area.

Requirements: Option 1. Historic District: Locate the project on an infill location in a historic district.

Option 2. Brownfield Remediation: Locate on a Brownfield where soil or groundwater contamination has been identified, and where the local, state, or national authority (whichever has jurisdiction) requires its remediation. Perform remediation to the satisfaction of that authority.

Reference:

1. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering-Massachusetts institute of technology- USA- 2005- p 15.
2. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p 15.
3. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013-p 71:76
4. http://www2.epa.gov/superfund/superfund:national:priorities:list:npl
5. http://portal.hud.gov/hudportal/HUD?src=/program offices/comm planning/economicdevelopment/programs/rc
6. Kormaz.Kasim armagan, Syal.Matt, Kormaz.Sinem and Harichandran. Ronald S: (2012), Implementation of Sustainability in Bridge Design, Construction and Maintenance, Michigan State University School of Planning, Design and Construction, Annual Report, p 45.

Standard/Resource:

EPA 2011, Environmental Protection Agency, Brownfield Sites, Region 4: Land Revitalization and Reuse. Any other equivalent local standard.

CR6: Sensitive Land Protection LEED

Intent: To avoid the development of environmentally sensitive lands and reduce the environmental impact from the location of a building on a site.

Requirements: Locate the development footprint on land that has been previously developed or that does not meet the following criteria for sensitive land:

Prime farmland. Prime farmland or important lands which as defined by local codes.

Floodplains. A flood hazard area shown on a legally adopted flood hazard map or otherwise legally designated by the local jurisdiction or the state.

Habitat. Land identified as habitat for the following (species listed as threatened or endangered by local codes, within 30 meters from water bodies and 15 meters of wetlands)

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p 13:14.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013-p 63:69.
3. http://www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/
4. Fws.gov/endangered
5. Natureserve.org
6. Msc.fema.gov

CR7: LEED For Neighborhood LEED

Intent: To avoid development on inappropriate sites. To reduce vehicle distance traveled. To enhance livability and improve human health by encouraging daily physical activity.

Requirements: Locate the project within the boundary of a development certified under LEED for Neighborhood or Certified Project under the LEED v4 rating system).

Reference:

14. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p 12.
15. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013-p 59:61.

CR8: Context Sensitive Solution Greenroads

Intent: Deliver projects that synthesize transportation requirements and community values through effective decision making and thoughtful design.

Requirements: Design the project according to the principles of Context Sensitive Solutions (CSS).

Fill out the submission form from the CSS National Dialog website for project design And construction. The form can be found here:
http://www.cssnationaldialog.org/documents/design.pdf.

OR Create a short white paper (narrative) document describing the following:

1. The purpose and need for the project.
2. The planning horizon and proposed timeline or schedule for project completion.
3. A list or organizational chart of the management structure for the project: this includes, project planners, design professionals, consultants, agency leads, and other stakeholders involved.
4. The elements of the decision making process used.
5. The local and regional context and issues surrounding the project, other federal Context and issues, and applicable jurisdictional regulations and policies.
6. The public involvement process for CSD and results of this process.
7. The transportation modes considered and results of this consideration.
8. The visual and aesthetic components of the project.
9. The plan for long term ongoing monitoring during operations (if any).
10. The final alternatives and design elements chosen for implementation (a summary is sufficient).

Note: This credit must be earned in order to earn credits CR: Traffic Emissions Reduction, CR: Pedestrian Access, CR: Bicycle Access, and CR Transit Access.

Context Sensitive Solutions (also Context Sensitive Design; CSD) Figure (A-2) and Table (A-2).

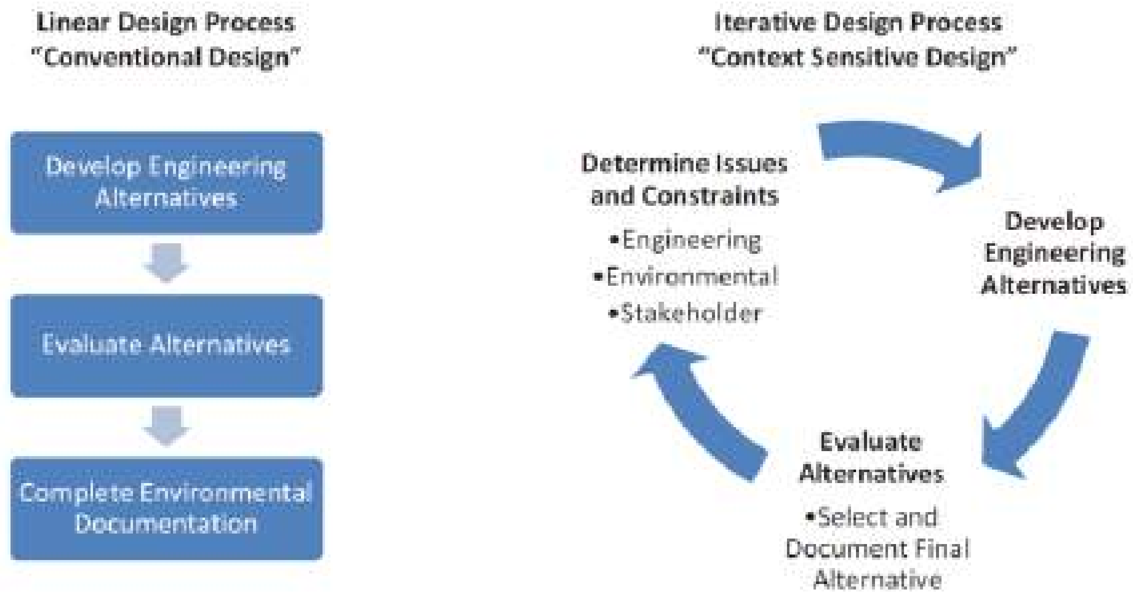


Figure A-2: Interurban Trail Bicycle and Pedestrian Bridge over SR 99 road: USA

Table A-2: Comparison of a conventional design process to a Context Sensitive design process.

<table>
<tr><td colspan="13">Create a lasting value for the community and Use agency resources effectively</td></tr>
<tr><td>Maintain environmental harmony</td><td>Address community and social issues</td><td>Address aesthetical treatments and enhancements</td><td>Utilize full range of design choices</td><td>Document project decisions</td><td>Track and meet all commitments</td><td>Use full range of communication strategies</td><td>Achieve consensus on purpose and need</td><td>Address alternatives and all modes</td><td>Consider a safe facility for users and community</td><td>Use interdisciplinary teams</td><td>Involve stake holders</td><td>Seek broad: based public involvement</td></tr>
<tr><td colspan="13">Graphical depiction of 15 principles of Context Sensitive Solutions.</td></tr>
</table>

Reference:

1: Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R., and Söderlund, M. et al. (2011). Greenroads Rating System v1.5. (J.L. Anderson and S.T. Muench, Eds.). Seattle, WA: University of Washington. PR1: p 219:230.

2: http://www.wsdot.wa.gov/projects/SR99/Shoreline NCTHOV/

3: Neuman, T. R. et al. A guide to best practices for achieving context sensitive solutions. National Cooperative Highway Research Program – NCHRP Report 480. Washington, D.C.: Transportation Research Board-USA- 2002.

4: Stamatiadis, N. et al: Quantifying the benefits of Context Sensitive Solutions. National Cooperative Highway Research Program – NCHRP Report 642. Washington, D.C.: Transportation Research Board- USA- 2009

5. Context Sensitive Solutions. (2005). Bridgeport Way – University Place, Washington. Available at http://www.contextsensitivesolutions.org/content/case studies/kentucky bridgeport/

6. Federal Highway Administration (FHWA). Manual for Uniform Traffic Control Devices (MUTCD). Washington, DC: FHWA-USA- 2009 Available at http://mutcd.fhwa.dot.gov/htm/2009/html index.htm

CR9: Scenic View Greenroads

Intent: to enjoy the view from the bridge

Requirements: Provide at least one access from the project to a designated area for vehicles to exit the traffic stream, stop and experience scenic, natural or recreational features along the roadway. These areas may be scenic viewpoints or overlooks, welcome centers, tourist activities or information centers or recreation areas.

Reference:

1: Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R., and Söderlund, M. et al. (2011). Greenroads Rating System v1.5. (J.L. Anderson and S.T. Muench, Eds.). Seattle, WA: University of Washington. PR1: p 259:266.

CR10: Safety Audit: Greenroads

Intent: Improve roadway safety through review by an independent audit team.

Requirements: Conduct a road safety audit (RSA) on the project roadway in accordance with local codes, regulations and procedures set forth in FHWA‘s Road Safety Audit Guidelines. There are three general phases of a project during which a RSA may be conducted.

1. Preconstruction phase RSA. Performed before construction begins. Recommended Changes are generally less costly and result in less delay.
2. Construction phase RSA. Performed during preparations construction. They allow the roadway to be viewed as built and offer a last chance to assess safety before it is opened to the public.
3. Post construction phase RSA. Performed on existing roads to identify road safety issues for different road users.

Reference:

2: Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R., and Söderlund, M. et al. (2011). Greenroads Rating System v1.5. (J.L. Anderson and S.T. Muench, Eds.). Seattle, WA: University of Washington. PR1: p 207:210.

3: http://safety.fhwa.dot.gov/rsa/guidelines.

CR11: Cultural Outreach Greenroads

Intent: Promote cultural awareness, community connectivity and art.

Requirements: Any part of the project or any item within 10 miles of the project boundary is either:

Listed in the Egyptian ministry of tourism as a historical or cultural place.

And Install informational infrastructure (e.g., viewpoint, kiosk, sign, or other small scale installation for visitors detailing historical, cultural, or archeological significance) to explain the site or direct roadway users to the site. An existing installation meets this Informational infrastructure portion of the requirement.

OR Dedicate a minimum of 1% of the total project budget (not to exceed $200,000) to art or community culture installations along the roadway right of way (ROW). Figure (A-3)

Reference:

2: Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R., and Söderlund, M. et al. (2011). Greenroads Rating System v1.5. (J.L. Anderson and S.T. Muench, Eds.). Seattle, WA: University of Washington. PR1: p 220:230.

3: http://safety.fhwa.dot.gov/rsa/guidelines.

Richard Beyer‘s People Waiting for the Interurban (1979) at the corner of Fremont Avenue: USA

Jack Mackie‘s Dancers' Series: Steps (1982) found in 8 locations along Broadway Avenue in Seattle. USA

James Angus, Ellipsoidal Freeway Sculpture (2008) Eastlink freeway: USA

(http://www.roslynoxley9.com.au/arti sts/5/James Angus/1116/41258).

Figure A-3: Cultural Outreach

1-2- Encourage Environmental Friendly Transportation Solution (Traffic Efficiency)

CR12: Bicycle Lane: LEED: Researcher

Intent: To promote bicycling and transportation efficiency and reduce vehicle distance Traveled. To improve public health by encouraging utilitarian and recreational physical Activity.

Requirements: a) Develop plans to include bicycle pathways

b) Appoint a bicycle coordinator in order to promote the maximum use of no motorized modes of transportation. Figure (A-4)


Bike lane Amsterdam streets


The green bike lane on Market Street approaching 10th Street. Photo: Bryan Goebel

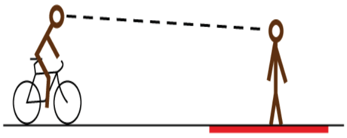

Helsinki Bike/Pedestrian lane

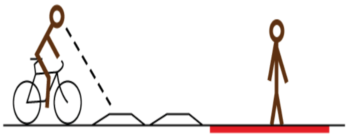

Fahy Bridge to get pedestrian lane next to unsafe sidewalks:

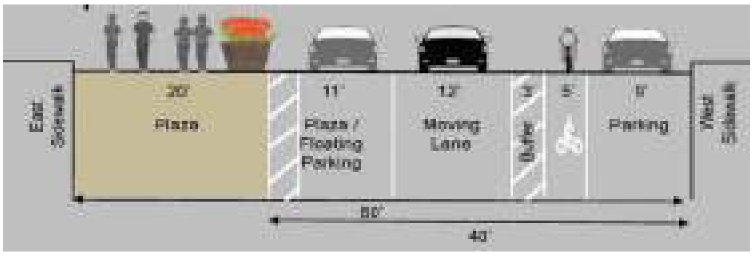

north of Union Square on 17th Street is a new protected contra flow bike lane and pedestrian lane


Cycle and pedestrian signage


How the safety cross for pedestrian cuts cycle, roadway and pedestrian lanes at Amsterdam


situation was not very safe: at peak times, large numbers of pedestrians are attempting to cross the street so the cyclist don't have enough time and space to slow down


This situation isnot safe also because the cyclists looks down to speed bumps and didnot concentrate on the pedestrian so This could be done by increasing the space between the bike lane and the road, so people can focus on each obstacle separately



The New Broadway: More Pedestrian Space, Redesigned Bike Lane

Figure A-4: Bicycle and Walk able leans

Reference:

1. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p 185.
2. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p 22.
3. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013-p 100:110
4. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012- p 62.

CR13: Walk Able Lane "pedestrian Lanes" LEED: Researcher: Greenroads

Intent: The objective of this credit is to promote the use of alternative transportation through walking, thus minimizing pollution and energy demand.

Requirements: a) Develop plans to include sidewalks pathways.

b) Appoint a pedestrian coordinator in order to promote the maximum use of no motorized modes of transportation.

c) Provide safe pedestrian pathways during the replacement or rehabilitation phase Of the bridge. D) Provide a safe walk able access to cross large bridges Figure (A-4)

Reference:

6. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p 18.
7. Kormaz.Kasim armagan, Syal.Matt, Kormaz.Sinem and Harichandran. Ronald S: (2012), Implementation of Sustainability in Bridge Design, Construction and Maintenance, Michigan State University School of Planning, Design and Construction, Annual Report, p 62.
3. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p 22.
4. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p100:110
5:http://blog.sfgate.com/transportation/2010/05/10/san:francisco:gets:its:first:green:bike:lanes:on:market:street/
6:http://www.streetsblog.org/2012/11/07/the:new:new:broadway:more:pedestrian:space:bike:lane:redesign/
7:http://www.petitbourgeois.com/2009/12/the:usability:of:public:spaces:dangerous:pedestrian:crossing/
8:http://www.petitbourgeois.com/2009/12/the:usability:of:public:spaces:dangerous:pedestrian:crossing/
9:http://www.dreamstime.com/stock:photo:vancouver:pedestrian:cycling:lane:sign:british:columbia:image54859028
10:http://www.streetsblog.org/2010/09/22/cutting:the:ribbon:on:the:newest:stretch:of:broadways:green:ribbon/
11:http://www.lehighvalleylive.com/bethlehem/index.ssf/2011/10/new fahy bridge walkway in bet.html
12: http://www.fastcoexist.com/3031392/the:case:for:protected:bike:lanes

CR14: Green Vehicles and HOV Lane "LEED: Researcher: Greenroads

Intent: To promote use of alternative transportation through High occupancy vehicles HOVs, green vehicles to reduce pollution.

Requirements: Provide one or more travel lanes in each direction of traffic to be used exclusively by at least one of the following HOVs: 2 or more person carpools, Green vehicle, Liquid, Gas or battery vehicles. as exclusive HOV lanes. Identify sources of additional funding(Transit agency, regional agencies, Advertisings and tollbooth). Also to encourage people to use this credit, the fees of crossing the bridge(in case of tollbooth) may be reduced.

A green car: or Access HOV lane sticker should be on green cars to be checked by traffic policemen or may be smart sticker attached to satellite.

Note: a project may be added to bridge like a electrical train or a monorail, this may add exemplary performance points per cost and environmental effect. Figure (A-5)

Reference:

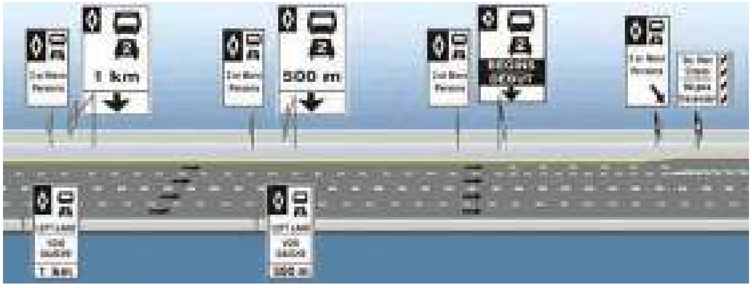
1. Hunt Lauren R: “Development of a rating system for sustainable bridge”- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p 18.
2. Kasim Armagan Korkmaz: “Implementation of Sustainability in Bridge Design, Construction and Maintenance” - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 62.
3. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- pp 22.
4. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p100:110
5. http://www.hybridcars.com/should:california:welcome:hybrids:back:hov:lane:31413/

6. http://electriccarsreport.com/2013/09/california:extend:hov:lane:access:2019/
7.http://www.mto.gov.on.ca/english/ontario:511/hov:lanes.shtml

California Extend HOV Lane Access

Green car sticker: California state

California state HOV lane:



High Occupancy Vehicle (HOV) Lanes, Ontario.

Figure A-5: Green Vehicles and HOV Lane

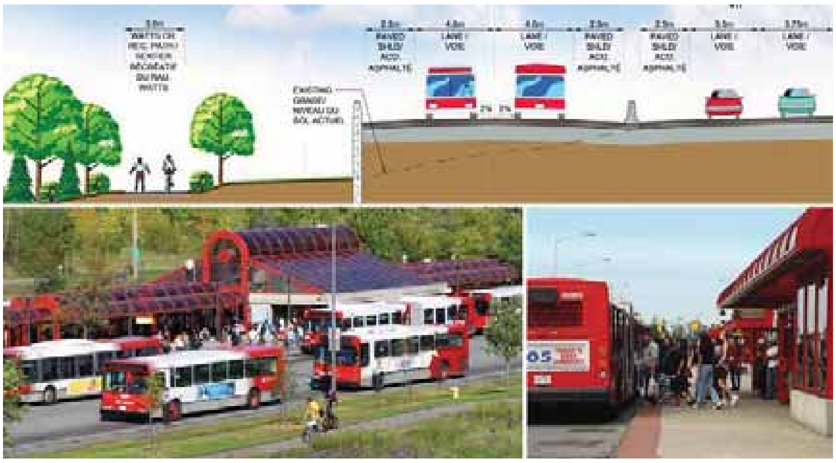
CR15: Transit Lane (Access to Quality Transit) LEED: Researcher: Greenroads

Intent: To encourage development in locations shown to have multimodal transportation choices or otherwise reduced motor vehicle use, thereby reducing greenhouse gas emissions, air pollution, and other environmental and public health harms associated with motor vehicle use.

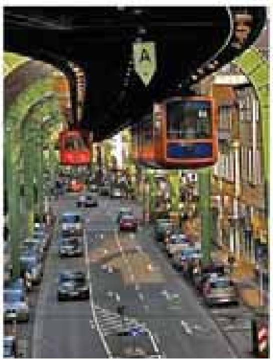
Requirements: Provide one or more travel lanes in each direction of traffic to be used exclusively by Transit buses or any other transportation. Figure (A-6)

Reference:

1. Hunt Lauren R: “Development of a rating system for sustainable bridge”- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p17: 18.
2. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p- p 19,20,28.
3. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p121:135
4. http://www.mto.gov.on.ca/english/ontario:511/hov:lanes.shtml
5. http://www.mmmgrouplimited.ca/!Archive/Ottawa/key:projects/transportation/ottawa:transitway/
6. http://www.urbanrail.net/eu/de/w/wuppertal.htm



Ottawa Transit way examples



The Wuppertal Suspension -Germany.

Figure A-6: Transit Lane (Access to Quality Transit)

CR16: Lane Adaptability Researcher

Description: Bridges should be designed considering future traffic conditions. The increased traffic can increase the load on a bridge, which may deteriorate the bridge if it is not designed for carrying additional traffic, possibly resulting in additional maintenance activities. Therefore, a framework should be made to allow for additional future lanes in should any unforeseen conditions arise.

Intent: To provide a framework that allows for additional lanes should there be any unforeseen conditions.

Requirements: a) Design the bridge so that two or more lanes can be added without strengthening the **substructure**. Develop preliminary construction plans for the addition of lanes in the future. b) Design the structural elements so that they can bear additional loads created by the additional lanes. Therefore, consider using high performance materials, additional materials, or high strength materials in the design.

Reference:

1. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p 17.
2. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 63.

CR17: Tollbooth Transponders on Bridge Entrance Researcher

Intent: to provide extra financial resources for bridge to promote sustainability but in the same time to reduce the impact from cars stopped at toll booth stations.

Requirements: Tollbooths idea to be enhanced but with a technology by electronic transponder payment system (like EZ pass electronic system). Figure (A-7)

Reference:

1. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p18.
2. http://www.e:zpassiag.com/
3. http://www.moheet.com/2015/03/04/22268
4. http://hamptonroads.com/2014/01/not:paying:tunnel:tolls:your:bills:mail
5. http://www.e:zpassiag.com/

The conventional Toll booth
Old and New Cairo: Alexandria road toll booth

E:Zpass System idea and E:Zpass devise fixed to car glass

Figure A-7: Tollbooth Transponders on Bridge Entrance

CR18: Sponsors, Advertisements and Signs: Researcher

Intent: to provide extra financial resources for bridge to promote sustainability and to reduce the bad effect on environment.

Requirement: Sponsor a Bridge provides civic minded companies an opportunity to enhance bridge by "sponsoring" segments of Bridge. Companies who utilize this program pay a fee to (Sponsor: a Bridge) or Adopt a bridge Litter Removal Service of This will allow for the sponsor to place corporate logos, colors and other identifiable messages, Arches for advertisements. Additionally, sponsor funded maintenance for the bridge, this will enhance the beauty of the bridge and its sustainability.

Reference:

1. https://www.massdot.state.ma.

CR19: Traffic Emission Reduction Researcher

Intent: Reduce operational mobile source emissions to improve air quality and human health.

Requirements: Use the EPA MOVES2010 software to compute the total greenhouse gas emissions and criteria pollutant emissions reduced by the tolling or pricing program compared to the non-priced alternative for the length of the project.

Emissions modeling will require establishing a baseline case. This should consist of The length of the project without congestion pricing and should use the same assumptions that are made in the congestion pricing case. Congestion pricing schemes reduce the number of vehicles on a roadway by charging money for use during peak periods, therefore reducing fuel use and total emissions. Congestion pricing need not apply to all lanes of a roadway. **Example:** Congestion Pricing in Puget Sound – Traffic Choices Study In 2002 Seattle, USA, These results included:

- All trips (tours per week) decreased 7%
- Vehicle miles traveled (miles per week) decreased 12%
- Drive time (minutes of driving per week) decreased 8%
- Tour segments (segments of tours per week) decreased 6%
- Miles driven on tolled roads (tolled miles per week) decreased 13%.

Reference:

1: Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010-p 231: 240.

2. http://www.psrc.org/transportation/traffic

CR20: Intelligent Transportation System Greenroads

Intent: Meet economic and social needs and improve mobility without adding capacity, or improve the efficiency of transportation systems.

Requirements: Include intelligent transportation system (ITS) applications listed in the Federal Highway Administration‘s (FHWA) Research and Innovative Technology Administration (RITA) Office of Intelligent Transportation Systems Applications Overview portion of their ITS website The intelligent transportation include (Adaptive Signal Control , Advanced Signal Systems , Variable Speed Limits , Bicycle and Pedestrian , Special Events, Good traffic control and infrastructure, HOV Facilities, Ramp Rollover , Curve Speed Warning , Downhill Speed Warning , Overweight /Over width Warning , Highway Rail Crossing Warning Systems , Intersection Collision Warning , Pedestrian Safety , Bicycle Warning ,Animal Warning etc..)

Reference:

1. Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010-p 211: 217.
2. http://www.itsoverview.its.dot.gov
3. http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ByInfo/WhatIsBClassifications#goal

Category 2: Sustainable Sites and Construction Activities (SC)

2-1: Sustainable Sites

CR 21: Site Assessment LEED

Intent: To assess site conditions before design to evaluate sustainable options and inform related decisions about site design.

Requirements: Complete and document a site survey or assessment that includes the following information:

- Topography. Contour mapping, unique topographic features, slope stability risks.
- Hydrology. Flood hazard areas, delineated wetlands, lakes, streams, shorelines, rainwater collection and reuse opportunities, initial water storage capacity of the site.
- Climate. Solar exposure, heat island effect potential, seasonal sun angles, prevailing winds, monthly precipitation and temperature ranges.
- Vegetation. Primary vegetation types, Greenfield area, significant tree mapping, threatened or endangered species, unique habitat, and invasive plant species.
- Soils. Natural Resources Conservation Service soils delineation.
- Human use. Views, adjacent transportation infrastructure, adjacent properties, construction materials with existing recycle or reuse potential.
- Human health effects. Proximity of vulnerable populations, adjacent physical activity opportunities, proximity to major sources of air pollution.

The survey or assessment should demonstrate the relationships between the site features and topics listed above and how these features influenced the project design; give the reasons for not addressing any of those topics. All these topics should be connected to local standers.

Reference:

4. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p33.
5. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p387:403.

CR 22: Site Development (Protect and Restore): Habitat Restoration

LEED and Greenroads

Intent: To conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.

Requirements: Preserve and protect from all development and construction activity 40% of the Greenfield area on the site (if such areas exist).

AND restore more area by 5% beyond what is required, this area may be in or out site or provide equivalent financial support.

Egyptian example: Abo kerdan bird after creating Cairo Ring road and building on Maryotia Green areas and filling Tereet El-Mariotya, Abo kerdan bird is eating from rubbish.

Reference:

1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p34:35.
2. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p163:176.
3. Liv.Haselbach: “The engineering guide to LEED- new construction: sustainable construction for engineers”- Mcgraw:Hill Companies- USA- 2008- p 52:56.
4. Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010- p 183:191.

CR 23: Site Recycling Plan Greenroads

Intent: Minimize the amount of construction related waste destined for landfill and promote environmental stewardship through good housekeeping practices at the work site.

Requirement: Establish, implement, and maintain a formal Site Recycling Plan as part of the Construction and Demolition Waste Management Plan (CWMP) during construction.

The Site Recycling Plan must clearly describe the plan for implementing, communicating, monitoring and maintaining appropriate recycling and diversion practices on site.

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010-p 291:301.
2. Environmental Protection Agency (EPA). Landfills | Municipal Solid Waste | Wastes | US EPA. Accessed December 16, 2009. Available at http://www.epa.gov/waste/nonhaz/municipal/landfill.htm

CR 24: Open Space LEED

Intent: To create exterior open space that encourages interaction with the environment, social interaction, passive recreation, and physical activities specially living bridges or bridges with scenic views.

Requirements: Provide outdoor space greater than or equal to 30% of the total bridge area (. A minimum of 25% of that outdoor space must be vegetated (turf grass does not count as vegetation) or have overhead vegetated canopy.

The outdoor space must be physically accessible and be one or more of the following:

- A pedestrian oriented paving or turf area with physical site elements that accommodate outdoor social activities;
- A garden space with a diversity of vegetation types and species that provide opportunities for year round visual interest;
- A garden space dedicated to community gardens or urban food production;
- Preserved or created habitat that meets the criteria of SS Credit Site Development.

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p36.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013-p177:181.

CR 25: Heat Island Reduction LEED

Heat islands are temperature differences between developed and undeveloped areas.

The heat island effect is created when developed areas have higher temperatures than Surrounding rural areas. An urban heat island effect is caused by sunlight heating up dark colored surfaces such as roads and rooftops. Urban heat islands effects can also be created by narrows streets and tall buildings reducing the air flow through the city, as well as vehicle exhaust. Huge quantities of heat are generated in buildings that have dark rooftops and absorb heat rather than reflect it. Outside, we all know how much hotter a blacktop parking lot is than a grassy field.

Intent: To minimize effects on microclimates and human and wildlife habitats by reducing heat islands.

Requirements: Non roof and Roof (covered pedestrian bridges) meet the criteria mentioned at LEED reference guide.

Cool Pavements: Conventional paving materials can reach peak summertime temperatures of 120– 150°F (48–67°C). This extra heat is transferred to the air and results in additional evaporation of rainwater after periods of rain. Pavements that are more reflective – those with a higher SRI – can be installed to alleviate the negative properties of lower SRI materials such as black asphalt.

References:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 201539:40.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013-p197:206.

3. -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- p 98: 107.
4. Liv.Haselbach: “The engineering guide to LEED- new construction: sustainable construction for engineers”- Mcgraw:Hill Companies- USA- 2008- p 73:77.

CR 26: Light Pollution Reduction LEED

Prevent Light Pollution: Light pollution is excessive or intrusive artificial light, Light Pollution obscures the stars in the night sky for city dwellers, interferes with astronomical observatories, and, like any other form of pollution, disrupts ecosystems and has adverse health effects such as sleep disorder. Light pollution can be divided into two main types: 1) annoying light that intrudes on an otherwise natural or low:light setting and 2) excessive light (generally indoors) that leads to discomfort and adverse health effects.

Intent: To increase night sky access, improve nighttime visibility, and reduce the consequences of development for wildlife and people. The project uses fixtures that provide downward lighting to enhance safety and save energy while retaining the natural beauty of the night sky.

Requirements: Meet up light and light trespass requirements, using either the backlight up glare (BUG) method (Option 1) or the calculation method (Option 2). Projects may use different options for up light and light trespass. Meet these requirements for all exterior luminaries located inside the project boundary as demonstrated at LEED reference guide (LZ0, LZ1, LZ2, LZ3 and LZ4) LZ for Lighting Zone. Figure (A-8)

References:

1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p41:44.
2. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p207:224.
3. -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- p 107:111.
4. Liv.Haselbach: “The engineering guide to LEED- new construction: sustainable construction for engineers”- Mcgraw:Hill Companies- USA- 2008- p 77:83.
5. http://www.slideshare.net/TheGaru/light:pollution:52431231

Figure A-8: Types of external luminaries light pollution

2:2: Sustainable Construction Activities.

CR 27: Quality Management System Greenroads

Intent: Improve construction quality .

Requirement: using a contractor that has a formal quality management process.

Reference:

1. Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010- p 291:301.
2. International Organization for Standardization (ISO). (2009). ISO 9000 essentials. ISO website. Available at http://www.iso.org/iso/iso catalogue/management standards/iso 9000 iso 14000/iso 9000 essentials.*htm*

CR 28: Fossil Fuel Reduction Greenroads

Intent: Reduce the overall consumption of fossil fuels by non-road construction equipment.

Requirements: Reduce the fossil fuel requirements of non-road construction equipment by using bio fuel or bio fuel blends as a replacement for fossil fuel. Reduce the fossil fuel requirements of the non-road construction equipment fleet by 15% to 25% through the use of bio fuel or bio fuel blends as a replacement for fossil fuel.

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010-p 303:308.
2. BioPower London. (2006). ―Frequently Asked Questions.‖ Available at http://www.biopowerlondon.co.uk/index.htm.
3. Energy Information Administration. (2010). ―Gasoline and Diesel Fuel Update.‖ Available at http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp.
4. European Biodiesel Board. (2010). ―Statistics.‖ Available at http://www.ebb eu.org/stats.php.

CR 29: Non road Equipment Emission Reduction Greenroads – Researcher

Non road engines are all internal combustion engines except motor vehicle (highway) engines, stationary engines (or engines that remain at one location for more than 12 months), engines used solely for competition, or engines used in aircraft. The non-road Standards cover mobile non road diesel engines of all sizes used in a wide range of construction, agricultural and industrial equipment‖. So, non-road equipment is used in construction and not on roads like cars, buses, etc.

Intent: Reduce air emissions from non-road construction equipment.

Requirements: At least 50% to 75%of the non-road construction equipment fleet operating hours for the project are accomplished on equipment with installed emission reduction exhaust retrofits and add on fuel efficiency technologies that achieve the EPA Tier 4 emission standard.

References:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010-p 309:314.
2. The EPA describes several diesel engine emission reduction effort case studies at:
3. http://www.epa.gov/diesel/construction/casestudies.htm
4. EPA. Non:Road Diesel Engines. Retrieved June 29, 2012, from Environmental at www.dieselnet.com/standards/us/non:road.php
6. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis-School of Planning, Design and Construction- Michigan State University- 2012-p 72.

CR 30: Contractor Warranty Greenroads

Intent: Incorporate construction quality into the public low bid process through the use of warranties.

Requirements: The project construction contract shall include, as a minimum, a 3 year warranty for constructed portions of the pavement structure to include surfacing (e.g., hot mix asphalt, Portland cement concrete, etc.) as well as any underlying layers (e.g., granular base material).

References:

12. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 327:335.
2. Anderson, S.D. and Russell, J.S. (2001). National Cooperative Highway Research Program (NCHRP) Report 451
3. Guidelines for Warranty, Multi Parameter, and Best Value Contracting. Transportation Research Board,
4. National Research Council, Washington, D.C. Available at
5. http://144.171.11.40/news/blurb detail.asp?id=5476.

CR 31: Accelerated Bridge Construction Techniques Researcher

Accelerated construction is used to achieve the construction of structures in the shortest possible time while decreasing delays and traffic disruption. It is not just building structures rapidly, but also entails a variety of techniques, processes, and technologies to achieve the desired result of reducing congestion due to construction, while improving quality.

Intent: The objective is to reduce the construction time of the project thereby reducing environmental and traffic mobility impacts.

Requirement: Adopt and demonstrate any technique to minimize construction time and this minimization do not impact on quality and cost.

References:

1. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis-School of Planning, Design and Construction- Michigan State University- 2012-p 66:76.
2. FHWA. Accelerated Bridge Construction. Retrieved June 5, 2011, from US Department of Federal Highway Administration: http://www.fhwa.dot.gov/bridge/abc/index.cfm

CR 32: Construction and Demolition Waste Management LEED–Researcher

Intent: To reduce construction and demolition waste disposed of in landfills and Incineration facilities by recovering, reusing, and recycling materials.

Requirements: Recycle and/or salvage nonhazardous construction and demolition materials. Calculations can be by weight or volume but must be consistent throughout.

Exclude excavated soil, land clearing debris, and alternative daily cover (ADC). Include wood waste converted to fuel (bio fuel) in the calculations; other types of waste to energy are not considered diversion for this credit.

However, for projects that cannot meet credit requirements using reuse and recycling methods, waste to energy systems may be considered waste diversion if the European Commission Waste Framework Directive 2008/98/EC and Waste Incineration Directive 2000/76/EC are followed and Waste to Energy facilities meet applicable European Committee for Standardization (CEN) EN 303 standards (Or any other equivalent local standards).

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p87.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013-p587– 594.
3. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis-School of Planning, Design and Construction- Michigan State University- 2012-p 73:74.

CR 33: Soil Erosion and Sedimentation Control Plan Researcher

Erosion is a process or combination of processes in which the earth materials are loosened or transported by natural agents such as wind or water. Soil is a valuable resource for plant growth and maintains biodiversity. Loss of soil may lead to water quality issues and inhibits biodiversity. Sedimentation is the deposit of soil particles or other pollutants in storm sewers or adjacent water resources. It affects the flow capacity of the stream channels and increases turbidity levels. Turbidity reduces sunlight penetration in water, which reduces photosynthesis and in turn affects aquatic vegetation and decreases oxygen levels. Air borne dust generation is another major environmental problem and could lead to many human health problems. Construction activities may result in air borne contaminants, including dust, mists, smoke, and fumes. This may lead to widespread lung diseases such as pneumoconiosis

Intent: The objective of this credit is to reduce pollution from soil erosion, which may be due to wind or water, sedimentation, and dust, and particulate matter generation during construction activities.

Requirements: a) Develop a comprehensive erosion and sedimentation control (ESC) plan prior to earth activities. Show ESC requirements in specifications, drawings, and cost estimates for bridge projects.

b) Apply ESC practices to prevent excessive on site damage.

c) Develop a schedule and implement inspection and maintenance program.

d) Follow the Best Management Practices (BMP‘s) mentioned in Principles of Runoff Control for Roads, Highways, and Bridges Erosion, Sediment and Runoff Control for

Roads and Highways and the Environmental Protection Agency (EPA) to control the addition of pollutants to coastal waters and erosion and runoff control for bridges.

Reference:

1. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p 15.

2. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 43:44.

3. WHO: Hazard Prevention and Control in the Work Environment: Airborne Dust. Retrieved November 15, 2011, from World Health Organization.

4. EPA.: Reducing Storm:Water Costs Through Low Impact Development (LID) Strategies and Practices. Retrieved August 5, 2011, from Environmental Protection Agency: epa.gov/owow/nps/lid/costs07/factsheet.html

Other references to help bridge design team to achieve credit

5. Eisenman. Ana Athalia Plaut (2012): SUSTAINABLE STREETS AND HIGHWAYS: AN ANALYSIS OF GREENROADS RATING SYSTEMS, MSc Thesis, Georgia Institute of Technology, p.

6. Muench.Stephen, Anderson.Jeralee, and Bevan.Tim (2010): Greenroads: A Sustainability Rating System for Roadways, Paper, International Journal of Pavement Research and Technology, Vol.3 No.5 Sep. 2010,p.

7. Muench.Stephen, Anderson.Jeralee (2012): SUSTAINABILITY TRENDS MEASURED BY THE GREENROADS RATING SYSTEM, Paper, TRB 2012 Annual Meeting.

8. Clevenger. Caroline M, Ozbek. Mehmet E and Simpson.Sherona (2013): Review of Sustainability Rating Systems used for Infrastructure Projects, Paper, 49th ASC Annual International Conference Proceedings, Associated Schools of Construction, Colorado State University Fort Collins, Colorado.

9. Simpson. Sherona P., Ozbek. Mehmet, Clevenger. Caroline, and Atadero. Rebecca (2014): A Framework for Assessing Transportation Sustainability Rating Systems for Implementation in U.S. State Departments of Transportation, Research, Mountain:Plains Consortium, Department of Construction Management and Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, p.

10. HAWK.HUGH (2003), NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM, NCHRP REPORT 483, Bridge Life:Cycle Cost Analysis, Research Sponsored by the American Association of State Highway and Transportation Officials in Cooperation with the Federal Highway Administration, TRANSPORTATION RESEARCH BOARD WASHINGTON, D.C. USA

Category 3: Material, Resources and Pavement Technologies (MRPT)

3:1: Material and Resources.

CR 34: Life Cycle Cost Analysis Researcher

Life cycle cost analysis is an important technique that assists transportation agencies in making investment decisions. It is a set of economic principles and computational procedures for comparing initial and future costs to arrive at the most economical strategy for ensuring that a bridge provides the services for which it was intended.

Intent: To estimate the overall costs of project alternatives and to select the design that ensures the facility will provide the lowest overall cost of ownership consistent with its quality and function.

Requirements: Perform the calculations for the life cycle cost analysis of a bridge project. It is encouraged to compare various design alternatives.

References:

1. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 64.

2. Fuller, S. (2010). Life Cycle Cost Analysis. Retrieved May 10, 2012, from Whole Bridge Design Guide: http://www.wbdg.org/

3. Hawk.hugh: National cooperative highway research program, nchrp report 483, Bridge Life:Cycle Cost Analysis, Research Sponsored by the American Association of State Highway and Transportation Officials in Cooperation with the Federal Highway Administration, transportation research board Washington, D.C- 2003- USA

4. NCHRP. Bridge Life Cycle Cost Analysis. http://www.trb.org/NCHRP/NCHRP.aspx

CR 35: Life Cycle Assessment (Bridge Life Cycle Impact Reduction)

LEED: Greedroads–Researcher

Intent: To encourage adaptive reuse, optimize the environmental performance of products and materials.

Requirements: Demonstrate reduced environmental effects during initial project decision making by reusing existing bridges resources or demonstrating a reduction in materials use through life cycle assessment. Achieve one of the following options.

Option 1. Historic Bridge Reuse

Option 2. Renovation of Abandoned or Blighted Bridge

Option 3. Bridge and Material Reuse
Option 4. Whole Bridge Life Cycle Assessment. Figure (A-9)

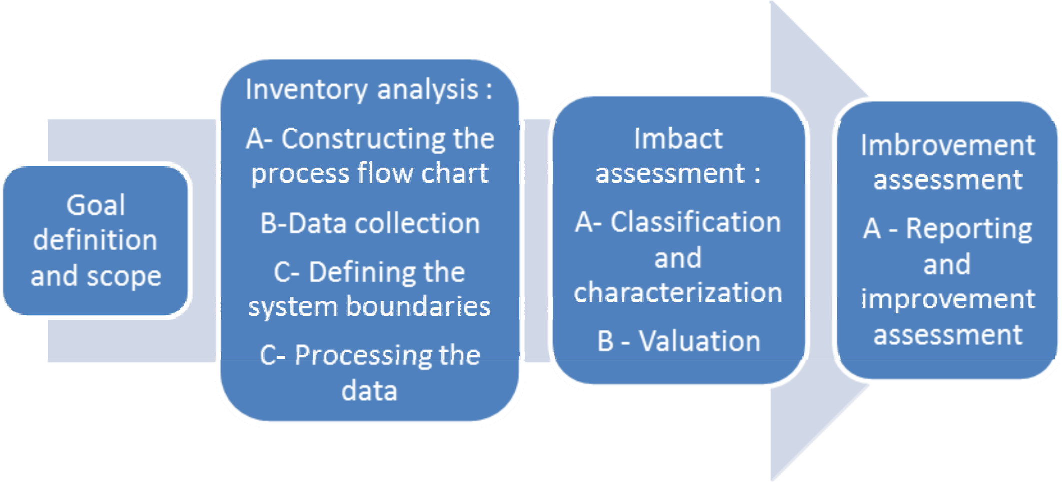


Figure A-9: The framework for Life Cycle Assessment

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p90:92.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013-p495:511.
3. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010-p 339:355.
4. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering-Massachusetts institute of technology- USA- 2005- p 15.
5. ISO 14044: iso.org/
6. National Register of Historic Places: nrhp.focus.nps.gov/
7. Stripple, H. Life Cycle Assessment of Road: A Pilot Study for Inventory Analysis, Second Revised Edition. IVL Swedish
8. Environmental Research Institute Ltd report for the Swedish National Road Administration, 2001. http://www3.ivl.se/rapporter/pdf/B1210E.pdf
9. International Organization for Standardization. ISO 14040:2006(E) Environmental Management — Life Cycle Assessment — Principles and Framework. 2nd ed. 2006
10. Consoli, F: Guidelines for life cycle assessment: A "code of practice. -: Society of Environmental Toxicology and Chemistry (SETAC). Pensacola, FL, U.S.A-1993

Bridge Product Disclosure and Optimization Credits

Intent: To encourage the use of products and materials for which life cycle information is available and that have environmentally, economically, and socially preferable life cycle impacts. and have been extracted or sourced in a responsible manner.

CR 36: Bridge Product Disclosure and Optimization: Environmental Product Declarations and Certified Wood LEED –Researcher

Option 1: Environmental Product Declaration (EPD)

Use at least 20 different permanently installed products sourced from at least five different manufacturers that meet one of the disclosure criteria (ISO, EPD products or USGBC approved environmental products).

Option 2: Use at least 50 % by cost environmental products as mentioned at same credit in LEED reference guide.

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p93:94.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013-p513:523.
3. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering-Massachusetts institute of technology- USA- 2005- p 22.
4. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis-School of Planning, Design and Construction- Michigan State University- 2012-p 75.

5. Mcconnell, T., Irby, N: “A Preservative Treated Wood: A Sustainable Consumer Choice". Retrieved July 3, 2012, from www.ohioline.osu.edu/for:fact/pdf/0071.pdf
6. USGBC. :“LEED Green Building Reference Guide”- MR Credit 7, Certified Wood-Washington D.C- USA- 2009.

CR 37: Bridge Product Disclosure and Optimization: Sourcing of Raw Material LEED

Requirements: Use at least 20 different permanently installed products from at least five different manufacturers that have publicly released a report from their raw material suppliers which include raw material supplier extraction locations, a commitment to long term ecologically responsible land use, a commitment to reducing environmental harms from extraction and/or manufacturing processes, and a commitment to meeting applicable standards or programs voluntarily that address responsible sourcing criteria.

Reference:

1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p95:96.
2. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p524:539.

CR 38: Bridge Product Disclosure and Optimization: Material Ingredients: LEED

Requirements: Option 1. Material Ingredient Reporting

Use at least 20 different permanently installed products from at least five different manufacturers that use any of the mentioned programs at same credit on LEED reference guide to demonstrate the chemical inventory of the product to at least 0.1% (1000 ppm).

Option 2. Material Ingredient Optimization: Use products that document their material ingredient optimization using the paths below for at least 25%, by cost, of the total value of permanently installed products in the project.

GreenScreen v1.2 Benchmark, Cradle to Cradle certified or Cradle to Cradle Certified.

Reference:

1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p97:99.
2. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p541: 552.

CR 39: Earth Work Balance Greenroads

Intent: Reduce need for transport of earthen materials by balancing cut and fill quantities.

Requirements: Minimize earthwork cut (excavation) and fill (embankment) volumes such that the percent difference between cut and fill is less than or equal to 10% of the average total volume of material moved. For purposes of this credit, use the method and definitions detailed in Chapter 8 at Greenroads reference guide (Earthwork) of the Road Design Manual from the South Dakota Department of Transportation (SDDOT), or equivalent, to compute cut and fill volumes.

Include miscellaneous additional cut and fill such as outlet ditches and muck excavations (see definitions in Chapter 8 of the Manual) and account for moisture and density as well as shrink and swell. Balance cut and fill material volumes:

A = Volume of Cross Section Cut B = Volume of Cross Section Fill
C = Volume of Miscellaneous Cut D = Volume of Miscellaneous

Fill

$$\frac{(\boldsymbol{A}+\boldsymbol{C})-\ (\boldsymbol{B}+\boldsymbol{D})}{\frac{1}{2}(\boldsymbol{A}+\boldsymbol{C}+\boldsymbol{B}+\boldsymbol{D})}\times 100\% \leq 10\%$$

References:

1. Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010- p 375:383.

2. SDDOT's Chapter 8 is available here: http://www.sddot.com/ Pizer Inc. EARTH: Earthwork Quantity Software. Available at http://www.earthworksoftware.com/

3. British Columbia Ministry of Transportation and Infrastructure. (2010). Kicking Horse Canyon Project: Photo Gallery Phase 3 East Construction. Accessed 14 August 2010. Available at http://www.th.gov.bc.ca/kickinghorse/khc gallery 01 Phase3 east.htm

CR 40: Recycled Materials Greenroads

Pre consumer material is material from industry scraps that was diverted from the waste stream and used for other purposes. Examples include sawdust, wood shavings, wood chips, and print overruns. Excluded are materials that are reincorporated into the same manufacturing process that generated it.10 An example of what would not qualify is scraps of metal saved from a cutting process that are melted down and returned to the Same manufacturing process. When the material is incorporated into a new product it is Called pre consumer content. The percentage of recycled material in the new product. **An example** is a newspaper made with 25% pre consumer content.

Post-consumer material is a waste type produced by the end consumer of a material stream; that is, where the waste producing use did not involve the production of another product. Examples include construction and demolition debris, yard waste, and materials from curbside recycling programs (aluminum cans, newspapers, plastic bottles, milk jugs) The percentage indicates the percentage of postconsumer material included in the product. For example a plastic bottle with 50% postconsumer content.

Durable Goods: Durable goods are not specifically defined or addressed by LEED, but ultimately using more durable materials will reduce future demand. If a particular carpet lasts longer it means the building owner will not have to tear the carpet out and replace it frequently.

Intent: Reduce lifecycle impacts from extraction and production of virgin materials.

Requirements: Use recycled materials as a substitute for virgin materials. The fraction of recycled materials used can be calculated using one of four options below:

1. Consider only the pavement binder materials.
2. Consider only the hot mix asphalt (HMA) or Portland cement concrete (PCC) pavement materials.
3. Consider all pavement materials including granular base layers.
4. Consider all project materials.

Use Equation to compute the average recycled content (ARC) that will be achieved by the pavement section or by the binders.

$$ARC\ (\%) = \frac{\sum r_n}{\sum W_n} \times 100\%$$

rn is the total weight of recycled materials for that individual material or assembly
Wn is the total weight of each individual material or assembly
n represents the number of materials used in the pavement section

References:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 385:401.

2. -----: "LEED Principles and Green Associate Study Guide"- Green Building Education Services- USGBC -USA- 2014- p180:184.

3. Cascadia Consulting Group, Inc. (2004). Statewide Waste Characterization Study. Publication No. 340 04 005. For the California Integrated Waste Management Board (CIWMB).

4. Washington State Department of Ecology (DOE). (2007). Waste in Washington State: Sixteenth Annual Status

5. U.S. Environmental Protection Agency (EPA). (2009). Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2008. U.S. EPA, Washington, D.C.

6. Matos, G. and Wagner, L.: "Consumption of Materials in the United States" 1900-1995. US Geological Survey, Washington, DC. USA http://pubs.usgs.gov/annrev/ar 23 107/aerdocnew.pdf.

CR 41: Regional Materials Greenroads: LEED2009: Research

Intent: To increase demands for materials and products that are extracted and manufactured within the region, thereby supporting the use if indigenous resources and reducing the environmental impacts resulting from the transportation

Requirements: Make an itemized list of all materials, parts, components and products intended for permanent installation on the project including weights, total costs, shipping costs, and location of purchase and/or source of these materials.

Option 1. Choose local materials and product suppliers.

Compute the total cost of all materials, parts, components and products used for project construction including all shipping and transport costs based on the project bid list. Compute the percentage of this total cost that has been paid to materials suppliers, processors, distributors and producers within a 50 mile radius of the geographic center of the project. Points are awarded according to percentage, minimum percentage is 75%.

Option 2. Minimize travel distance for project construction materials.

Disaggregate each material, part, component or product into its “basic materials" by weight and express as a percentage of the sum of these weights. Compute the cumulative front haul distance traveled for each basic material from point of origin to the final endpoint on the project. Note this distance includes all intermediary points, such as assembly or distribution, between the original source and the final placement on the project. Report the total distance in terms of total freight miles (road, air, rail or barge) traveled for each basic material. Show that at least 95% of these basic materials by weight have traveled less than the 500 miles.

References:

1. Kasim Armagan Korkmaz: “Implementation of Sustainability in Bridge Design, Construction and Maintenance” - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 58:59.

2. Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010- p 403:409.

3. Hunt Lauren R: “Development of a rating system for sustainable bridge”- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p 21.

4. United States Green Building Council (USGBC). (2009) *LEED 2009 for New Construction and Major Renovations Rating System.* Available at http://www.usgbc.org/DisplayPage.aspx?CMSPageID=220

5. Liv.Haselbach: “The engineering guide to LEED- new construction: sustainable construction for engineers”- Mcgraw:Hill Companies- USA- 2008- p 192:195.

CR 42: Reduction in Quantity of Materials Researcher

Intent: The objective is to reduce the amount of material, used in the construction of bridges by using innovative civil engineering techniques.

Requirements: This credit can be achieved by either employing structural techniques such as supplementing the cement, recycling good quality steel members, or high strength materials. It may also incorporate materials that can be replaced by recycled content. Calculations can be done by weight or volume but must be consistent throughout.

Reduction in material (25%) = (Total reduction in quantity of material)/(Total quantity of all material used without employing strategies) X 100

References:

1. Kasim Armagan Korkmaz: “Implementation of Sustainability in Bridge Design, Construction and Maintenance” - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 54:55.

CR 43: Material Reuse (Salvaged Materials) Researcher

Reused materials do not become waste, so they don‘t end up in landfills. Reusing materials can also be considered a way of reducing waste; however, reused materials have their own strategies Potential ideas for using salvaged materials include: Salvaged brick used for walkways, Salvaged wood for flooring, cabinets, desks, design features, Salvaged tiles, etc.

Intent: The objective is to reuse the demolished bridge materials in road construction to reduce demand for virgin materials and reduce waste; thereby lessening impacts associated with the extraction and processing of virgin resources.

Requirement: Integrate salvaged or demolished material in the construction of roadways. Layout comprehensive plans and strategies to make use of demolished material in base, sub base, sub grade, embankment fills, and foundation stabilization.the reused materials should be from 5% to 10% from total materials by cost and should follow AAHSTO 2009 standard.

References:

1. -----: "LEED Principles and Green Associate Study Guide"- Green Building Education Services- USGBC -USA- 2014- p 172:174.
2. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 56:57.
3. AASHTO (2009). Part 5.7.3, Recycle Concrete Materials, Chapter 5, Pavement, Materials and Recycling. Center for Environmental Excellence by the American Association of State Highway and Transportation Officials. Retrieved November 3, 2011
4. http://environment.transportation.org/environmental issues/construct maint prac/compendium/manual/5 7.aspx

CR 44: Corrosion Resistant Steel Reinforcement Researcher

Intent: To prevent bridge reinforcement from corrosion by penetration of chloride, thus preventing the bridge from early deterioration and extending the service life of the bridge

Requirements: a) Consider using corrosion resistant reinforcing steel such as epoxy coated reinforcement, stainless steel reinforcement, and stainless steel clad reinforcement.

b) The stainless steel industry share of CO2 emissions could be around 12% of global emissions. Stainless steel contributes greatly towards sustainability and it leaves a reduced carbon footprint.

Scoring Criteria:

Minimum Points will be awarded if epoxy coated reinforcement is used on the project and maximum points will be awarded for both stainless steel reinforcement and epoxy coated reinforcement.

References:

1. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 68:69.
2. Gopal, R. (2006). How Green is Stainless Steel? Nickel Institute, Indian Stainless Steel Development Association.

CR 45: Cement Replacement (Supplement Cementations Material) Researcher

Intent: Reduce the co2 emission created by cement production.

Requirements: Replace a minimum of 20% by weight of Portland cement to be used with byproduct cementations material such as fly ash, silica fume or Ground granulated blast furnace Slag (GGBFS).

Reference:

1. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master thesis- Civil and Environmental Engineering- Massachusetts institute of technology- USA- 2005- p 21.
2. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 52:53.
3. Meyer, Christian : Concrete Materials and sustainable Development in the USA: Structural engineering international Vol 12 No 3 august 2004, p 203:207.
4. http://wsmtl.engr.wisc.edu/WSMTL:WEB:pg02E:NEWS:Mason.htm

3:2: Paving Credits.

CR 46: Paving Emission Reduction Greenroads

Intent: Improve human health by reducing worker exposure to asphalt fumes.

Requirement: Place at least 90% of the hot mix asphalt (HMA) on the project using a paver that is certified to have met National Institute for Occupational Safety and Health (NIOSH) emission guidelines as set forth in Engineering Control Guidelines for Hot Mix Asphalt Pavers, Part 1: New Highway Class Pavers (Department of Health and Human Services (NIOSH) Publication No. 97 105, April 1997 printing). Using this equation:

$$\frac{\textit{Total HMA Pavement Placed by NIOSH Pavers}}{\textit{Total HMA Pavement on Project}} \times 100\% \geq 90\%$$

References:

1. Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010-p 315:319.
2. Construction Innovation Forum (CIF): NOVA Award Nomination 12: Highway Asphalt Paver Fume Controls. Construction Innovation Forum, Walbridge, 2006. Available at http://www.cif.org/nom2006/Nom 12 2006.pdf.
3. National Institute for Occupational Safety and Health (NIOSH). (April 1997 second printing). Engineering Guidelines for Hot Mix Asphalt Pavers: Available at http://www.cdc.gov/niosh/asphalt.html

CR 47: Pavement Reuse Greenroads

Intent: Reuse existing pavement and structural materials.

Requirements: Reuse at a minimum 50% of existing pavement materials or structural Elements for minimum points and for maximum points reuse 90% of existing pavement materials. The materials considered in volume calculations can include but are not limited to hot mix asphalt (HMA), Portland cement concrete (PCC), unbound granular base material, stabilized base material, reinforced concrete, structural steel, and timber. In general, pavement materials will be easier to calculate by volume while structural materials should be calculated in terms of weight, unless material volumes are adjusted for density.

This credit IS appropriate for:

- Pavement rehabilitation actions that place new material over the existing pavement structure such as hot mix asphalt (HMA) overlays, PCC overlays (either bonded or unbounded) and pavement surface treatments .
- In place reprocessing operations (even though some are referred to as “recycling”) such as hot in place recycling, cold in place recycling, full depth reclamation, Portland cement concrete (PCC) crack and seat.
- Repurposing of existing material for other purposes in the same project. The material must not leave the project boundary to be considered. If it does leave the project boundary it may still be considered in the recycled Materials credit.

References:

1. Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010-p 357:374.
2. Washington Department of Transportation (WSDOT). (2010). WSDOT – SR 104 – Hood Canal Bridge – 2009 Frequently Asked Questions. Accessed August 20, 2010. Available at http://www.wsdot.wa.gov/Projects/SR104HoodCanalBridgeEast/faq.htm

CR 48: Long-Life pavement Greenroads

Intent: Minimize life cycle costs by promoting design of long lasting pavement structures.

Requirement: Design at least 75% of the total new or reconstructed pavement surface area for regularly trafficked lanes of pavement to meet long life pavement design criteria.

References:

1. Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010-p 419:427.

CR 49: Permeable Pavement Greenroads

Intent: Improve flow control and quality of storm water runoff through use of permeable pavement technologies.

Requirements: Use a permeable (porous) pavement or pavers to control and treat at least 50% of the 90th percentile average annual rainfall event post construction runoff volume to 25 mg/L concentration of total suspended solids (TSS) or less.

Note: Low impact development (LID) storm water controls must be considered in the scope and budget of the project for this credit to be applicable AND permeable pavement must be considered a feasible design best management practice within the storm water management plan. This means that the feasibility study completed for PR Low Impact Development must clearly show that permeable pavement (of any type) is appropriate for application on the project. Figure (A-10)

Porous concrete surface course | variety of permeable pavers, bricks, and non porous asphalt. | Permeable artificial turf (keys for scale). | Turf reinforcing grid installed in gravel parking area

Figure A-10: Permeable Pavement

References:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 429:439.

2. Hun Dorris, T: "Advances in Porous Pavement | stormh20.com Stormwater. Accessed January 9, 2010. Available at http://www.stormh2o.com/march april 2005/pavement materials watershed.aspx

1. North Carolina Division of Water Quality (NCDWQ). NCDWQ Stormwater BMP Manual. N.C. Division of Water Quality. 2007- Available at http://h2o.enr.state.nc.us/su/bmp updates.htm

2. Blair County Conservation District. (n.d.) Stormwater Best Management Practices. Accessed January 9, 2010. Available at http://www.blairconservationdistrict.org/SWBMP.htm

CR 50: Warm Mix Asphalt Greenroads

Intent: Reduce fossil fuel use at the hot mix asphalt plant, decrease emissions at the plant, and decrease worker exposure to emissions during placement

Requirements: Reduce the mixing temperature of hot mix asphalt by a minimum of 50°F from that recommended as the mixing temperature by the asphalt binder supplier. Mixing temperature shall be measured as the temperature of the mixture as it exits the mixing drum. This reduced temperature mix must comprise a minimum of 50% of the total project pavement (hot mix asphalt or Portland cement concrete) by weight.

References:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 441:445.

2. More information on that I:90 in Vantage, WA project can be found here:http://www.wsdot.wa.gov/Projects/I90/WGeorgePaving/

CR 51: Cool Pavement Greenroads

Intent: Reduce contribution to localized increased air temperatures due to pavement Reflectance and minimize storm water runoff temperatures in order to reduce heat island effect.

Requirements: Use a pavement surface with a minimum albedo of 0.3 (measured using ASTM E 903) for a minimum of 50% of the total project pavement surfacing by area.

OR Use a porous pavement or pavers for a minimum of 50% of the total project pavement surfacing by area. In either case, the surfaces intended for use by vehicles (e.g., roads, parking lots) must all be included in the calculation. Other surfaces (e.g., sidewalks) may be included if desired. A combination of materials may be used to meet the 50% area requirement.

Reference:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 447:454.

2. Cambridge Systematics, Inc: Cool Pavement Report – EPA Cool Pavements Study Task 5. Prepared for Heat Island Reduction Initiative, EPA, Washington, D.C- USA- 2005

CR 52: Quit Pavement Greenroads

Intent: Improve human health by reducing tire pavement noise. Figure (A-12)

Requirements: Design at least 75% of the total new or reconstructed pavement surface area for regularly trafficked lanes of pavement where the speed limit meets or exceeds 30 miles per hour (mph) with a surface course that produces tire pavement noise levels or listed on original credit at greenroads reference guide which describes test vehicle speed parameters and the points corresponding to the level of noise reduction achieved.

Tire pavement noise can either be measured from the side of the road as a vehicle passes by or from a point or by an appliance attached to car tires. OBSI measurement device

Figure A-11: Pavement Surface Noise Measurement

References:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 455:464.

2. The AASHTO Center for Environmental Excellence has many guidelines and resources for addressing NEPA compliance, including a guidebook for SAFETEA LU Environmental Review Processes.
http://environment.transportation.org/center/products programs/practitioners handbooks.aspx

1. Donavan, P. R. and B. Rymer.: Assessment of Highway Pavements for Tire/Road Noise Generation. SAE Noise and Vibration Conference and Exhibition, Grand Traverse, MI, USA, Session: Drive By Noise.-2003.

2. Donovan, P.R. (no date given). Comparative Measurements of Tire/Pavement Noise in Europe and the United States: A Summary of the NITE Study. Illingworth and Rodkin, Inc. prepared for the California Department of Transportation, Sacramento, CA.

3. Bennert, T., Hanson, D., and Maher, A: Demonstration Project – The Measurement of Pavement Noise on New Jersey Pavements Using the NCAT Noise Trailer. Report No. FHWA NJ 2003 021. New Jersey Department of Transportation, Trenton, USA-2004

CR 53: Pavement Performance Tracking Greenroads

Intent: Allow for more thorough performance tracking by integrating construction quality and pavement performance data.

Requirements: Use a process that allows construction quality measurements and long term pavement performance measurements to be spatially located and correlated to one another. This implies four requirements:

1. Construction quality measurements must be spatially located such that the location of the quality measurement is known to within 25 ft of the actual location where the material or process that was measured is actually located.
2. Pavement condition measurements must be taken at least every 2 years and must be spatially located to a specific portion of roadway or location within the roadway.
3. An operational system, computer based or otherwise that is capable of storing construction quality measurements, pavement condition measurements and their spatial locations.
4. The designated system must be demonstrated in operation, be capable of updates and have written plans for its maintenance in perpetuity.

References:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 465:468.

2. White, G.C., Mahoney, J.P., Turkiyyah, G.M., Willoughby, K.A., and Brown, E.R.: Online Tools for Hot Mix Asphalt Monitoring. Transportation Research Record, No. 1813, Transportation Research Board, National Research Council, Washington, D.C.- USA- 2002- p. 124 132.

Category 4: Energy and Atmosphere (EA)

CR 54: Enhanced Commissioning LEED

Intent: To further support the design, construction, and eventual operation of a project that meets the owner‘s project requirements for energy, water and durability.

Requirements: Implement, or have in place a contract to implement, the following commissioning process activities in addition to those required under Prerequisite Fundamental Commissioning and Verification.

Commissioning Authority: The CxA must have documented commissioning process experience on at least two bridge projects with a similar scope of work. The experience must extend from early design phase through at least 10 months of occupancy;

The CxA may be a qualified employee of the owner, an independent consultant, or a disinterested subcontractor of the design team.

Enhanced and Monitoring Based Commissioning: Develop monitoring based procedures and identify points to be measured and evaluated to assess performance of energy and water consuming systems. Include the procedures and measurement points in the commissioning plan.

References

1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p71:73.
2. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p387:404.
3. ASHRAE Guideline 0–2005, The Commissioning Process: ashrae.org
4. ASHRAE Guideline 1.1–2007, HVACandR Technical Requirements for the Commissioning Process: ashrae.org
5. NIBS Guideline 3–2012, Exterior Enclosure Technical Requirements for the Commissioning Process: nibs.org

CR 55: Optimize Energy Performance LEED

Intent: To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic harms associated with excessive energy use.

Requirements: Establish an energy performance target no later than the schematic design phase. The target must be established as kBtu per square foot/year (kW per square meter year) of source energy use.

Whole: Bridge Energy Simulation Analyze efficiency measures during the design process and account for the results in design decision making. Use energy simulation of efficiency opportunities, past energy simulation analyses for similar bridges, or published data (e.g., Advanced Energy Design Guides) from analyses for similar bridges. points are given according to percentage of improvement in energy as shown at original credit on LEED reference guide.

References

1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p74:78.
2 -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p405:412.
3. ASHRAE 90.1–2010 and ASHRAE 90.1–2010 User’s Manual: ashrae.org
4. ASHRAE 50% Advanced Energy Design Guides: ashrae.org

CR 56: Advanced Energy Metering LEED

Intent: To support energy management and identify opportunities for additional energy Savings by tracking bridge level and system level energy use.

Requirements: Install advanced energy metering for the following:

- All whole: bridge energy sources used by the bridge; and any individual energy end uses that represent 10% or more of the total annual consumption of the bridge.
- The advanced energy metering must have the following characteristics.
- Meters must be permanently installed, record at intervals of one hour or less, and transmit data to a remote location.

- Electricity meters must record both consumption and demand. Whole: bridge electricity meters should record the power factor, if appropriate.
- The data collection system must use a local area network, bridge automation system, wireless network, or comparable communication infrastructure.
- The system must be capable of storing all meter data for at least 36 months.
- The data must be remotely accessible.

References
1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p77:78.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- p413:420

CR 57: Renewable Energy Production LEED

Intent: To reduce the environmental and economic harms associated with fossil fuel energy by increasing self-supply of renewable energy.

Requirements: Use renewable energy systems to offset building energy costs. Calculate the percentage of renewable energy with the following equation:

$$\%\ \text{renewable energy} = \frac{\text{Equivalent cost of usable energy produced by the renewable energy system}}{\text{Total building annual energy cost}}$$

The use of solar gardens or community renewable energy systems is allowed if both of the following requirements are met.

- The project owns the system or has signed a lease agreement for a period of at least 10 years.
- The system is located with the same utility service area as the facility claiming the use.
- Credit is based on the percentage of ownership or percentage of use assigned in the lease agreement. Points are awarded according percentage of renewable energy (1%, 5% and 10%)

Eligible Renewable Energy Systems Allowable sources for renewable energy include the following:

- Photovoltaic
- Solar thermal
- Wind
- Befoul (in some cases)
- Low:impact hydroelectricity
- Wave and tidal energy
- Geothermal energy (in some cases)

References
1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p80:81.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- p429:440.
3. -----: "LEED Principles and Green Associate Study Guide"- Green Building Education Services- USGBC -USA- 2014- p 159.
4. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 61
5. Center for Resource Solutions Green:e Program: http://www.green:e.org/energy
6. Commercial Building Energy Consumption Survey (CBECS): eia.gov/consumption/commercial
7. ANSI/ ASHRAE/ IESNA Standard 90.1:2007 (Exterior Lighting) https://www.ashrae.org/.../20120510 9012007 lighting forms.pdf

CR 58: Green Power and Carbon Offset LEED

Intent: To encourage the reduction of greenhouse gas emissions through
The use of grid source, renewable energy technologies and carbon mitigation projects.

Requirements: for a minimum of five years, to be delivered at least annually. The contract must specify the provision of at least 50%(minimum points) or 100%(maximum points) of the project‘s energy from green power, carbon offsets, or renewable energy certificates (RECs).

Green power and RECs must be Green-e Energy certified or the equivalent For U.S. projects, the offsets must be from greenhouse gas emissions reduction projects within the U.S. Determine the percentage of green power or offsets based on the quantity of energy consumed, not the cost.

References

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- p82.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- p453:464.
3. Green:e Energy and Green:e Climate: http://www.green:e.org/energy
4. U.S. Department of Energy's Commercial Buildings Energy Consumption Survey (CBECS): eia.gov/consumption/commercial/index.cfm
5. ENERGY STAR Portfolio Manager: Methodology for Greenhouse Gas Inventory and Tracking Calculations: energystar.gov/ia/business/evaluate performance/Emissions Supporting Doc.pdf?72c6:8475
6. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2010. Annex 2 Methodology and Data for Estimating CO2 Emissions from Fossil Fuel Combustion: epa.gov/climatechange/ghgemissions/usinventoryreport/archive.html
7. 2006 IPCC Guidelines for National Greenhouse Gas Inventories: ipcc:nggip.iges.or.jp/public/2006gl/index.html
8. epa.gov/cleanenergy/energy:resources/egrid/index.html
9. Greenhouse Gas Protocol: ghgprotocol.org/standards

CR 59: Environmental Management System Greenroads

Intent: Improve environmental stewardship by using a contractor that has a formal environmental management process.

Requirements: The prime contractor, design builder or construction management firm shall have a documented environmental management system (EMS) for the entire company or at least the portion(s) of the company participating in the project. The EMS must be in place for the duration of project construction. As a minimum, the EMS and its documentation shall meet the requirements of International Standards Organization (ISO) 14001:2004.

Reference:

1: Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 129:133.

2: International Organization for Standardization (ISO). (2004). ISO 14001:2004 Environmental management systems Requirements with guidance for use. ISO, Geneva, Switzerland.

3: International Organization for Standardization (ISO). (2009). ISO 14000 essentials. ISO website. http://www.iso.org/iso/iso 14000 essentials. Accessed 11 January 2010.

CR 60: Energy Efficiency Greenroads

Intent: Reduce lifetime energy consumption of lighting systems for roadways.

Requirements: Install lighting systems with luminaries that meet or exceed the 2009 Energy Star standard for roadway lighting and are compliant with all safety requirements applicable to the roadway project Points are awarded based on the fraction of total luminaries installed on the project with energy efficient fixtures that are 2009 Energy Star compliant in the following manner: 20% minimum points and 100% maximum points. Figure (A-12)

Figure A-12: Renewable energy luminaries at ring road /Cairo-Alexandria desert road

Reference:

1. http://www.pnl.gov/main/publications/external/technical reports/PNNL:18687.pdf
2. The 2009 Energy Star Standard is available at: http://www.drintl.com/htmlemail/ESOutdoorDraft2 01Jul09.pdf.

3. Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010- p 411:418.
4. http://solareng.org/solar:street:lighting

Category 5: Water Efficiency (WE)

CR 61: Runoff Flow Control Greenroads

Intent: Mimic predevelopment hydrological conditions in the right of way (ROW) and minimize offsite storm water controls.

Requirements: 1. Develop a storm water management plan for the site using storm water best management practices (BMPs) for flow control. Explicitly state the goals of this plan and how performance will be measured.

2. Use low impact development (LID) BMPs to the maximum extent feasible as determined in Project Requirement PR 8 by a licensed professional.

3. Compute the 90th percentile average annual rainfall event values for the following Predevelopment and post construction conditions

4. Provide BMPs for storm water flow control. List the types, manufacturers, total volumes and flow rates controlled by BMPs within the ROW or outside of the ROW. Points are awarded based on type of alignment, location of BMPs and level of control achieved. For more calculations refer to original credit at Greenroads reference guide p135:152. Figure (A-13)

Reference:

1: Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010- p 135:152.
2: -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- p 94:97.
3: Liv.Haselbach: “The engineering guide to LEED- new construction: sustainable construction for engineers”- Mcgraw:Hill Companies- USA- 2008- p 60:65
4:www.masralarabia.com/ سوشيال
5:https://i.ytimg.com/vi/ujI5BPesoSk/hqdefault.jpg

CR 62: Runoff Quality Greenroads: LEED

Intent: Improve water quality of storm water runoff leaving the roadway Right of Way (ROW)

Requirements: To achieve this credit, previous credit must be achieved then Provide treatment for a desired percentage of the total computed runoff volume, points could be earned according to treated volume of storm water to all volume of storm water(minimum 80%: maximum 90%) Figure (A-14)

Reference:

1: Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010- p 153:172.
2: -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- p 94:97.
3: Liv.Haselbach: “The engineering guide to LEED- new construction: sustainable construction for engineers”- Mcgraw:Hill Companies- USA- 2008- p 60:65.
4: http://www.ladstudios.com/ladsites/sustainability/strategies/Strategies TreeWell.shtml

CR 63: Storm water Cost Analysis Researcher, Greenroads

Intent: Determine lifecycle costs and savings associated with low impact development techniques and best management practices for stormwater utilities.

Requirements: Conduct a lifecycle cost analysis (LCCA) for stormwater utilities according to the National Cooperative Highway Research Program (NCHRP) Report 565: Evaluation of Best Management Practices for Highway Runoff Control Guidelines Manual.

Use a financial approach (strictly monetary costs and benefits) for the LCCA.

Evaluate design alternatives based on the goals of the storm water management plan.

Set up a spreadsheet to compute costs based on budget inputs.

Use estimated costs for LID Bmp Consider avoided costs of storm water treatment at off site locations, or avoided permitting costs.

Include several different methods and alternatives in the evaluation of the storm water System when performing the LCCA. Investigate both structural and non-structural Controls, including conventional controls such as detention or infiltration

Reference:

1: Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010-p 153:172.

2: NCHRP Report 565 can be accessed at the following link:
http://144.171.11.107/Main/Blurbs/Evaluation of Best Management Practices for Highwa 158397.aspx

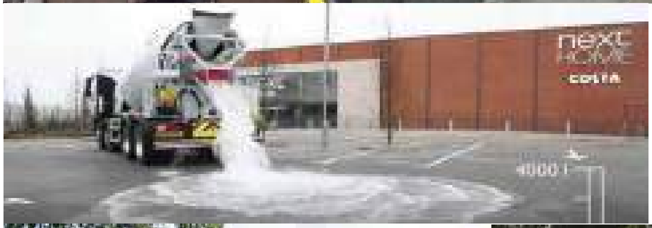
3: BMPs available from the BMP Database (BMPDB) available at: http://www.bmpdatabase.org.

4: Environmental Protection Agency (2007). Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. [Publication Number EPA 841 F 07 006, December 2007

5: Huber W.C., Strecker, E.W., Heaney, J.P., and Weinstein, N: Evaluation of Best Management Practices and Low Impact Development for Highway Runoff Control User's Guide for BMP/LID Selection Guidelines Manual. National Cooperative Research Program- USA-2006.

Washington. permeable pavement bikelanes -permeable sidewalk- A bioswale with flow control weirs.USA

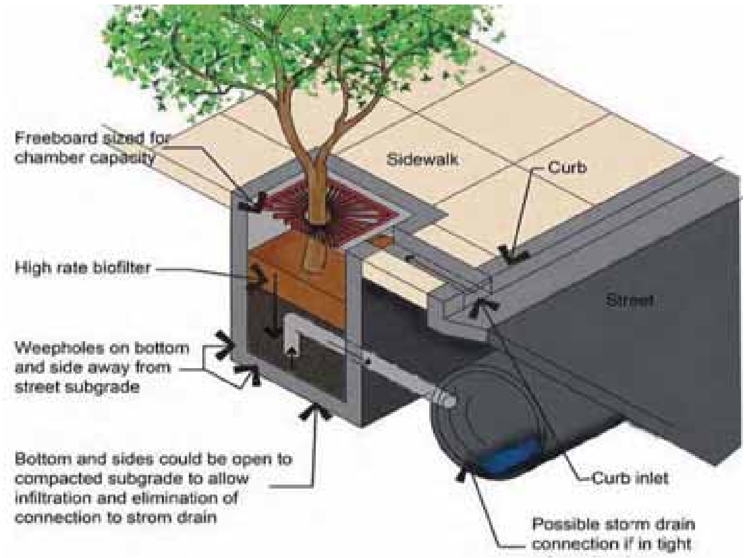
Examples of bad storm water control Alexandria: October 2015



Permeable asphalt to absorb 4000 liters of rain water

The High Point subdivision in the West Seattle neighborhood of Seattle, Washington: The grassy area (left) is actually turf placed over a large infiltration basin. A bios wale (center) is featured, and still in early growth. Alsoand the street (right) are paved with permeable concrete.

Figure A-13: Runoff Flow Control



Tree box filter schematic

A well established vegetated swale/Bioswale that uses compost amended soil and no flow control devices or structures.
Residential street to right.
Seattle, USA / Greenroads

Figure A-14: Runoff Quality

CR 64: Site Vegetation (Water Use Reduction) Greenroads, *LEED*

Intent: Promote sustainable site vegetation that does not require irrigation. To reduce outdoor water consumption.

Requirements: Site vegetation shall be subject to the following requirements in order to receive the points listed:

1 point: Use noninvasive plant species only,1 point: Do not use water (no irrigation) after the plant establishment period, 1 point: Use native plant species only "Site vegetation "is defined as all vegetation associated with a particular roadway project and shall include all vegetation within the roadway's right of way. This can include roadside vegetation, decorative planting (e.g., planter boxes or potted plants in urban areas) and vegetation contained in storm water facilities (e.g., bio swales and rain gardens).

The following items must be performed to ensure that a plant species is considered "noninvasive":

1. Consult existing local (e.g. city, county, state, park service) vegetation policy and procedure that is applicable to the roadway project and is specifically formulated to prevent the use of invasive plant species and noxious weeds.
2. Use local and/or regional lists to identify invasive plant species.
3. Comply with local and/or national noxious weed laws. "No water use" means that the site vegetation will not require any irrigation after the plant establishment period. The "plant establishment period "shall be stated in the project specifications. Typical plant establishment periods are 1 3 years. This requirement means that vegetation requiring irrigation such as seasonal planter boxes cannot receive the associated point even if it is fully comprised of noninvasive or native species. "Native plant species "are plants native to the EPA Level III ecoregion that contains the roadway project site or known to naturally occur within 200 miles of the roadway construction site. Figure (A-15)

Reference:

1: Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 177:182.
2: -----: "LEED Principles and Green Associate Study Guide"- Green Building Education Services- USGBC -USA- 2014- p 114:120.
3: Liv.Haselbach: "The engineering guide to LEED- new construction: sustainable construction for engineers"- Mcgraw:Hill Companies- USA- 2008- p 93:100.
4: -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- p287:296

5: Steinfeld, D.E., Riley, S.A., Wilkinson, K.M., Landis, T.D. and Riley, L.E.: Roadside Revegetation: An Integrated Approach to Establishing Native Plants. FHWA WFL/TD 07 005. Federal Highway Administration, Western Federal Lands Highway Division, Vancouver, WA- 2007.

6: The Sustainable Sites Initiative: Guidelines and Performance Benchmarks. American Society of Landscape Architects, Lady Bird Johnson Wildflower Center at the University of Texas at Austin, United States Botanic Garden- 2009.

7:https://www.behance.net/gallery/22818277/Dar:Al:Handasah New:Premises All:RIghts:Reserved

8:http://benitezbroslandscaping.com/xeriscaping

Techniques to reduce Outdoor water consumption

Landscape Design	Outdoor Water Reduction	Landscape Maintenance
Appropriate Plant Selection	Drip Irrigation	Raise Mowers
Xeriscaping	Scheduling	Leave the Clippings
Mulching	Weather Based Irrigation Controllers	Maintain the Watering System
Reduce Turf Grasses and Monocultures	Water Audits	

Xeriscaping at dar al handasah New premises Smart Village LEED Gold certificate

Xeriscaping Ideas

Figure A-15: Site Vegetation

CR 65: Ecological Connectivity Greenroads

Intent: Provide or improve wildlife access and mobility across roadway facility boundaries and reduce vehicle wildlife collisions and related accidents.

Requirements: Complete a site specific wildlife assessment for the roadway project. Report the resulting impacts that the roadway has on surrounding major ecosystems, identifying all non-human life that is impacted by the roadway facility according to the best scientific knowledge available for the ecosystem. Both point scenarios below require approval of the project ecologist.

And complete one of the two of the following options:

Option **A** Existing Alignments only

Replace in kind, retrofit, or upgrade any and all existing culverts and wildlife fencing Structures deemed structurally deficient, damaged, obsolete, insufficiently sized, or Otherwise inadequate.

Or option **B** New and Existing Alignments

Install new dedicated wildlife crossing structures and protective fencing (if needed) as Recommended by the wildlife assessment. In addition, existing alignments must also replace in kind, retrofit, or upgrade all existing culverts and fencing structures deemed structurally deficient, damaged, obsolete, insufficiently sized, or otherwise inadequate.

Reference:

1: Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R., and Söderlund, M. et al. (2011). Greenroads Rating System v1.5. (J.L. Anderson and S.T. Muench, Eds.).Seattle, WA: University of Washington. PR1: p 193:200.

CR 66: Water Use Tracking (Water Metering) Greenroads: LEED

Intent: Generate project level information about construction water use. And To support water management and identify opportunities for additional water savings by tracking water consumption.

Requirements: Install permanent water meters for bridge water consumption (irrigation, cleaning, operation, maintenance, etc...)

Reference:

1: Muench S.T. and Anderson, J.L: “Greenroads Rating System” v1.0. - University of Washington- Seattle-Washington-USA-2010-p 321:325.
2: -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013-p31111:316
3: -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 201562.

Category 6: Bridge Maintenance (BM)

A majority of the bridges built around the 1960‘s and 1970‘s need significant repair and maintenance actions. Lead and chromate based paints and coatings removal may have significant impacts on the environment, workers, and public. This section outlines the requirements of inspection technologies, bridge painting, cleaning, deck drainage, in order to reduce associated environmental impacts.

CR 67: Efficient Inspection Technologies Researcher

Intent: To use efficient inspection technologies and processes for proper maintenance action decisions, thus enhancing the service life and reducing associated environmental impacts.

Requirements: a) Follow Recommended Framework for a Bridge Inspection QA/QC Program of National Bridge Inspection Standards, FHWA. The framework describes the quality control and quality assurance procedures for accuracy and consistency in the bridge inspections. The framework outlines documentation of QA/QC program, Quality Assurance (QA) procedures, and Quality control (QC) procedures. b) Use of specialized bridge equipment such as under bridge inspection vehicles, mobile inspection platforms, nondestructive evaluation equipment, and data collection and analysis equipment for efficient data collection and to allow workers to maneuver safely into position, allowing for hands on inspection and maintenance work. The office of bridge technology, FHWA, outlines a policy regarding the use of federal aid funds, specifically highway bridge replacement and rehabilitation programs (HBRRP) funds for the purchase or rent of specialized inspection equipment. Federal HBRRP funds may also be used for the installation of permanent features that facilitate inspection activities on highway bridges as defined in 23 CFR 650.305. Such features as handrails, anchor points for a horizontal lifeline, and catwalks would be a few examples. In addition to HBRRP funds, National Highway System, Surface Transportation Program, and State Planning and Research funds may be used for the development, establishment, and implementation of bridge management systems and associated data collection activities or Any other local equivalent standard could be used.

References:

1. Kasim Armagan Korkmaz: “Implementation of Sustainability in Bridge Design, Construction and Maintenance” - Phd Thesis-School of Planning, Design and Construction- Michigan State University- 2012-p 77:78.
2:FHWA. INVEST Sustainable Highways Self:Evaluation Tool. Retrieved May 5, 2012,from US Federal Highway Administration:
3:https://www.sustainablehighways.org/124/score.html
4:Lwin, M. M: Funding for Bridge Inspection Equipment and Access Features. US federalHighway Administration.
Inspection Standards (NBIS) 2005, http://www.fhwa.dot.gov/bridge/nbis.cfm
5:MDOT Bridge Inspection Manuals: http://www.michigan.gov/mdot/0,1607,7:151:9625 24768 24773::,00.html
6:http://www.hbrc.edu.eg/: المعهد القومي لبحوث البناء و الاسكان

CR 68: Bridge Painting and Coating Researcher

Intent: To prevent bridge components from deterioration due to corrosion thus increasing the life expectancy of bridges and also protect workers and the environment from paint related byproducts. Paint should be used to slow corrosion cause by moisture, air, and oxidizing chemicals.

Requirements: a) Utilize best practices to protect workers and the environment during lead paint removal and remove lead from existing structures; replace with zinc:rich type

4 systems

b) Consider applying coating to the structural steel or reinforcement i.e., consider following these standards.

Reference:

1. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis-School of Planning, Design and Construction- Michigan State University- 2012-p 79:80.

2. AASHTO (2012). Part 7.4, Bridge Painting.Coating.Sealing and Containment Stewardship Practices: Chapter 7 Bridge Maintenance Manual. Retrieved from American Authority of State Highway and Transportation Officials: http://environment.transportation.org

3. http://www.hbrc.edu.eg/: البناء و الاسكان لبحث القمي المعهد

Standards/Resources:

1. Kline, E. (2009). Durable Bridge Coatings.,MODERN STEEL CONSTRUCTION magazine november 2009.
2. FHWA Bridge Coatings Technical Note: Zinc:Rich Bridge Coatings. Retrieved May 17, 2012, from US Federal Highway Administration: http://www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/zinc.cfm
3. Zinc:Rich Bridge Coatings, FHWA Bridge Coatings Technical Note: Zinc:Rich Bridge Coatings
4. Clean Air Act Amendments
5. Society for Protective Coatings (SACE)
6. National Association of Corrosion Engineers (NACE)
7. GS11 Green Seal Environmental Standard for Paints and Coatings or Any other local equivalent standard.

CR 69: Corrosion Resistant Steel Reinforcement (Credit): Research

Intent: To prevent bridge reinforcement from corrosion by penetration of chloride, thus preventing the bridge from early deterioration and extending the service life of the bridge.

Requirements: a) Consider using corrosion resistant reinforcing steel such as epoxy coated reinforcement, stainless steel reinforcement, and stainless steel clad reinforcement.

b) The stainless steel industry share of CO2 emissions could be around 12% of global emissions. Stainless steel contributes greatly towards sustainability and it leaves a reduced carbon footprint

References:

1. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis-School of Planning, Design and Construction- Michigan State University- 2012-p 68:69.

Standards/Resources:

1. Performance of epoxy:coated rebar in bridge decks volume 60:No. 2, FHWA
2. Stainless steel reinforcement, MDOT bridge design manual section 7.04
3. Epoxy coated rebar bridge decks; expected service life, MDOT bridge design manual section
4. ASTM E937: 93(2011) Standard Test Method for Corrosion of Steel by Sprayed Fire:Resistive Material (SFRM) Applied to Structural Members
5. ASTM A1035 (low carbon, chromium) – MMFX2
6. Stainless steel conforming to ASTM A955 – UNS designations: S24100, S30400, S31603,S31653, S32101, S32201, S32205
7. Stainless steel clad bars conforming to AASHTO MP13M Any other local equivalent standard.

CR 70: Corrosion Control Materials Researcher

This criterion will address corrosion control materials that can be used during rehabilitation and maintenance of bridges.

Intent: To prevent or minimize the corrosion of bridge elements due to the penetration of chloride based deicers. This minimizes early deterioration of the structure. Each recommended method would either result in an increased amount of time between maintenance cycles or extend the bridge‘s service life.

Requirements: a) Consider using galvanic anodes in all concrete patches that extend below the top layer of reinforcement. Only galvanic anodes listed on MDOT‘s QPL can be used.

b) Consider using Carbon Fiber Reinforced Polymer (CFRP) wrap. This increases the strength, is lightweight and provides additional corrosion resistance.

References:

1. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis-School of Planning, Design and Construction- Michigan State University- 2012-p 85.

Standards/Resources:

1. MDOT standard specifications for construction section 712.03
2. Michigan State University Report, 2000, ―Repair of Corrosion Damaged Columns Using FRP Wraps‖

CR 71: Bridge Cleaning Researcher

Intent: To clean components of bridges vulnerable to dirt, bird drop, accumulation, etc. thus increasing the longevity of the bridge components and lessening future maintenance requirements.

Requirements: Bridge components subjected to dirt, bird drop accumulation, etc., should be cleaned periodically by using hand tools, air blasting, or preferably water jetting.

References:

2. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 81:82.

Standards/Resources:

1. Drainage System cleaning, Pavement Cleaning, MDOT Scoping Manual, Michigan Department of Transportation.
2. Part 7.1.3, Bridge Cleaning; Chapter 7, Bridge Maintenance, Center for Environmental Excellence by AAHSTO‖ American Association of State and Transportation Officials.
3. NCDOT Guidelines for Managing Bridge Wash Water Version 1.0.

CR 72: Bridge Deck Drainage Researcher

Intent: To avoid impacts on the deck structure and reinforcing bars due to inefficient drainage.

Requirements:

a) Gutter flow from roadways should be intercepted before it reaches a bridge;

b) Avoid zero gradients and sag vertical curves on bridges;

c) Larger grates and inlet structures can be used onto the subsequent roadway sections to collect runoff from bridge decks immediately (AASHTO, 2009).

References:

1.Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 81:82.
2.AASHTO (2009). Part 5.7.3, Recycle Concrete Materials, Chapter 5, Pavement, Materials and Recycling. Center for Environmental Excellence by the American Association of State Highway and Transportation Officials. Retrieved November 3, 2011
3.AASHTO (2009). Part 7.1.2, Maintaining Drainage form Bridge Deck; Chapter 7, Bridge Maintenance. Center for Environmental Excellence by the American Association of State Highway and Transportation Officials.
4. AASHTO (2009). Part 7.1.3, Bridge Cleaning; Chapter 7, Bridge Maintenance, Center for Environmental Excellence by AAHSTO. Retrieved September 5, 2012, from American Authority of State Highway and Transportation Officials: environment.transportation.org

CR 73: Bridge Deck Joints and Deck Joint Seals Researcher

Intent: To minimize or eliminate poorly maintained bridge deck joints and seals thus maintaining the service life of the bridge

Requirements: Consider:

a) Eliminating bridge deck joints (when possible) or moving joints off bridge with the use of sleeper slabs.

b) If possible, discontinue the use of compression seals in new construction, replacement, and rehabilitation. Replace existing compression seals and block out style joints in those locations where expansion or rotation is needed with strip seal style expansion devices.

c) Establish a routine maintenance procedure to maintain joints.

References:

1.Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis- School of Planning, Design and Construction- Michigan State University- 2012-p 88:89.

Category 7: Innovation and Custom Credits

ICC1: LEED AP LEED

Intent: To encourage the team integration required by a LEED project and to streamline the application and certification process.

Requirements: At least one principal participant of the project team must be a LEED accredited professional (AP) and appropriate qualifications for the project.

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- pp 142.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- pp 785:788.

ICC2: Innovation (Custom Credits) Greenroads: LEED

Intent: To encourage projects to achieve exceptional or innovative performance.

Requirements: Project teams can use any combination of innovation, pilot, and exemplary performance strategies.

Option 1. Innovation (1 point)

Achieve significant, measurable environmental performance according to a strategy that is subject to the developed rating system Identify the following.

- The intent of the proposed innovation credit.
- The proposed compliance requirements.
- The proposed submittals to demonstrate compliance.
- The design approach or strategies used to meet the requirements.

Option 2. Pilot (1 point)

Achieve one pilot credit from USGBC's LEED Pilot Credit Library

Reference:

1. -----: "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2015- pp 140:141.
2. -----: "LEED Reference Guide for building Design and construction V4"- Accredited Professional (AP) - USGBC-USA- 2013- pp 779:784.
3. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 471:482.

ICC3: Environmental Training Greenroads

Intent: Provide construction personnel with the required information to identify the environmental issues and the best practice methods to minimize environmental impacts.

Requirements: Provide an environmental training plan that is customized to the project, including:

1. List of the types of project personnel to be trained. This may be a list by job type or by employer without containing actual employee names.
2. Description of types, goals and objectives of training to be given.
3. A process to track training efforts, including dates, means (e.g., online, classroom, field training), topics, the identification of those participating in training, and attendance numbers.
4. A process to measure training effectiveness such as self-assessment, pretest and Posttest, and productivity measurement.

References:

1. Muench S.T. and Anderson, J.L: "Greenroads Rating System" v1.0. - University of Washington- Seattle-Washington-USA-2010- p 285:291.

ICC4: Building under the Bridge: Researcher

Intent: Design a sustainable certified building under the bridge.

Requirements: In case of constructing a building under the bridge, this building should follow all prerequisites of LEED BD+C rating system and achieve minimum credits that make it LEED certified building.

ICC5: Bridge Rentable Spaces: Researcher

Intent: Maximize usage of spaces under and around the bridge and provide extra

funding resources.
Requirements: Create more rentable spaces under and around the bridge and use the renting money in bridge development and maintenance. These areas may be rented as car parking, shops, bus stops, open markets, etc..

ICC6: Governmental Monitoring Rules of the Bridge's surface:

Researcher
Intent: Bridge architecture and sustainability success observation.
Requirements: Conduct a monthly inspection to monitor break of any governmental rules in connection to the bridge as (Street vendors, bridge different usages as pedestrians on vehicle bridges, etc...).

ICC7: Governmental Rules Monitoring of the Bridge's surrounding areas:

Researcher
Intent: Bridge surroundings architecture and sustainability success observation.
Requirements: Conduct a monthly inspection to monitor break of any governmental rules related to the bridge's surrounding areas as (illegal buildings around the bridge such as the Ring Road indiscriminate land use, illegal usage of area the under the bridge, etc...).

ICC8: Regional Priority

LEED
These Regional priority credits encourage the project teams to focus on their local environmental priorities.
USGBC established a process that identifies six RP credits for every location and every rating system within chapter or country boundaries. Participants were asked to determine which environmental issues were most salient in their chapter area or country. The ultimate goal of RP credits is to enhance the ability of project teams to address critical environmental issues across the country and around the world.
Intent: To provide an incentive for the achievement of credits that address geographically specific environmental, social equity, and public health priorities.
Requirements: Earn up to four of the six Regional Priority credits. These credits have been identified by the USGBC regional.
Reference:

1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p97:99.
2. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013- p789: 793.
3. -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- 220.

ICC9: Architectural Creativity

Researcher
Intent: To encourage designing a creative and unique bridge which is considered as a landmark.
Requirements: Developing any creative architectural technologies, solutions which are not mentioned at any credit or designing a land mark bridge which represents its neighborhood, city or country.

ICC10: Structural Innovative Solutions:

Researcher
Intent: To encourage structural creativity.
Requirements: Innovate any new structure technique, solution, system, the construction material, construction method, etc... Or modify an existing one to achieve same safety requirements in shorter time with less cost.

مستخلص البحث

تؤثر الكباري علي التشكيل العام للمدينة كما أنها تؤثر إجتماعياً وثقافياً في المجتمع. أيضاً بالإضافة إلي الوظائف الأساسية للكباري، فإن لها وظائف أخري مكتسبة و التي تعبر عن تطور المجتمع أوتخلفة. أيضا الكثير من الكباري تعتبر من العلامات البصرية التي تميز المدن وتعبر عن الحضارات.
يمكن تلخيص المشكلة البحثية كالآتي: إن معظم الكباري المصرية تواجة مشاكل جمالية ووظيفية وقصور في الإستدامة (البيئية والإقتصادية والإجتماعية). أيضا لوحظ استبعاد المعماري من عمليات تصميم وإنشاء وتشغيل الكباري المصرية وتم تفويض مهمات تصميم وإنشاء وتشغيل الكباري بالكامل إلي المهندس الإنشائي الذي يهتم فقط بسلامة الكوبري وتكلفته دون النظر إلي نجاح الكوبري في أداء وظائفة الاساسية والمكتسبة وأيضا بغض النظر عن جماليات الكوبري أوإستدامتة البيئية والإقتصادية والإجتماعية.

ان الهدف الأساسي من الدراسة البحثية هوإستخراج نظام مستدام للتقييم المعماري للكباري في مصر. حيث يستخدم هذا النظام المستخرج كدليل إرشادي لفريق عمل الكباري لتخطي هذة المشاكل وتجنب حدوثها في الكباري المستقبلية في كلا من تصميم وتنفيذ وتشغيل الكباري. وذلك لأن إنشاء الكباري يستهلك أكبر قدر من تجهيز الموقع وإستخدام المواد ويؤثر بشكل كبير علي تشكيل المدينة.
لذا سيقوم هذا النظام بتقييم عمارة الكباري (تقييم الكباري وظيفياً وجمالياً) و أيضا تقييم الإستدامة البيئية والإقتصادية والاجتماعية للكباري.

الملخص العربي للبحث

تعتبر الكباري واحدة من أهم المنشآت التي تؤثر علي شكل الشارع المصري. معظم الكباري المصرية تواجه مشاكل وظيفية وجمالية وقصور في الاستدامة (البيئية والاقتصادية والاجتماعية) لذا يجب دراسة تلك المشاكل لتجنب حدوثها في الكباري الجديدة التي تكون قيد عملية التصميم. للوصول إلي هذا الهدف سيتم تطوير نظام مستدام للتقييم المعماري للكباري في مصر خلال هذا البحث. لتطوير هذا النظام المستدام، تم تقسيم البحث كالتالي:

الجزء الاول: الدراسة النظرية
مدخل إلي الكباري والأستدامة

الفصل الأول: التطور التاريخي للكباري علمياً وفنياً وإنشائياً

تناولت الدراسة في هذا الباب التعريفات الأساسيه للكباري وأيضا تاريخ الكباري عالمياً وتاريخ الكباري في مصر وعمل مقارنة بين تطور الكباري في مصر وتطورها في العالم.

أيضاً تم تحليل علاقة الكباري بالإتجاهات و المدارس المعمارية عبر التاريخ ومعرفة مدي الترابط بين التطور المعماري للكباري وبين الإتجاهات المعمارية العالمية وذلك من خلال اتخاذ نماذج من الكباري المميزة في كل فترة ودراسة علاقتها بالإتجاهات و المدارس المعمارية في نفس الفترة.

في نهاية الفصل، تم إستخلاص مجموعة من الإشتراطات والنقاط التي سيتم تجميعها في نظام االتقييم والمتعلقة بتاريخ الكوبري وإتجاهاتة المعمارية.

الفصل الثاني: الكباري المستدامة

تهدف الدراسة في هذا الفصل إلي تعقب التدرج في مفاهيم الإستدامة من المفاهيم العامة للإستدامة إلي إستدامة الكباري وذلك من خلال المرور بكل من التنمية المستدامة ومبادئ الإستدامة والعمارة المستدامة والتصميم المستدام وإستدامة الإنشائات والتنقلات.

لتحقيق إستدامة الكباري، تم دراسة كلا من الترابط بين الإنشاء والإستدامة والمدينة المستدامة.

في نهاية الفصل تم الإجابه علي هذة التساؤلات: ما الهدف من القيام بتصميم كوبري مستدام؟ وماهي المنهجية المتبعة لتحديد مبادئ الإستدامة في الكباري؟

الجزء الثاني: الدراسة التحليلية
نظام تقييم الكبـــــاري معماريـــــــــــاً

يتكون هذا الجزء من شقين: الشق الأول يتكون من ستة فصول و يتناول عمليتي تصميم وإنشاء الكباري، أما الشق الثاني فيتكون من فصل واحد ويتناول عملية تشغيل الكباري وإستخدامها.

أولاً: العوامل المؤثرة في عمارة الكباري خلال مرحلتي التصميم والتنفيذ.

الفصل الثالث: أنواع الكباري المختلفة وعمارتهـــــا

يطرح المصمم عدة أسئلة في بداية عملية تصميم الكوبري منها: ما هو الهدف من إنشاء الكوبري؟ ما هي وظيفة الكوبري الأساسية؟ هل الكوبري يستخدم بواسطة المشاة أم السيارات أم القطارات.. الخ؟

لذا سيتم التناول في هذا الفصل الشرح التفصيلي للوظائف المختلفة للكباري وأيضاً أنواع الكباري تبعاً لقابلية الحركة (كباري ثابتة أوكباري متحركة) والمميزات والعيوب لكل نوع.

في نهاية الفصل سيتم إستخراج مجموعة من الإشتراطات والنقاط الخاصة بنوع ووظيفة الكوبري لتقييم مدي نجاحهما والتي سيتم إضافتها لنظام التقييم.

الفصل الرابع: العلاقة بين الكباري ومحددات الموقع

السؤال الثاني المطروح بواسطة المصمم خلال عملية تصميم الكباري هوأين سيكون موقع الكوبري؟

تتأثر عمارة الكباري تأثراً كبيراً بموقعها فتصميم كوبري في قلب المدينة يختلف عن تصميم كوبري علي أحد الطرق السريعة الذي يكون مختلف تماماً عن تصميم كوبري في أحد المناطق الأثرية.

لذا سيتم التناول بالتفصيل في هذا الفصل دراسة المحيط العمراني للكباري عن طريق دراسة المحددات الطبيعية والمحددات المبنية والشبكة العمرانية المحيطة بالكوبري محل التصميم وايضا العلاقة بين الكوبري الجديد وبين

كوبري آخر قائم أوأثري أومنطقة أومنشأه أثرية.

أيضا لنهر النيل أهمية كبيرة علي شكل الكباري والجسور النيلية في مصر، لذا سيتم دراسة الكباري الحية "الكباري المطلة علي الأنهار" من خلال دراسة نماذج مصرية ومقارنتها بأخري عالمية.

أيضا سيشمل الفصل دراسة التصميم الجمالي للكوبري ككل تبعاً للموقع والعائق المار فوقه الكوبري وتقاطع الكوبري مع غيرة من الكباري ثم يتم إستخراج مجموعة من الإشتراطات والنقاط الخاصة بموقع الكوبري ومحيطه العمراني والتي سيتم إضافتها إلي نظام التقييم.

الفصل الخامس: إنعكاس الإعتبارات الإنشائية للكباري على الشكل والتكوين.

إن الإعتبارات الإنشائية للكباري من نظام إنشائي ومواد البناء يعد من أهم المؤثرات علي شكل الكوبري وتكوينه، لذا سيتم دراسة تأثير كلا من النظم الإنشائية المختلفة للكباري ومواد البناء المختلفة المستخدمة في الكباري علي الشكل النهائي للكوبري وتكوينه. أيضا سيتم دراسة تأثير كلا من الأحمال المحسوبة بواسطة المتخصصين والبحور المطلوبة للكوبري وطرق الإنشاء المختلفة علي إختيار النظام الإنشائي ومواد الإنشاء من منظور معماري ومن ثم التأثير علي شكل الكوبري وتكوينه و عمارته.

في نهاية الفصل، سيتم إستخلاص مجموعة من الإشتراطات والنقاط التي تضمن إختيار أفضل النظم والمواد الإنشائية من وجهة نظر معمارية مستدامة.

الفصل السادس: علاقة الأجزاء المختلفة للكباري بالشكل والتكوين.

بعد تحديد النظام الإنشائي ومواد البناء المستخدمة تحول الكوبري إلي منشأة معمارية ذات شكل وتكوين، بحيث تتكون هذة المنشأة من مجموعة من الأجزاء والتفاصيل الإنشائية والغير إنشائية.

سيتم تناول تأثير إختيار هذه التفاصيل الإنشائية (جسم الكوبري والأعمدة والكمرات..إلخ) والأجزاء الغير إنشائية (الأسوار ووحدات الإضائة واللافتات.. إلخ) علي الشكل النهائي للكوبري.

في نهاية الفصل سيتم إستخلاص مجموعة من الإشتراطات والنقاط التي تساعد علي إختيار أفضل أشكال أجزاء وتفاصيل الكوبري الإنشائية والغير إنشائية لضمان الحصول علي أفضل تصميم معماري للكوبري.

الفصل السابع: تأثير الإعتبارات الجمالية والإبتكارية على التصميم المعماري للكباري.

تناولت الدراسة في هذا الفصل أساسيات التصميم الجمالي والقيم الجمالية (مثل النسب والإيقاع والترتيب ..إلخ) وأيضا الأهداف الجمالية المرجوة من تصميم الكباري (مثل وضوح الوظيفة والإيقاع والتناغم ..الخ).

أيضا تم دراسة العوامل المؤثرة علي تمييز الكباري مثل (الألوان ومواد النهو والزخارف.. إلخ) أيضا إستقبال المشاهد للكوبري والذي يختلف من تصميم لآخر ومن مشاهد لآخر.

إن الأبتكار في تصميم الكباري من أهم العوامل المؤثرة علي تطور الكباري والتي تم دراستها من خلال تعريف الإبتكار وخصائص العملية الإبتكارية.

في نهاية الفصل تم إستخراج مجموعة من الإشتراطات والنقاط التي تضمن أفضل الإعتبارات الجمالية والإبتكارية للكوبري والتي تضاف إلي نظام التقييم.

الفصل الثامن: العملية التصميمية للكباري المستدامة ودور المعماري فيها.

هناك عاملان رئيسيان شديدي التاثير علي تصميم الكباري المستدامة وهما فريق التصميم المتكامل والعملية التصميمية المتكاملة. في هذا الفصل سيتم دراسة الفارق بين كلا من الكباري التقليديه والكباري المستدامة في ضوء كلا من فريق التصميم والعملية التصميمية مستعرضاً المنهجيات المختلفة لتصميم الكباري وموضحاً الأطراف المشاركة في عمليتي تصميم الكباري وتنفيذها من المالك إلي فريق التصميم إنتهاءاً إلي فريق التنفيذ وعلاقة كلا من هؤلاء الأفراد ببعضهم البعض وتأثيرهم علي الشكل النهائي للكوبري.

من أهم أسباب تأخر الكباري المصرية في مواكبة التقدم العالمي لتصميم وتنفيذ الكباري هوإستبعاد المهندس المعماري من عملية تصميم الكباري وتفويض المهندس الإنشائي للقيام بالعملية التصميميه والتنفيذية بالكامل. لذا سيتم دراسة أهمية دور المعماري والمسابقات المعمارية في صناعة الكباري مصرياً وعالمياً، كما سيتم إستعراض مجموعة من الكباري والتي صممت بواسطة أشهر المعماريين العالميين. أيضا سيتم دراسة تكلفة عمل كوبري ناجح معمارياً ومستدام بيئياً وإقتصادياً وإجتماعياً بالمقارنة مع الكباري التقليدية.

في نهاية الفصل تم إستخراج مجموعة من الاشتراطات والنقاط لتقييم العملية التصميمية ولتوضيح أهمية دور المعماري والتي تضاف لنظام التقييم.

ثانيا: العوامل المؤثره علي عمارة الكباري خلال مرحلة التشغيل والاستخدام

الفصل التاسع: التآزر بين الكوبري ومحيطة العمراني في مرحلة التشغيل والإستخدام

يتناول هذا الفصل دراسة تأثير الكوبري بعد الإنشاء علي المجتمع المحيط وعلي المحيط العمراني حيث تأثير الكوبري علي الفراغ المحيط به وإستخدامات الأراضي المحيطة وأيضا الإستخدامات المختلفة للمنطقة تحت الكوبري كفراغ عام. أيضا مساهمة الكباري في تكوين الصورة البصريه للمدينة وتأثيرها إما بالأيجاب أوبالسلب علي الشكل العام للمدينة. ومن ثم إلقاء الضوء علي بعض إستخدامات الفراغات المحيطه بالكوبري وفراغات ما تحت الكوبري في مصر لتجنب هذة المشاكل في الكباري المستقبلية.

سيتم إستخلاص مجموعة من الإشتراطات والنقاط المستخدمة في توقع إستخدامات المحيط العمراني للكباري وتجنبها او التعامل معها.

الجزء الثالث: الدراسة الإستقرائية
تطوير نظام مصري لتقييم إستدامة الكباري

الهدف من هذا الجزء هو تطوير نظام لتقييم إستدامة الكباري المصرية، للوصول لهذا الهدف تم دراسة المحاولات السابقة لدراسة إستدامة الكباري وأيضاً دراسة أكثر أنظمة التقييم المستدام العالمية إستخداماً سواء أنظمة تقييم لإستدامة الطرق اولتقييم إستدامة المباني.

وينقسم هذا الجزء لفصلين: الفصل العاشر و الفصل الحادي عشر. يدرس الفصل العاشر نبذة عن اهم نظم تقييم الاستدامة العالمية لأختيار أنسب أنظمة الإستدامة ليتم تطويرها لإستخراج نظام التقييم المصري. أما الفصل الحادي عشر يتضمن تطوير النظامين الذي تم إختيارهما (LEED BD+C) للتقييم المستدام للمباني و(Greenroads) للتقييم المستدام للطرق. سيتم تطوير نظام الإستدامة المصري عن طريق إختيار وتطوير الإشتراطات والنقاط المناسبة للكباري من النظامين السابق ذكرهما و تجميع هذة الإشتراطات و النقاط لعمل النظام المطلوب.

الفصل العاشر: مفاهيم التقييم المستدام

في هذا الفصل يتم دراسة مفاهيم التقييم المستدام من خلال مقدمة عن نظم تقييم الإستدامة البيئية حيث التقييم العملي والتحليلي للإستدامة البيئية وايضا معايير التقييم المستدام. وتم عمل نبذة عن اهم أنظمة التقييم المستدام سواء للمباني اوللطرق في العالم ووضع معايير لأختيار أنسب نظامين للتقيم (LEED BD+C) للتقييم المستدام للمباني و(Greenroads) للتقييم المستدام للطرق حيث سيتم تطويرهما للوصول إلي نظام التقييم المصري.

الفصل الحادي عشر: تطوير نظام مصري لتقييم إستدامة الكباري

الهدف من هذا الفصل هوالوصول إلي نظام مصري لتقييم إستدامة الكباري لذا سيتم دراسة التجارب الاكاديمية السابقة في إستدامة الكباري وإستخلاص منهجية تصميم وتنفيذ الكباري المستدامة وأيضا كيفية الحفاظ علي تلك الإستدامة من خلال الصيانة. كما سيتم إلقاء النظر علي كل من نظامين التقيم السابق إختيارهما

(LEED BD+C and Greenroads) عن طريق عمل مقارنة بينهم تستعرض الأهداف والمميزات وطريقة التقيم الخ.. لكل منهما.

الفصل الثاني عشر: الخاتمة والتوصيات

يشمل هذا الفصل النتائج العامة للبحث والتوصيات التي تم إستخلاصها وينتهي بإقتراحات الباحث لمجالات بحثية مكملة لموضوع البحث (إستدامة وعمارة الكباري).

الملاحق

وفيها سيتم شرح الهدف الخاص بكلاً من الإشتراطات والنقاط المطروحين في نظام التقييم المعماري والذي تم استخراجهم من خلال البحث وايضا سيتم شرح كلا من الإشتراطات والنقاط لنظام تقييم الإستدامة والذي تم استخراجهم من نظامي (LEED BD+C and Greenroads) وأيضا وضع منهجية التقييم وتجميع النقاط لتيسير إستخدام نظام التقييم في الكباري المستقبلية.

ملخص ذوثمانية أسطر

تحتوي معظم الكباري المصرية علي مشاكل وظيفية وجمالية بالإضافة إلي قصور في الاستدامة البيئية والإقتصادية والإجتماعية. تحتاج هذه المشاكل إلي الدراسة المتقنة لتجنب حدوثها في الكباري الجديدة قيد عملية التصميم. كذلك لوحظ إستبعاد المعماري من عمليات تصميم وإنشاء وتشغيل الكباري المصرية وتم تفويض مهمات تصميم وإنشاء وتشغيل الكباري بالكامل إلي المهندس الإنشائي الذي لا يهتم إلا بسلامة الكوبري وتكلفته دون النظر إلي نجاح الكوبري في أداء وظائفة الأساسية والمكتسبة وأيضا بغض النظر عن جماليات الكوبري أوإستدامتة البيئية والإقتصادية والإجتماعية. لذا فإن الهدف من هذه الدراسة هو تطوير نظام مصري مستدام لتقييم الكباري الجديدة معمارياً. يهدف هذا النظام إلي عمل دليل ارشادي لفريق عمل الكباري لتفادي المشاكل السابق ذكرها في كلا من عمليات التصميم والتنفيذ والتشغيل للكباري الجديدة قيد عملية التصميم.

جامعة حلوان
كلية الهندسة بالمطرية
قسم الهندسة المعمارية

نظام مستدام للتقييم المعماري للكباري في مصر

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