كلـــــيه الهندســـة
جامعة عين شمس

العمارة الشمسية و الحاسب الآلى

(تأثيرالعوامل الطبيعية على تشكيل المبانى السكنية بإقليم بحيرة ناصر)

مقدم من

م/ احمد صفوت مصطفى عيسى

بكالوريوس الهندسة المعمارية ، 1999

كلية الهندسة – جامعة عين شمس

رسالة مقدمة للحصول على درجة الماجستيرفى الهندسة المعمارية

تحت اشـــــراف

أ.د.م / ياســـــر منصور

الاستاذ بقسم الهندسة المعمارية

كلية الهندسة – جامعة عين شمس

د.م/ سمير صادق حسنى

الاستاذ المساعد بقسم الهندسة المعمارية

كلية الهندسة – جامعة عين شمس

(i) Problem Definition

- The research problem addresses the effect of solar radiation on the shaping of the external envelope of the building, where the scope of this research falls under the umbrella of "Solar Architecture".

- The four main goals of any building are (social, artistic, symbolic, & functional). Although the approach of the research is drawn under the latter, it is also tightly engaged with the other three goals; this is well noticed throughout history which traces different ways of reaching a human comfort condition inside the building.

- The accumulation of these experiences throughout history must add to our knowledge concerning this issue where both science & architecture combine together for the sake of man's well being.

(i-i) Research Problem

- The big problem was generated when architecture turned its back to the nature, depending on mechanical systems & expensive treatments to fix its internal conditions; which represented a great load upon the economy in the industrialized countries, moreover the modern architectural style was transmitted to colonies & developing countries, ignoring the completely different climatic and cultural conditions from one place to another, the glitter of the modern movement lead to imitation of this style despite of its problems.

- In Egypt the same problem appeared in a similar way; exact models were designed for residential units, office buildings, & markets, these models were repeated allover Egypt from Alexandria to Aswan using same materials despite of any climatic, social or cultural factors.

- Accordingly, these buildings failed to adapt to the wide ranged differences from one place to another & in some places were left by the users (Aswan).

(i-ii) Research Rationale

- The research problem is double sided:

1-Economically:

a- Huge energy consumption needed lots of money to operate these buildings.
b- Rapid dissipation in world's fuel resources lead to a great increase in the fuel prices.
c- Lots of projects were abandoned, or modified by the users.

2-Humanly:

a- The unbearable conditions of the internal environment of the building.
b- The language of the modern architecture gave no attention to the culture of the people as it ignored their personality & forced a strange style which turned its back to both nature & people.

(i-iii) Research Approach

- Nowadays, many strategies which make use of solar energy have been improved since the energy crisis (1973).

  1- By using solar energy as a renewable & clean sort of energy needed to operate the building (active solar architecture).

  2- By integrating the design of the building to adapt as much as possible with the existing climatic conditions, reaching maximum building efficiency (passive solar architecture).

- The research tends to manipulate the items forming the external envelope of the building as one of the strategies of passive solar architecture in order to reach maximum efficiency of the building thermal performance in its site, where a comparative numerical analysis is done using a specially developed computer program.

(ii) Value of Solving the Problem:

- The value of solving this problem can be illustrated as follows:

  a- Securing a comfortable human condition inside the buildings' environment by using the possible effective solutions so as to fulfill one of the most important functions of the house as a shelter in an economic, healthy way.

  b- The way of solving the problem in the chosen spot -"Adindan" on the east bank of Lake Nasser near the Sudanese borders - can represent a prototype of a new approach towards ecological architecture in Egypt.

  c- The interaction between culture & science leads to a new hybrid that integrates with the place & represents a real output of all the factors specifying the site.

(iii) Goal of the Research:

- To reach a reasonable design of the external envelope of a residential unit in the chosen site, representing a nucleus for a whole community by using a combination between previous qualitative inherited experience, & nowadays quantitative scientific tools (computer programs) together with new building materials.

- This will be done by proposing a method of comparing different solutions numerically using the computer as a precise mean of evaluation; the best proposal will be the one having most satisfying numerical outputs relative to other ones.

- This method is hopefully easily understood and used by non-specialist architects who need support in decision making in the schematic phase of design while the basic lines of the plan are still being drawn.

iv) Objectives of the Research:

- The objectives are the successive goals of each chapter of the research, where these goals act in a one way direction and integrate together to reach the research main goal in a cooperative manner, the following table illustrates these objectives showing the classification of the chapters into three main parts:

		Chapter	Title	Objective
Part I	Introduction	Chapter I	A Historic Review Towards Solar Architecture	To benefit from previous inherited experience in the field of solar architecture, and to trace the evolution of this science until reaching its recent strategies.
Part II	Building Performance with Respect to Acting Thermal Forces	Chapter II	Solar Radiation as External Thermal Force Acting on the Building.	To detect the magnitude and direction of solar radiation falling on the surfaces of the building for the sake of calculating solar heat gains.
		Chapter III	Building Skin Parameters Affecting Thermal Heat Gains.	To study the building envelope components affecting the thermal behavior of the building with respect to the acting external and internal forces.
		Chapter IV	Balance Point Temperature and Evaluating the Building's Thermal Performance	Using a quantitative methodology to evaluate the performance of the building with respect to acting thermal forces.

		Chapter	Title	Objective
Part III	Solar Architecture and Computer Simulation	Chapter V	Simulation of the Building's Thermal Performance.	To show the advantages of using computer simulation in bioclimatic design and to introduce the research tool used in the case study.
		Chapter VI	Case Study	To propose *one of the possible alternatives* of the building envelope composition in the chosen site according to the best monitored numerical results, also to introduce a possible strategy of decision making in the schematic phase of the design that can be applied for any other site.

v) Scope & Limitations of the Research:

- The scope of the research focuses on the design strategies of the external envelope of the residential buildings at Adindan; a small village lying on the east bank of Lake Nasser near the Sudanese borders using a specially designed computer program as a research tool.

- There are a number of limitations that make a further identification of the research scope, and define accurately the field of specialization meant to be studied.

  The scope and limitations are given in the following table:

Scope		Limitations
Building type	**Residential buildings**	Designed rates of internal heat gains in the research tool matches those of residential buildings only, as other kinds of buildings are characterized by different rates of internal heat gains, which are not represented in the suggested tool.
Study scale	**Design Strategies**	Design strategies manipulate the external envelope components only, no details or urban studies are included.
Location	**Adindan**	Lying on the east bank of Lake Nasser near the Sudanese borders, where it represents a special case due to the inflection of the sun path from the south to the north in summer, however, the research tool gives the opportunity for application in 28 different cities allover Egypt.
Variables	**Orientation**	All Facades are assumed to be perpendicular on each other, where the orientation refers to one of these façades (Elev.(A)) relative to the north in a clockwise direction.
	Geometry	A rectangular form is assumed, other forms of layouts (U-shape, L-shape, courted…etc.) are not included, no walls are inclined.
	Materials	All facades are assumed to have same building material.
	Glazing	Independency of each façade concerning the percentage and kind of glazing is assumed.
	Shading	Independency of each façade concerning the external and internal shading strategy is assumed.
	Color	All facades are assumed to have the same color.
Research tool	**Computer program**	A specially designed Excel application, having a visual basic developed interface.

vi) Methodology of the Research:

- The research follows several methodologies to fulfill the objectives previously mentioned, which in turn forms its structure

- “Chapter I” follows an *analytical documentary methodology,* where a historical survey tracing the evolution of solar architecture is done.

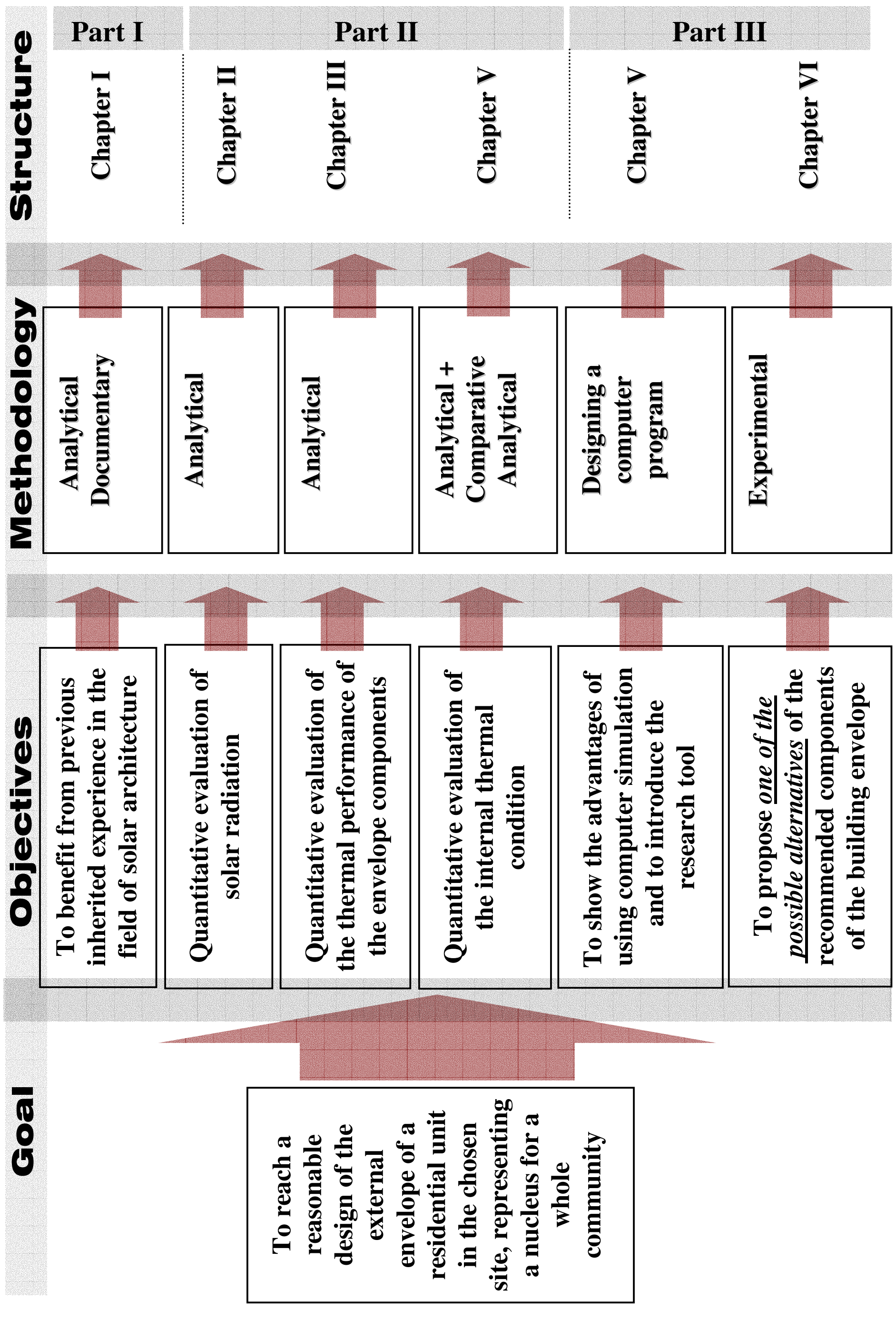
- “Chapter II” and “Chapter III” both follow an *analytical methodology*, in which a quantitative evaluation of the different phases of thermal transmission (outside and through the building envelope) is done with the help of standard numerical thermal properties of the building envelope together with mathematical formulas describing the behavior of solar radiation and building skin performance.

- “Chapter IV” follows an *analytical methodology* in its first part so as to describe the internal thermal condition of the building using the balance point concept, while a *comparative analytical methodology* is used in the case studies.

- The methodology of “Chapter V” depends upon *designing a computer program* which gathers all previous theoretical data in one package that links all thermal relationships in a dynamic way.

- Finally, “Chapter VI” follows an *experimental methodology,* where a practical application on the chosen site is done using the research tool introduced in the previous chapter.

- The following diagram shows the relation between the goal of the research, the objectives, the methodology and the structure of the research.


Structure
Part I
Chapter I
Part II
Chapter II
Chapter III
Chapter V
Part III
Chapter V
Chapter VI
Methodology
Analytical Documentary
Analytical
Analytical
Analytical + Comparative Analytical
Designing a computer program
Experimental
Objectives
To benefit from previous inherited experience in the field of solar architecture
Quantitative evaluation of solar radiation
Quantitative evaluation of the thermal performance of the envelope components
Quantitative evaluation of the internal thermal condition
To show the advantages of using computer simulation and to introduce the research tool
To propose one of the possible alternatives of the recommended components of the building envelope
Goal
To reach a reasonable design of the external envelope of a residential unit in the chosen site, representing a nucleus for a whole community

vii) Structure of the Research:

The research is composed mainly of three parts:

Part I:

A historic review towards solar architecture, it is consisted of one chapter.

Part II:

A quantitative evaluation of the different phases of thermal flow, it is consisted of three chapters:

Chapter II studies the quantitative evaluation of the solar radiation falling on external surfaces.

Chapter III studies the quantitative evaluation of the thermal performance of the components forming the external envelope of the building.

Chapter IV studies the quantitative evaluation of the internal thermal condition.

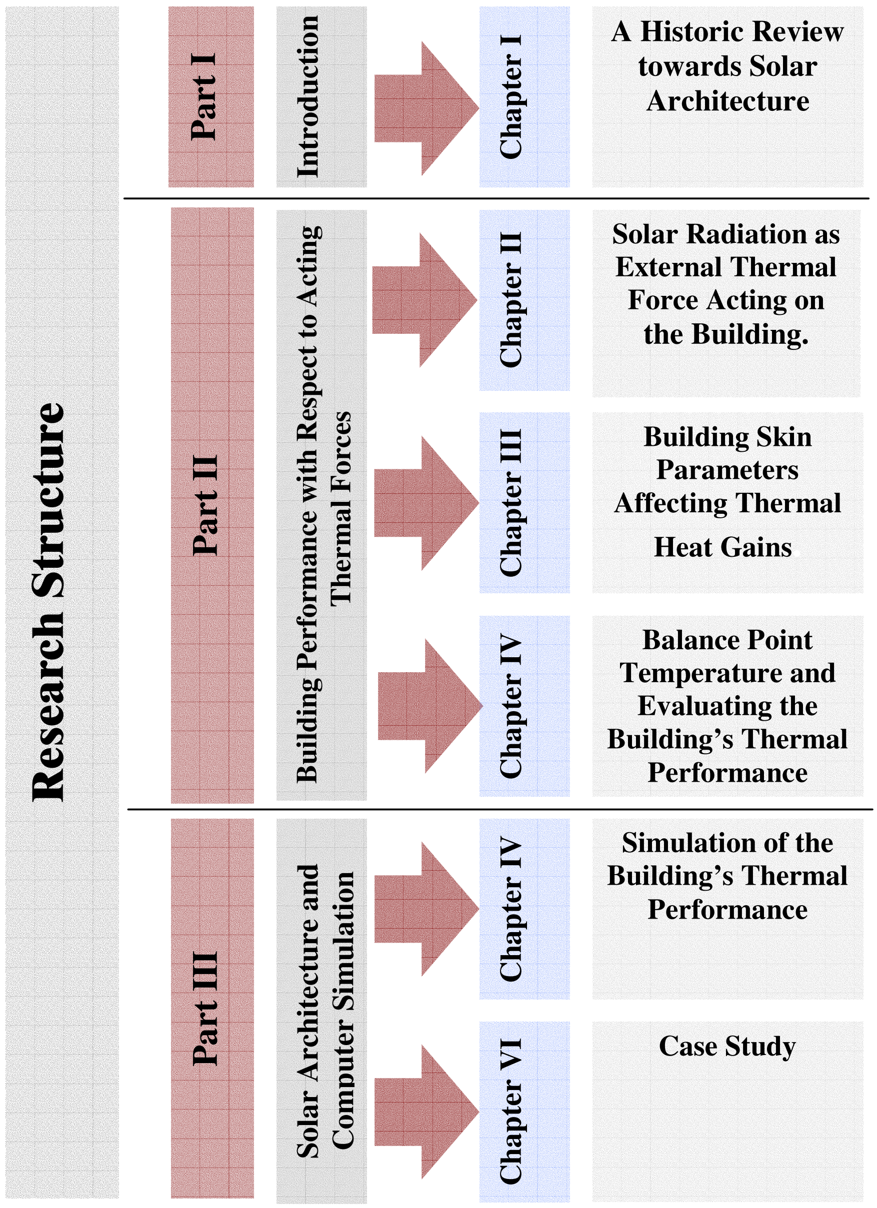
Part III:

Studies the role of computer simulation in the field of solar architecture, it is consisted of two chapters.

Chapter V evaluates the use of computer simulation in the field of solar architecture and introduces the research tool.

Chapter VI is an application on the chosen site using the research tool in order to choose the most suitable group of variables forming the external envelope.

The following diagram shows the structure of the research, being classified into parts including different chapters.


Research Structure
Part I
Introduction
Chapter I
A Historic Review towards Solar Architecture
Part II
Building Performance with Respect to Acting Thermal Forces
Chapter II
Solar Radiation as External Thermal Force Acting on the Building.
Chapter III
Building Skin Parameters Affecting Thermal Heat Gains
Chapter IV
Balance Point Temperature and Evaluating the Building's Thermal Performance
Part III
Solar Architecture and Computer Simulation
Chapter IV
Simulation of the Building's Thermal Performance
Chapter VI
Case Study

viii) Table of Contents

Part I "Introduction"

Part II
"Building Performance with Respect to Acting Thermal Forces"

Part II
"Building Performance with Respect to Acting Thermal Forces"

Part III
"Solar Architecture and Computer Simulation"

ix) Table of Figures:

Fig. No	Title	Reference
(3-7)	Mit-Rehan Villa	http://arch.ced.berkeley.edu/vitalsigns/workup/two_houses/two_ method.html
(3-8)	New Gourna Village - Mosque	http://www.geocities.com/egyptarchitect1/hasanfathi/ngourna/gmosque1.htm
(3-9)	Fractions of Solar Radiation with Respect to Window Pane	March, Andrews and Raines, Caroline, "Square One", www. Squ1.com
(3-10)	Incidence Angle and Fractions of Solar Radiation with Respect to Window Pane	D. G. Stephenson, Canadian building digest, CBD-39. "Solar Heat Gain Through Glass Walls",2002, p.2
(3-11)	Green House Effect	Pacific Energy Center Factsheet: Energy-Efficient Window Glazing Systems http://www.pge.com/pec
(3-12)	Solar Power Plants	Behling, Sophia & Stephen, "The Evolution of Solar Architecture"199 , p.197
(3-13)	The Hooker Building	Behling, Sophia & Stephen, "The Evolution of Solar Architecture"199 , p.202
(3-14)	Applied Films	Pacific Energy Center, "Energy Efficient Window Glazing Systems", a Pacific Energy Center factsheet, 2002, P.2, www.pge.com.pec org
(3-15)	Spectrally Selective Glazing	http://www.advancebuildings. org
(3-16)	Switchable Glazing	http://www.advancebuildings. org
(3-17)	Performance of curtains as internal shading devices	March, Andrews and Raines, Caroline, "Square One", www. Squ1.com

CHAPTER I
A Historic Review Towards Solar Architecture

Introduction:

- Historical heritage is a very rich mine to refer to, however progressive and improved our knowledge and science are, the new concepts' roots can often be found back in history, the accumulation of knowledge helps us to begin from the point where others ended.

- Solar architecture is not a new phenomenon but has been used as far as 5000 years ago by all early civilizations. Past civilizations evolved architectural styles that took advantage of the natural space conditioning; making use of Sun, wind and water to keep their rooms comfortable. This involved consideration of orientation, shape, color, and materials of the building, the windows as well as the shape, style and location of the external shading.

- This part of the research will travel back over five millennia to the present so as to trace the evolution of solar architecture which has always been a major concern of study, so as to show its progress from a descriptive inherited form into a quantitative scientific one.

- "With the emergence of Archaeoastronomy over the past few decades, the sciences have been presented with a unique opportunity to delve into the basis of ancient studies through the study of astronomical phenomena. Beginning with the interpretations of Harvard astronomist Gerald Hawkins in reference to astronomical alignments at Stonehenge in England, the field has expanded greatly to encompass prehistoric cultures on global basis". "Old World and New World cultures alike shared a vested interest in astronomy and the regularity of prediction to be gained from their knowledge of the skies."(1)

---

(1) Kicker, Lyndsay," Archaeoastronomy and the Search for Ancient Observatories" http://www.uiowa.edu/~anthro/webcourse/lost/projects97/Archae.html - accessed 16/10/2002

(1-1) Megalithic Solar Architecture

- The Megalithic monuments of Europe are considered as one of the oldest solar architectural mysteries, where many theories and researches were done to explain and analyze how they were built, by whom and what was their function.

Fig. (1-1)
The Stonehenge-England
The Architecture of the Ancient World
http://www.geocities.com/SoHo/Workshop/5220/ancient.html

(1-1-1) The Stonehenge (3000-1400) B.C. [(1)]

- The Stonehenge of England is the most famous megalithic European site, having the form of three concentric circular constructions of earth mounds and large stones some of which may weigh about 45 tons.

- When examined by Gerald Hawkins (1960) it was found to have astronomical alignments and several cylindrical systems which are believed to detect solar equinoxes, solstices and all important eclipses (both solar and lunar), which proves that the stone hinge beside its being a temple for the sun was used for astronomical calculations.

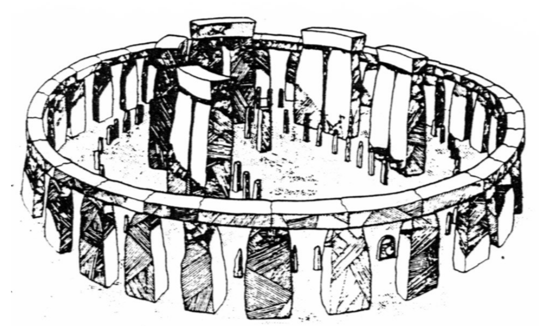


Fig. (1-2)
The Stonehenge (restored)
م.عباس محمد عباس الزعفرانى، "العمارة الشمسية فى المناطق الحارة"، ص15

(1) Kyker, Lindsay," Archaeoastronomy and the Search for Ancient Observatories" http://www.uiowa.edu/~anthro/webcourse/lost/projects97/Archae.html- accessed 16/10/2002

- The identity of the civilization responsible for the construction of the stone hinge is not clear; many theories tried to explain that point:

  - Von Danikan and Company suggested that the stone hinge is a product of extraterrestrial intervention.
  - Norman Lockyer (1901) suggested that the people responsible for construction had links with Ancient Egyptians.
  - Most theories suggest that it was built in three phases by three different cultures due to the different building materials.

- Whatever the identity of the builders, the stone hinges reflects the importance of the sun in the lives and believes of the ancient prehistoric civilizations.

- The methods of calculations of astronomical events using the stone hinge are not known.

- "Lockyer (the father of Archaeoastronomy) measured other alignments at Stonehenge, both along the axis and between certain stones, and tried to relate them to other calendrical events in the ancient Celtic calendar. Besides the summer solstice, he found evidence of alignments that marked midpoints separating the solstices and equinoxes. It needs to be stressed that for Lockyer these alignments were primarily symbolic and had been established by the builders of Stonehenge to serve calendar based rituals and celebrations. For Lockyer Stonehenge was neither a megalithic calendar nor an astronomical calculator in the way it was later to be interpreted by Gerald Hawkins. He believed that Stonehenge was a temple and that the ruined stone structure we see today is the remains of a much older temple built to celebrate the ancient Celtic festival of Beltane (May Day)".(1)

---

(1) Witcombe, Chris ," Sir J. Norman Lockyer", Sweet Briar College
http://witcombe.sbc.edu/earthmysteries/EMLockyer.html - accessed 21/10/2002

(1-2) Ancient Egyptian Solar Architecture

- The relation between the ancient Egyptians & the sun was very deep & sophisticated, as it was concerned with his beliefs.
- "The sun was at the heart of an ancient Egyptian belief, sun warship was a main symbolism of a universal principle" (1)
- Mainly, the treatments of the architectural solutions of ancient Egyptian buildings with regards to astronomical considerations were very successful and sometimes very precise to an amazing extent.

Fig. (1-3)
The Sun Was at the Heart of Ancient Egyptian Belief
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.80

(1-2-1) The Great Pyramids

- The astronomical considerations discovered in the construction of the pyramids reveal the fact of the great knowledge of the ancient Egyptian civilization.

(1-2-1-1) Orientation of Pyramids

- The orientation of the pyramids coincides exactly with the four main directions.
- "The Great Pyramid is the most accurately aligned structure in existence and faces true north with only 3/60th of a degree of error. The position of the North Pole moves over time and the pyramid was probably exactly aligned at one time"(2).fig.(1-4)

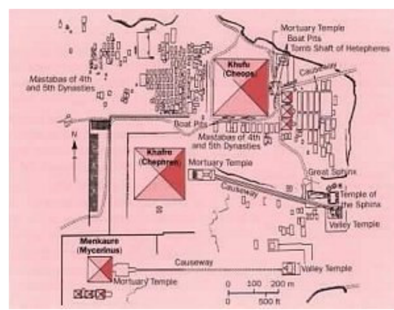


Fig. (1-4)
The Giza Pyramids Accurate Orientation
http://www.delange.org/Giza_Pyramids

(1) Behling, Sophia & Stephen, "The Evolution of Solar Architecture", 1996, p. 80.
(2) Hunkler Tim G, "Symbolism and Coincidences of the Great Pyramid" http://www.aloha.net/~johnboy/Pyramids/pyramid_symbolism.htm - accessed 16/12/2002

(1-2-1-2) The Orion Mystery

- The Orion theory suggests the location of the pyramids as an exact reflection of the Orion belt in an amazing congruency.

- "The specific purpose of these pyramids was to provide a place and means by which the dead Pharaoh would rise to the sky and join with the sun. The pyramid was also believed to be the mineral concentration of the sun's rays of light. Another Hypothesis is that the Pyramids and the Nile represent Orion and the Milky Way; thus focusing the strength and power of heaven to Egypt" [1].

- "The pyramids positions on the ground are a reflection of the positions of the stars in the constellation Orion circa (10,400 B.C.). Five of the 7 brightest stars have pyramid equivalents: The 3 great pyramids of Khufu, Khafra, and Menkaura for the belt of Orion, the pyramid of Nebka at Abu Rawash corresponds to the star Saiph, the pyramid at Zawat al Aryan corresponds to the star Bellatrix. The only two missing star positions are for Betelgeuse and Rigel".[2] (fig.(1-5)).

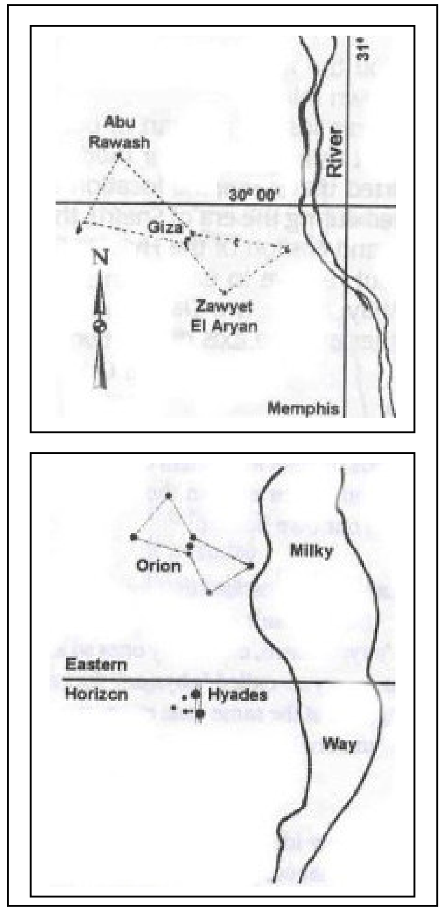


Fig. (1-5)
The Orion theory
http://www.delange.org/Giza_Pyramids

(1) http://www.delange.org/Giza_Pyramids - accessed 12/2002
(2) Hunkler Tim G, "Symbolism and Coincidences of the Great Pyramid" http://www.aloha.net/~johnboy/Pyramids/pyramid_symbolism.htm accessed 16/12/2002

(1-2-1-3) Astronomical Related Statistics of the Great Pyramid [1]

- Other astronomical statistics related to the geometry of the great pyramid shows amazing awareness of our solar system:

  - For example,
  Mean Distance to the Sun: The height of the pyramid X 10^9 = avg. distance to sun.
  Mass of the Earth: The weight of the pyramid is estimated at 5,955,000 tons Multiplied by 10^8 gives a reasonable estimate of the earth's mass.
  Earth's Volume: The product of the pyramid's volume to density ratio times 10^{15} equals the ratio of volume to density of the earth.

(1-2-2) Great Temple of Amun-Ra at Al-Karnak

- "The great temple of Amun-Ra at Al-Karnak consisted of rectangular structures build back-to-back on an east-west axis. The orientation was such that at solstice time a beam of sunlight would travel the whole length of a corridor (165m), passing from one part of the temple to the other between two obelisks, and for two minutes the sunbeam would strike the Holy of Holies with a flash of light at the far end of the corridor, thereby signaling the moment when the first day of the first month began the new year." [2]

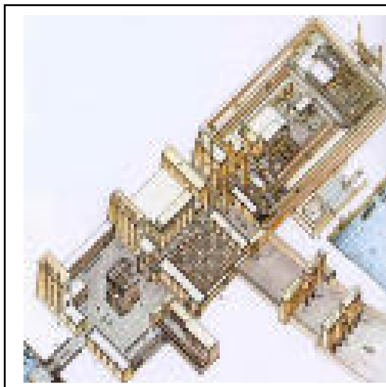


Fig. (1-6)
Great Temple of Amun-Ra at al-Karnak

(1) Hunkler Tim G, "Symbolism and Coincidences of the Great Pyramid" http://www.aloha.net/~johnboy/Pyramids/pyramid_symbolism.htm- accessed 16/12/ 02
(2) "The Ways of Heaven" http://www.geocities.com/elchasqui_2/ZSitchinbook4h1 .html -accessed 21/10/02

(1-2-3) The Great Temple of Abu Simbel- 1257 B.C

- This temple is not only famous for its enormous monumental statues at its entrance, or because it was carved in the heart of the mountain, but also for the precise calculations which were made during the design, where the temple is oriented so that twice every year, on 22 February and 22 October, the first rays of the morning sun shine down the entire length of the temple-cave (60m.) to illuminate the back wall of the innermost shrine and the four statues seated there (fig. (1-8)).(1)

- This proves that the science of ancient Egyptians concerning sun was not a simple descriptive one, but was a complicated and quantitive science based on calculations.

Fig. (1-7)
The Great Temple- Abu Simbel
http://www.arthistory.sbc.edu/sacredplaces/abusimbel.html

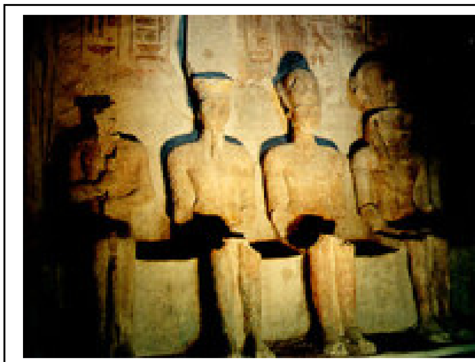


Fig. (1-8)
The holy of holies – Abu Simbel
http://www.arthistory.sbc.edu/sacredplaces/abusimbel.html

(1) Witcombe, Chris ,"Sacred Places, Abu Simbel-Egypt", Sweet Briar College, http://www.arthistory.sbc.edu/sacredplaces/abusimbel.html accessed 21/10/2002.

(1-3) The Greek Solar architecture

(1-3-1) The Megaron as a Prototype of the Greek Temple

- The need for sun in winter and shades in summer dominated life in the ancient Greece; the Megaron represented the prototype building for this time, from which the more sophisticated designs of monumental temples evolved (fig.(1-9)).

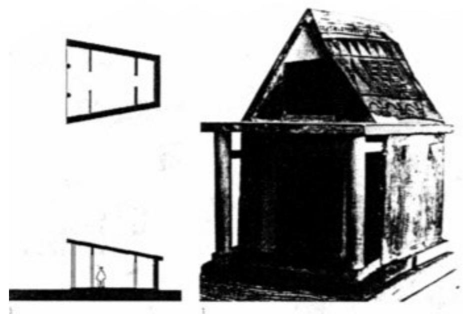


Fig. (1-9)
The Megaron
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p 92

- The Megaron was specified by its rectangular form and its shaded porch; it provided the plan for the first great temples in 800 B. C.

- Many archeologists referred the evolution of the Megaron to Socrates; "Socrates considered solar design principles in house construction. He advised that in houses oriented towards south, warming sunlight penetrates past the portico deep into the house in winter, while in summer, the solar orbit is so high that the portico casts the house interior in cool shade."(1) (fig.(1-10)).

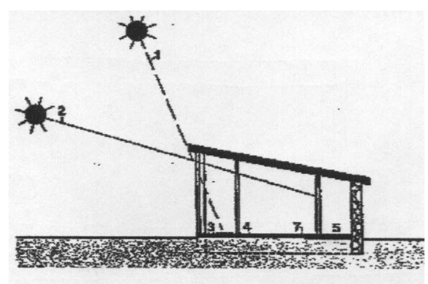


Fig. (1-10)
Socrates Theory Concerning the Megaron
Hastings, Robert, "The evolution of solar architecture", for the Swiss federal office of energy, p. 54

(1) Hastings, Robert, "The evolution of solar architecture", for the Swiss Federal Office of Energy, 2002, p. 54

(1-3-2) The Greek Temple

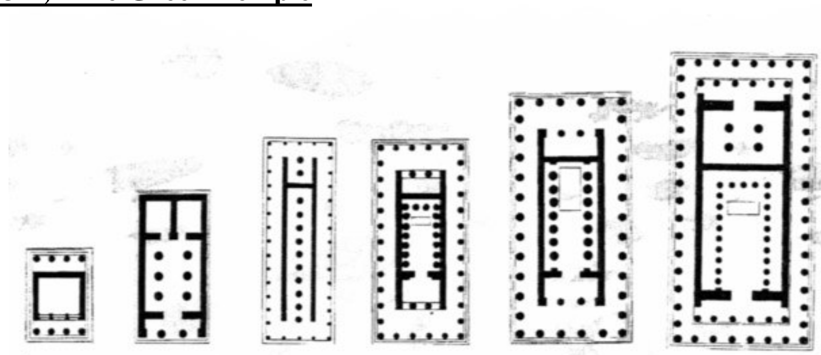


Fig. (1-11)
The Evolution of the Greek Temple from the Megaron
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.93

- Fig.(1-11) shows the successive phases of the evolution of the Greek temple which was driven from the Megaron (shaded porch + rectangular form), the extended shade around the building created a comfortable environment and added to the grandeur of the temple (fig.(1-12)).

Fig. (1-12)
The Parthenon
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.93

- According to solar design principles, the columns formed giant sun-breakers, (fig.(1-13)).

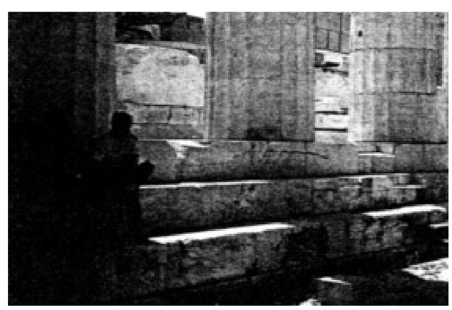


Fig.(1-13)
The Columns as Giant Sun Breakers
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.93

(1-3-3) The Greek Sundials

- The sundials though invented at the Babylonian era, gained a wide popularity within the lives of the Greek citizens, where they were widely spread in the form of buildings and apparatus, and improved into several forms.

- "About 340 B.C, a chaldean astronomer priest living in Egypt during the time of Alexander the great, developed the Hemisphericum in which a vertical post was placed centrally inside a hollowed out hemisphere. The inside surface of the hemisphere had vertical lines carved on it to divide the daylight period into twelve hours, and horizontal lines to show the seasons. From this, developed the Hemicyclium, (fig.(1-14)) which was widely used throughout the civilized world until the fourteenth century."[1]

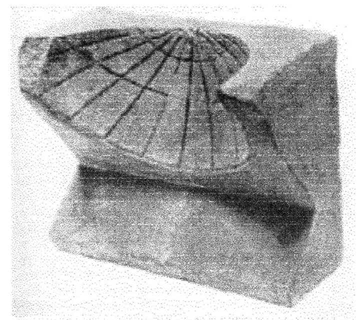


Fig. (1-14)
The Hemicyclium
Ward, John and Folkard , Margaret , "Sundials", for the Royal New Zealand Institute of Horticulture, p.2

- The tower of winds which was erected at the foot of the north slope of the Acropolis is the most popular Greek sundial ever, it was an octagonal tower having the 8 cardinal directions, and although it was originally designed to be a water clock (clepsydra), on each side of the tower a solar sundial was carved, the angle of the shadow showed the time whilst its length showed the date, so the building acted as both sundial and calendar. [2] (fig.(1-15))

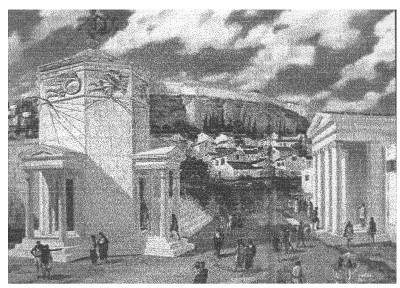


Fig. (1-15)
The Tower of Winds - Acropolis
Ward, John and Folkard, Margaret , "Sundials", for the Royal New Zealand Institute of Horticulture, p.3

(1) Ward, John and Folkard, Margaret, "Sundials", for the Royal New Zealand Institute of Horticulture, p.2
(2) Ward, John and Folkard, Margaret, "Sundials", for the Royal New Zealand Institute of Horticulture, p.3

(1-4) The Roman Solar Architecture

- Providing pleasure and comfort for the citizens became a primary concern in ancient Rome, many fragments of buildings showed different ways to fulfill this goal using different strategies dealing with shading comfort, & solar considerations.

(1-4-1) The Colosseum

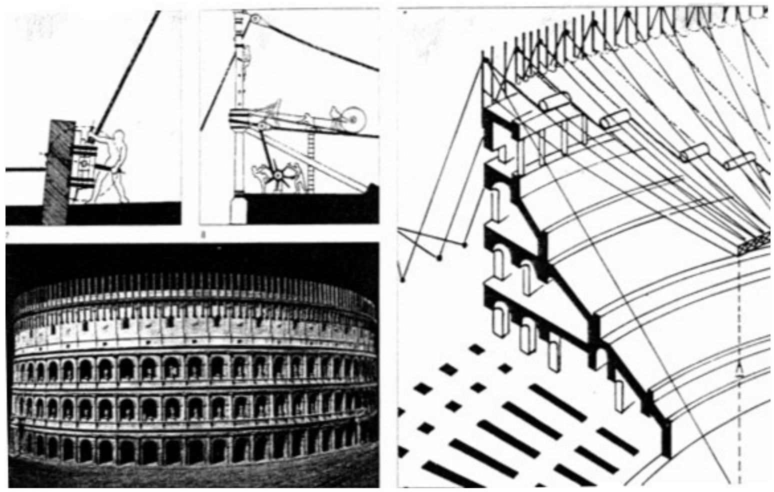


Fig. (1-16)
The Colosseum
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.97

- The Colosseum had the capacity of 50,000 spectators, in order to sit comfortably in their seats, shading devices were used, where a force of 200 sailors was responsible for the operation of these devices (figure(1-16)), the shading was called vela, meaning sails, reminding us with Otto's tent structure in Munich,1972.

(1-4-2) The Baths of Caracalla

- These baths were widely spread all over Rome; they reflected how keen the Romans were to fulfill human comfort conditions inside buildings.

- These baths could accommodate 1600 bathers in its frigidarium (cold water pool), tepidarium (warm water pool), and calidarium (hot water pool).

- The baths of Caracalla were characterized by their orientation towards the south-west to admit as much sun as possible during the peak-time use of the buildings in the afternoons. (fig.(1-18))

- "In some more elaborate bath buildings, the sweat rooms had enormous windows facing the south and south-west and a sand floor that absorbed solar heat during the day and released in the evening"(1)

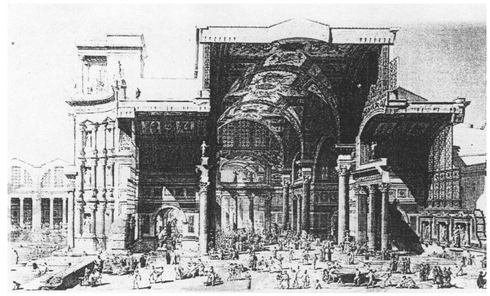


Fig. (1-17)
The Baths of Caracalla-section
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.96

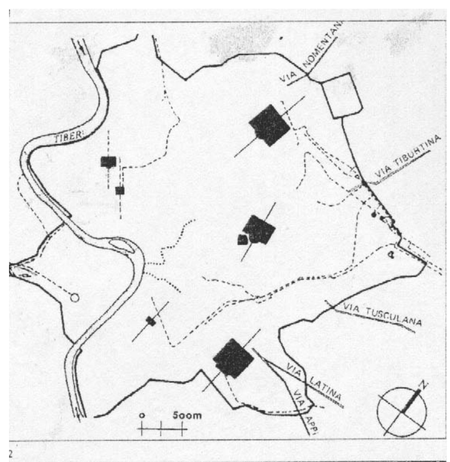


Fig. (1-18)
Orientation of the baths towards south west
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.96

(1) Behling, Sophia & Stephen, "The Evolution of Solar Architecture", 1996, p.96

(1-4-3) The Pantheon, Italy, Rome; (118-35 A.D)

- This example declares the fact that buildings in addition to their original function acted as giant sundials; sun hits the interior walls of the building as it enters from the oculus referring to the time of the day. (fig.(1-19))

- "Drama was created making use of sunlight, the (44m diameter) dome had an oculus at its apex (nearly 9m in diameter), which in addition to illumination acted as a sundial." [(1)]

Fig. (1-19)
The Pantheon (interior)
"History of Roman Architecture"
http://web.kyoto-inet.or.jp/org/orion/eng/hst/roma/pantheon.html

(1) Behling, Sophia & Stephen, "The Evolution of Solar Architecture", 1996, p.94

(1-5) The Islamic Solar Architecture:

(1-5-1) The Court as a Significant Feature

- The Islamic architecture was based on several ethical, religious, and climatic bases which resulted in the evolution of significant style characterized by the presence of a court which was probably surrounded by shaded colonnades for the sake of shade, privacy, and protection from intruders.

"The solar influence on Islamic design can be seen clearly in the plans of mosques at: Somarra, Kurouan, Cairo and Kufa; all have long shaded arcades extending around the courtyards. Islamic buildings are introverted so that the facade is on the inside of the buildings, no matter how individual mosques are oriented in relation to Mecca; they always follow the basic principle of providing maximum shade." (1)

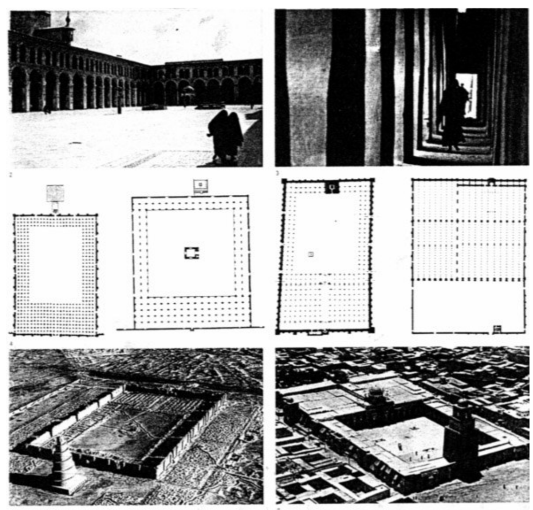


Fig. (1-20)
The courtyard in the Islamic mosque
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.100

(1) Behling, Sophia & Stephen, "The Evolution of Solar Architecture", 1996, p.100

- One of the most famous examples regarding this architectural feature is Al-Sultan Hassan Mosque, completed in 1361 A.D., where it is characterized by an enormously deep square court, 34m height, surrounded by four huge vaulted halls and having an octagonal fountain covered by a wooden dome for ablution, where it contributed in addition to the shadows cast by the court in securing a comfortable thermal condition.(fig.(1-21))

Fig. (1-21)
Al-Sultan Hassan Mosque Interior
http://www.islamonline.net/Arabic/history/1422/11/article29.shtml

- This concept was not only used in mosques, but also in residential buildings, where the Islamic building was characterized by the internal facades on the court. On the contrary, the exterior façade was a solid one so as to overcome severe climatic conditions and avoid direct solar radiation.
  Example: Gamal El-Din El-Dahaby Residence, (fig.(1-22)) and (1-23).

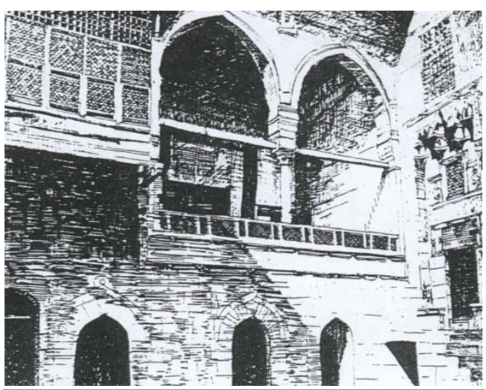


Fig. (1-22)
Gamal El-Din El-Dahaby Residence – Interior Facade
م.عباس محمد عباس الزعفرانى، "العمارة الشمسية فى المناطق الحارة"، ص 34

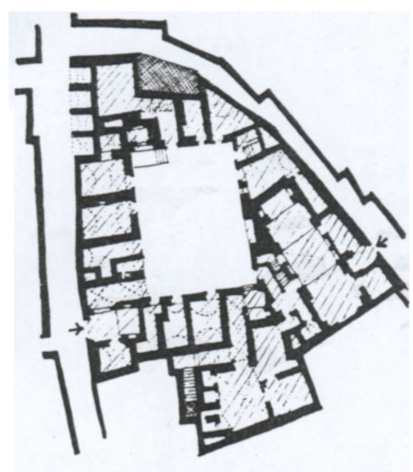


Fig. (1-23)
Gamal El-Din El-Dahaby Residence -Plan
م.عباس محمد عباس الزعفرانى، "العمارة الشمسية فى المناطق الحارة"، ص 34

(1-5-2) Orientation as an Essential Feature in Mosques

- The orientation of mosques towards Mecca is a common factor for all mosques, which appeared clearly in Cairo, especially at "Al-Mo'ez" street, where the mass of the mosque showed a contradiction between respecting the street border and respecting the orientation towards Mecca.(fig.(1-24))

- Whatever the method used for this purpose, an accurate tool was needed to detect the "Qebla".

- Knowledge from civilizations (Greek) were improved by Muslim scientists, the zero was invented, without which there would be no ability for numerical (quantitative) representation for different sciences.

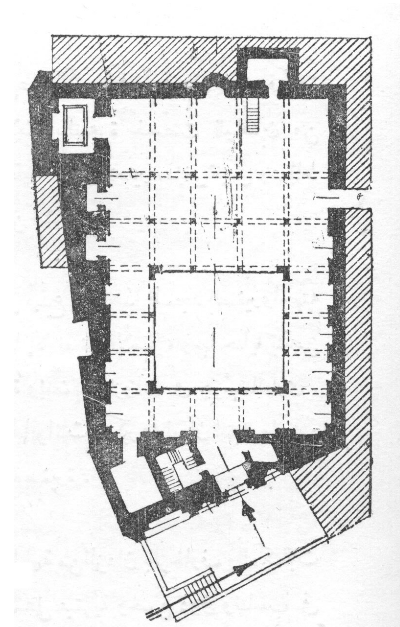


Fig. (1-24)
Al-Aqmar Mosque, Cairo
ا.د/ توفيق أحمد عبدالجواد ،"تاريخ العمارة، العصور المتوسطة الاوروبية و الاسلامية" ، 1969، ص305

- Accordingly, progress took place in many since branches, including astronomy, where the astrolabe was widely used in travels for directing travelers and locating their longitude and latitude although the fact that the earth is a globe was not yet known.

- "Islamic scientists were respected then and many of their findings became the foundations or important components of the sciences that we know today. There is much written about how advanced were Muslims during medieval times".[1]

(1) http://www.najaco.com/islam/fun_illustrations/4.htm - accessed 12/2002

(1-5-3) Scientific Detection of Orientation and Location

The following figures shows different apparatus invented and used by the Muslim scientists:

- Fig.(1-25) shows the Spherical Astrolabe (dated 1480): "These were rare and the only one known to exist. The large ecliptic circle bears the names of the signs of the zodiac. The rete, or star map, is attached to the globe with pointers for nineteen fixed stars."[(1)]
- Fig.(1-26) shows the Astrolabe (dated 9th century): "This was for measuring the altitude of heavenly bodies above the horizon, and so determining (among other things) the time of day or night. Readings are taken by means of rotatable alidade, a diametrical ruler with signs."[(2)]
- Fig.(1-27) shows the Celestial Sphere (dated 1285): This equipment is from Iran." It incorporates information derived from Abd Al-Rahman Al-Sufi's Book of Fixed Stars." [(3)]

Fig.(1-25)
The Spherical Astrolabe
http://www.najaco.com/islam/fun_illustrations/4.htm

Fig.(1-26)
The Astrolabe
http://www.najaco.com/islam/fun_illustrations/4.htm

Fig. (1-27)
The Celestial sphere
http://www.najaco.com/islam/fun_illustrations/4.htm

(1) , (2), (3) http://www.najaco.com/islam/fun_illustrations/4.htm - accessed 12/2002

(1-5-4) Different Climatic Design Criteria for Different Conditions

- Islamic architecture was a prototype of ideal ecological solutions for different climactic concerns such as in shading, ventilation and illumination. Because their lands extended from Europe to India in the Islamic age, there was a big variety in climatic conditions and the building's approach to them.
- Since Islamic civilization was a democratic one, no ideal architectural solution was forced, but for every region there were significant features, the only common factor was the soul and principles of Islam.[1]

Fig.(1-28)
Quaitbai Mosque
م.عباس محمد عباس الزعفرانى، "العمارة الشمسية فى المناطق الحارة"، ص 31

Examples:

Quaitbai Mosque – Cairo – Egypt

- Small openings, flat roofs, indicating sunny climate and lack of rain
  NB: Most of Cairo Islamic mosques have a small-tall court for severe climatic conditions-treatment and protection from Sun.

Fig (1-29)
Alhambra Palace
م.عباس محمد عباس الزعفرانى، "العمارة الشمسية فى المناطق الحارة"، ص 31

Alhambra Palace – Granada

- Wide openings, inclined pitched roofs indicating rainy climate and need of sun, notice the wide-short court on the contrary to those in Egypt.

(1) م.عباس محمد عباس الزعفرانى، "العمارة الشمسية فى المناطق الحارة"، ص21-ص 36

(1-6) Solar Architecture in the Middle Ages

The Christian architecture in the early middle ages showed a special concern with the role of light in the interior space to add a heavenly effect.(fig.(1-30)). “Flat roofs, together with domes, in addition to slim openings and interior courts dominated that style” (1)

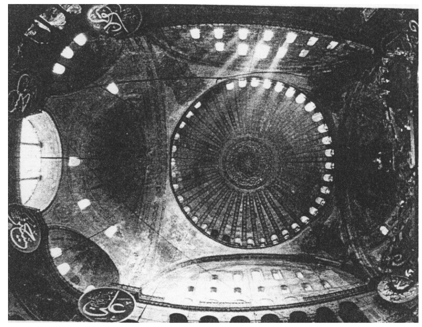


Fig.(1-30)
Hagia Sophia
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.96

The medieval showed the continuity of the previous concept of light penetration, where using colored glass in the Gothic churches added to the spirituality of space (fig.(1-31))

The Renaissance witnessed a new architectural style with significant features, the modified heritage of the classic styles was treated differently, where “reaching symmetry was the main goal”(2), which means that orientation had no influence on the design of the buildings on the contrary to the roman architecture.
Example: Villa Capra by Andrea Palladio, 1580 (fig. (1-32))

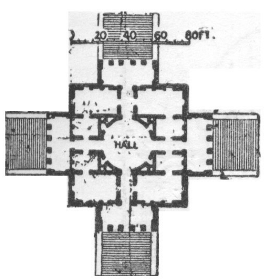


Fig.(1-32)
Villa Capra (Rotunda)
ا.د/ توفيق أحمد عبدالجواد ،"تاريخ العمارة، العصور المتوسطة الاوروبية و الاسلامية" ، 1969، ص186

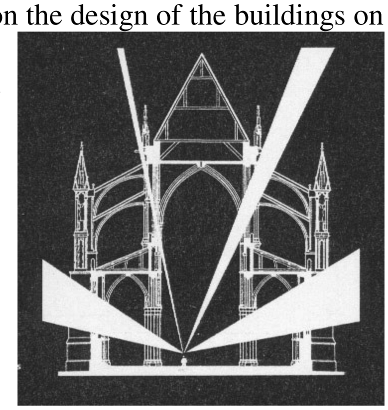


Fig.(1-31)
Gothic Church - Section
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.102

---

(1) ا.د / توفيق أحمد عبدالجواد ،"تاريخ العمارة، العصور المتوسطة الاوروبية و الاسلامية" ، 1969، ص17
(2) ا.د / توفيق أحمد عبدالجواد ،"تاريخ العمارة، العصور المتوسطة الاوروبية و الاسلامية" ، 1969، ص150

(1-7) The Industrial Revolution [1]

- The end of the 18th century and the beginning of the 19th century witnessed the birth of the industrial revolution, the attempts to reach a human comfort condition depended greatly upon installed systems, where the control of ventilation and heating was developed since the evolution of the cockle stoves; a special system depending upon the distribution of warmed air from solid fuel furnaces through a network of ducts. This was followed by the appearance of the steam heating which was introduced by William Cook in 1745 and became more popular, where it depended on system that distributes steam from a boiler around the building through a looped configuration of pipes. At 1831, Jacob Perkins, an American engineer patented a pressurized hot water system which depended upon piping for heat supply.

- The gap between the architect and the engineer grew wider and wider at the beginning of the 19th century, especially after the foundation of the "L'Ecole des Beux-Arts", in 1806, which classified architecture as a plastic art, however, by the middle of the century the attempts were made to integrate the role of both sides. "The relationship between the architecture and engineering has evolved to create a basis for collaboration in the production of increasingly complex buildings." [2]

- One of the most pioneering projects of that time is the cooperative work of the architect Charles Barry and the engineer David Reid in the project of the parliament accommodation buildings at London, 1835-1852. (fig.(1-33))

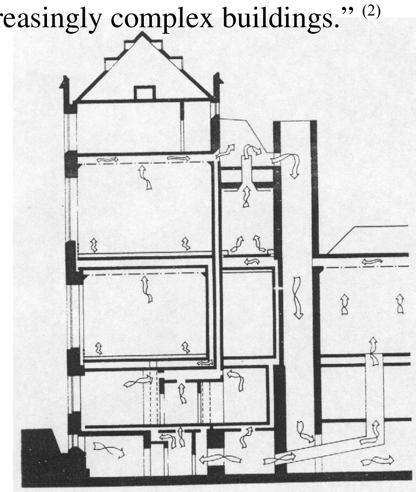


Fig. (1-33)
The Parliament Accommodation Buildings, London, 1835-1852
Hawkes, Dean and Foster, Wayne, " Architecture, Engineering and environment", 2002, p.12

(1) Hawkes, Dean and Foster, Wayne, " Architecture, Engineering and environment", 2002, p.p8-21
(2) Hawkes, Dean and Foster, Wayne, " Architecture, Engineering and environment", 2002, p.13

(1-8) Hassan Fathy

Considered one of the most famous Egyptian architects for his unique and pioneer role in the field of bioclimatic architecture and building for the poor, Hassan Fathy was not only concerned with the qualitative applications of the traditional Islamic architecture, this was revealed from his quantitative experiments that accompanied his various projects.
Fig.(1-34) shows an experiment comparing the fluctuation of the indoor temperature for a mud brick dome construction to that of a prefabricated concrete model with respect to ambient air temperature. The dome shows more stability in its internal thermal condition which was monitored within the human comfort zone.

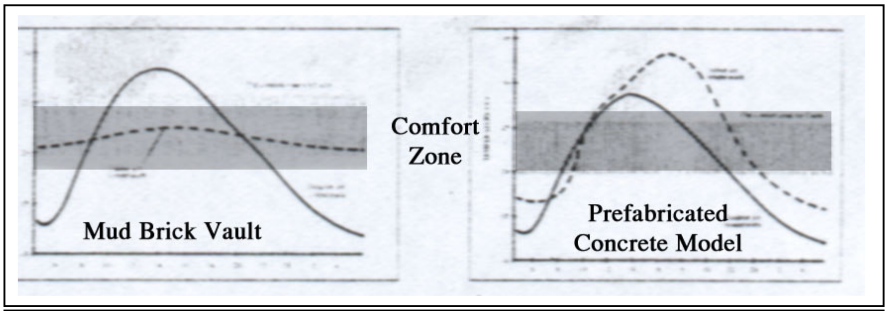


Fig. (1-34)
Fathy's Experiment on the Thermal Performance of Mud Brick Vaults
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.184

Other quantitative considerations in Fathy's work can be seen in his initial studies, fig.(1-35) shows some studies concerning orientation of double linear forms, and the positioning of the wind catchers (Malgaf) with respect to the prevailing wind

A practical application for such study is shown in the master plan of the Gourna village where the buildings were oriented towards the North, and the North-East. (fig.(1-36)).

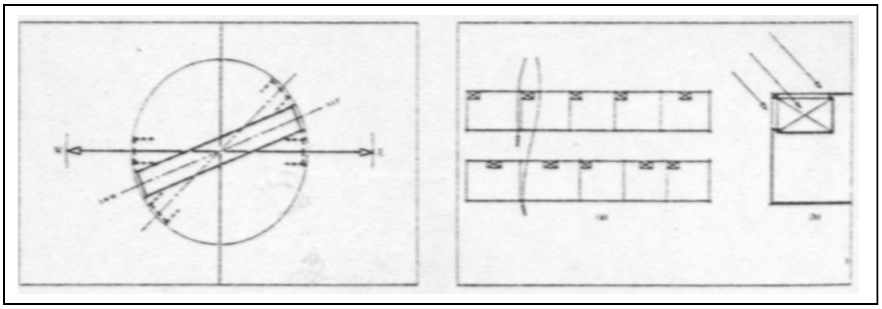


Fig. (1-35)
Orientation Considerations in Farhy's Initial Studies
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.184

The south elevations were characterized by shaded colonnades which provided further protection from direct solar heat gains, in addition to using perforated mashrabias for ventilation.
(fig.(1-37))

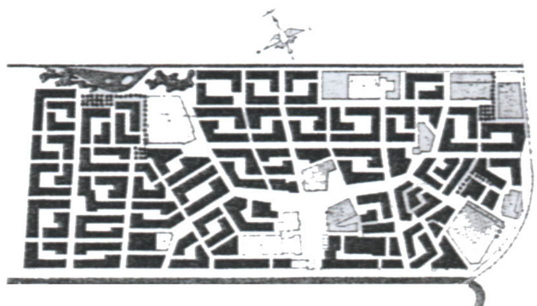


Fig. (1-36)
The Gourna Village- Master Plan
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.184

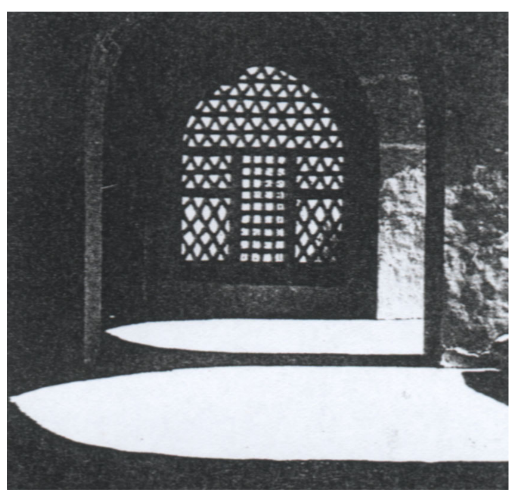


Fig. (1-37)
Shaded Colonnades for South Elevations
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.184

(1-9) Solar Architecture in the 20th Century

- The 20th century was divided into three phases regarding solar architecture:

  1- Early 20th century (masters of modern architecture).
  2- Energy crisis (1973).
  3- New trends of solar architecture after 1973.

(1-9-1) Early 20th Century.

- "In the first decade of the 20th century, a strong reaction against buildings of the previous century occurred, they were considered to be unhealthy. As a reaction, new buildings were erected with hygiene in mind, large windows to admit as much sun and light as possible, white walls, roof terraces-a bright, airy architecture- this was all considered a preventative measure against diseases such as tuberculosis." (1)

(1-9-1-1) Le Corbusier and the "Brise soleil"

- Le Corbusier was One of the most remarkable pioneers in the field of solar architecture, where he won his own experience from his project "The salvation army building" -1939 ; the façade was first a fully glass sealed one, leading to unbearable conditions inside the building, thus, the façade was completely replaced by another one with sun breakers.

Fig. (1-38)
The Salvation Army Building (before and after façade redesign)
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.176

(1) Hastings, Robert, "The evolution of solar architecture", for the Swiss Federal Office of Energy, 2002, p. 57

- This concept was repeated in many of Corbo's projects like villa Shodhan in Ahmed-abad, 1951 (fig. (1-39)) and the Mill Owners association at Ahmed-abad, 1954 (fig. (1-41)).

- "Realizing the insufficiency of the simple glass wall, Le Corbusier developed a wide range of solutions to incorporate shade into designs for glass box. Climatically responsive interactive architecture adopted the brise soleil as an integral part of the building." (1)

- This experience that was gained by Le Corbusier gave him deep expectations for the building's internal conditions, where he refused completely the proposal of his partner Wallis K. Harrison for the U.N building in New York and wrote to the Senator Warren Austin warning him from the expected "dangerous" situation. (fig. (1-40)).

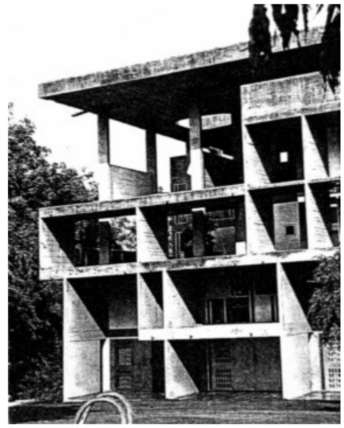


Fig.(1-39)
Villa Shodhan
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.176

Fig.(1-40)
The U.N building
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.188

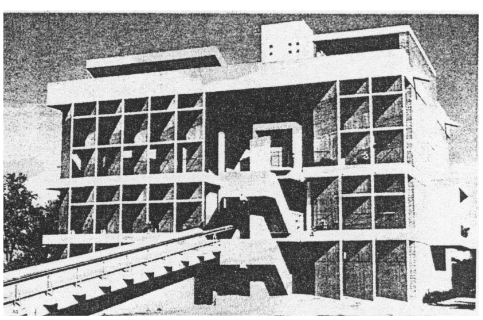


Fig.(1-41)
The Mill Owners Association
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.177

(1) Behling, Sophia & Stephen, "The Evolution of Solar Architecture", 1996, p.177

(1-9-1-2) Frank Lloyd Wright

One of the great American architects who dealt very consciously with the bioclimatic factor in his work.

The "Solar Hemicycle", Herbert Jacob's House, Wisconsin, 1948. [1]

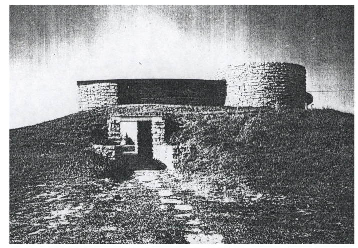


Fig.(1-42)
The Solar Hemicycle- North Facade
Pfeiffer, Bruce Brooks, "Frank Lloyd Wright" p.155

- Wright named this house "The Solar Hemicycle", as it was designed to take advantage of the elliptical path of the sun through the sky.
- The northern façade was a solid masonry one, having the earth piled up against it for extra insulation against cold conditions, (fig.(1-42)).
- On the other hand, the south façade was characterized by a double height glass wall with a horizontal overhang.
- The southern overhang is designed so that in summer, shade is cast upon the glass, while in winter; the glass faces directly the desired warmth of the sunshine. (fig.(1-43)).
- In his arid projects, Wright proposed several passive solar strategies concerning earth lodging and shading (Talesein west, Arizona, 1938) (fig.(1-44)), or concerning building solidity and material (the Pauson house, Arizona, 1940) (fig.(1-45)).

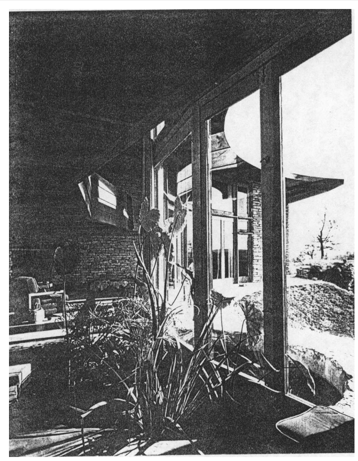


Fig.(1-43)
The Solar Hemicycle- South Façade
Pfeiffer, Bruce Brooks, "Frank Lloyd Wright" p.154

(1) Pfeiffer, Bruce Brooks, "Frank Lloyd Wright" p.154, 155

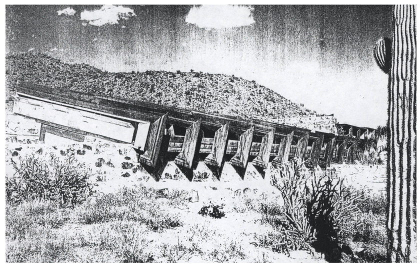


Fig.(1-44)
Taliesin West, Arizona
Pfeiffer, Bruce Brooks, "Frank Lloyd Wright" p.128

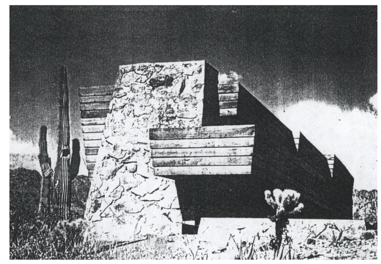
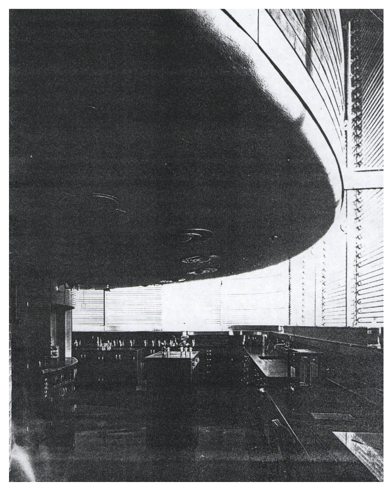


Fig.(1-45)
The Pauson House, Arizona
Pfeiffer, Bruce Brooks, "Frank Lloyd Wright" p.136

- Another building reflecting the pioneer ideas of Wright in that field, is the new extension of Johnson Wax Company, which he called "a sun worshipper", he used a special glazing consisting of glass pipes.

- "The entire outside surface was sheased in glass tubes with plate glass clipped onto the inside for further insulation"(1)



(1-46)
New Extension of Johnson Wax Company
Pfeiffer, Bruce Brooks, "Frank Lloyd Wright" P149

(1-9-1-3) MIT (Massachusetts Institute of Technology)

"In the period from 1940-1950, engineers became fascinated with the active use of solar energy, a series of houses were built by researchers of the (MIT), however, the focus was on collectors, pumps, storage, distribution, and control, not a complete architectural solution".(2)

(1) Pfeiffer, Bruce Brooks, "Frank Lloyd Wright" p.145
(2) Hastings, Robert, "The evolution of solar architecture", for the Swiss Federal Office of Energy, 2002, p. 57

(1-9-2) Energy Crisis - 1973

- Despite of all the previous recommendations and experience forced by the pioneers and their students concerning bioclimatic architecture, the modern move completely ignored the human needs inside the building, turning its back to the nature and depending completely on mechanical systems to overcome severe conditions.

- "America produced an international style for the business community. Business turned their back to the nature and buildings became completely dependant on a huge energy supply. In American cities, the glass tower came to represent both corporate and individual prestige, purity of form took precedence over human comfort and pleasure, even for low rise buildings, the sealed steel and glass box was the only design option".[1]

- "The glass box ruled. Its hard headed perfection and precision became the modern metaphor for power. In buildings, almost every environment could be produced within a sealed place. But they depended on machinery to achieve it, and the machines ran on energy. It is not surprising that these were the highest energy consuming buildings ever created".[2]

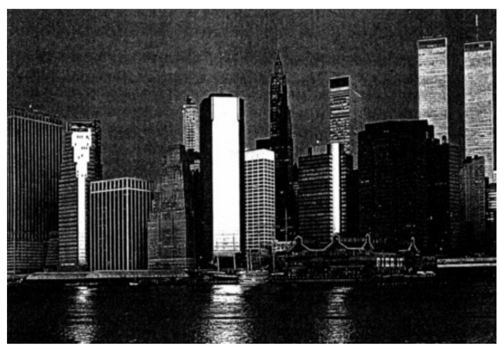


Fig. (1-47)
New York
Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , p.189

(1), (2) Behling, Sophia & Stephen, "The Evolution of Solar Architecture" , 1996, p.189

By time, the disadvantages of the glass box skyscrapers appeared:

- Consuming huge amounts of energy to fulfill suitable conditions inside buildings (heating, cooling, lighting…etc).
- There was no interaction between the users and the building, no window was opened.
- Environmental problems were linked to unawareness of using energy supplies; greenhouse and ozone problems began to float on the surface.
- This was confirmed by the energy crisis (1973) which was a turning point to consider using economic a renewable energy resources.

(1-9-3) The New Trends of Solar Architecture after 1973

(1-9-3-1) Passive Solar Architecture

- "After the oil shock early in the 1970's, interest grew in the idea of energy self sufficiency, the passive use of solar energy became instantly popular. This movement began in the southwest of the United States where conditions were ideal, much sun all winter and cold temperatures. National passive solar conferences brought together researchers who were investigating the houses, the designers of the houses, and architects from all across the country. Soon, passive solar design principles were being modified to adapt such houses to all climates across the continent. *The US Department of Housing and Urban Development* held competitions and offered thousands of grants to explore and publicize successful designs".[1]

- The European architects were not unaware of this movement, where the came across the Atlantic to attend these conferences and returned back to Europe, where the passive solar architecture of the Greek and Romans found a renaissance.

---

(1) Hastings, Robert, "The evolution of solar architecture", for the Swiss Federal Office of Energy, 2002, p. 57

(1-9-3-2) Active Solar Architecture

- Active solar architecture participated greatly in the development of the traditional house design into a self energy sufficient one, where unlike the earlier MIT houses the active solar system became an integral part of the house design and construction.

- The collector was built into the roof construction, massive floors (hypocausts) or walls (murocausts) with channels provided both heat distribution and storage; occupants could exactly control and optimize the system.

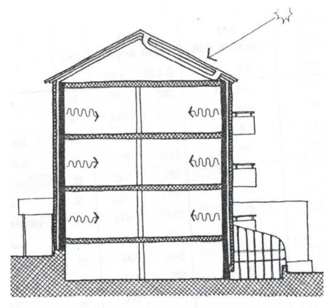


Fig.(1-48)
Apartment Block in Gothenburg
Brown,G.Z, and Dekay, Mark, "Sun,Wind and Light", p179

Example: Apartment Block in Gothenburg, Sweden, Christer Nordstrom. [1]

"Air warmed from the roof top collectors is ducted by mechanical ventilation to a murocaust cavity in the external walls formed by adding an insulated layer outside the existing un-insulated masonry walls" (fig.(1-48),(1-429),(1-50)).

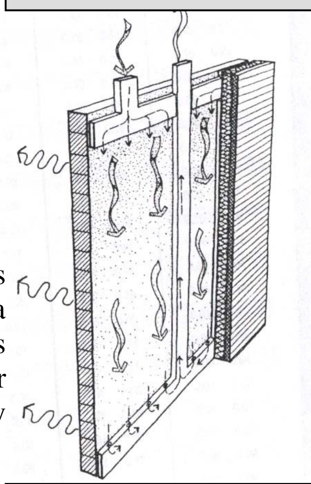


Fig.(1-49)
Murocaust Wall
Apartments in Gothenburg
Brown,G.Z, and Dekay, Mark, "Sun,Wind and Light", p179

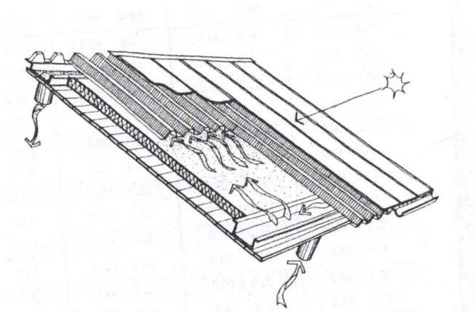


Fig.(1-50)
Collector Detail
Apartments in Gothenburg
Brown,G.Z, and Dekay, Mark, "Sun,Wind and Light", p179

Brown,G.Z, and Dekay, Mark, "Sun,Wind and Light", p179

(1-9-3-3) Green Architecture

- The green architecture is a term that describes the healthy mutual relation between the building and the surrounding environment, the creation of new buildings or civil engineering projects has the potential to improve our lives, and they also have long lasting effects on the wider environment.

- This concept is a more mature one which may include both active and passive solar architecture strategies together with more progressive building materials and integrated design solutions, where sustainability of the building is the main goal. Making use of the surrounding environment to fulfill a desirable indoor condition is not the only aim, as the output of the building to its environment is a question.

- "Sustainable development aims to meet the needs of the present without compromising the needs of the future, the broad aims of the sustainable construction are to:
  - Improve the quality of our lives
  - Acceptability to other people and future generations
  - Causing minimum effect to the wider environment and its resources."(1)

- "When identifying and assessing a building for sustainability, the following factors should be considered:
  - Land use
  - Use of materials
  - Use of energy
  - Use of water
  - Reduction of waste
  - Community benefits" (2)

(1), (2) McMullan, Randall, "Environmental Science in Building", 2002, p.345

(1-10) Solar Architecture and the New Millennium

- "Two technology developments have a strong influence on the further development of solar architecture now, after the turn of the century; powerful high speed computers and high performance building components".[1]

- These two factors together with the previous strategies form the tools of the architect to reach maximum efficiency in his design by improving the quantitative thermal performance of the building.

(1-10-1) Computer Simulation Programs

- A giant breakthrough was engaged to the exceeding interference of the computer programs which have the ability to evaluate and simulate the performance of a solar building for a year long period in few seconds; "whereas design of the passive solar houses in the 1970's was done with the help of hand calculators with a small magnetic strip which could feed in a few steps of construction for monthly energy balances, today, a full dynamic simulation can be done." [2]

(1-10-2) High Performance Building Materials

- New building materials with high performance levels found their way strongly, components hardly imaginable 20 years ago are taken for granted today, new glazings with a U value 0.7 W/m^2K is offered by many manufacturers.

---

(1), (2) Hastings, Robert, "The evolution of solar architecture", for the Swiss Federal Office of Energy,2002 p. 57

(1-11) Conclusions

- Historical heritage is a very rich mine to refer to, roots of the new concepts can always be found in the past.

- By the evolution of "Archeoastronomy" by Sir Norman Lockyer, 1901, many evidences were found insuring the awareness of the ancient civilizations with our solar system; sometimes to a very amazing extent.

- Many tools were invented making use of the solar path and the sky dome through successive eras, especially by Greek and Muslim scientists.

- The solar architecture found a renaissance at the beginning of the 20^{th} century by the masters of modern architecture.

- The modern movement produced a new international style which turned its back to the nature, and depended completely on mechan-ical systems to overcome the unbearable internal conditions leading to extensive consume of energy.

- After the energy crisis (1973), new concepts of active and passive solar architecture were suggested by the architects and researchers, trying to make use of the renewable energy resources, the evolution of the concept of green architecture represented a more mature relationship between the building and the environment.

- Two technology developments have a strong influence on the further development of solar architecture now, after the turn of the century; computers simulation programs and high performance building materials.

CHAPTER II
Solar Radiation as External Thermal Force Acting on the Building

Introduction

- Solar radiation represents the main thermal factor acting on the building, where it can be predicted for a certain location in terms of direction and magnitude, this is because the sun follows accurately predictable diurnal and annual patterns, so the radiation intensity striking a given area of the building at different hours and seasons is also predictable, and its impact can be controlled by design.
- This chapter will show the different methods to detect solar radiation in terms of both direction and magnitude.

(2-1) Direction of Solar Radiation

- It has always been important to know the position of the sun in the sky dome at a certain time for several architectural design purposes, accordingly, many predictions can be made like the amounts of solar radiation received by the building, appropriate distribution of windows for good illumination, the shadow cast around a building, the penetration of the sun inside the building, and how to treat unpleasant radiations by shadow masks…etc.

- This part will show several methods to indicate the position of the sun in the sky:

    - Mathematical calculations.
    - Graphical charts.
    - Computer aided calculators.

(2-1-1) Definitions

(2-1-1-1) Solar Altitude

The solar altitude represents the vertical angle that the sun makes with the ground plane [1]; it's given an angle with the range:

$$0° < \text{Altitude} < 90°$$

(2-1-1-2) Solar Azimuth

"The solar azimuth represents the horizontal angle of the sun relative to the true north in a clockwise direction when viewed from above." [2] Having the range:

$$0° < \text{Azimuth} < 360°$$

N.B.: Many references may note that the azimuth is measured from the south [3].

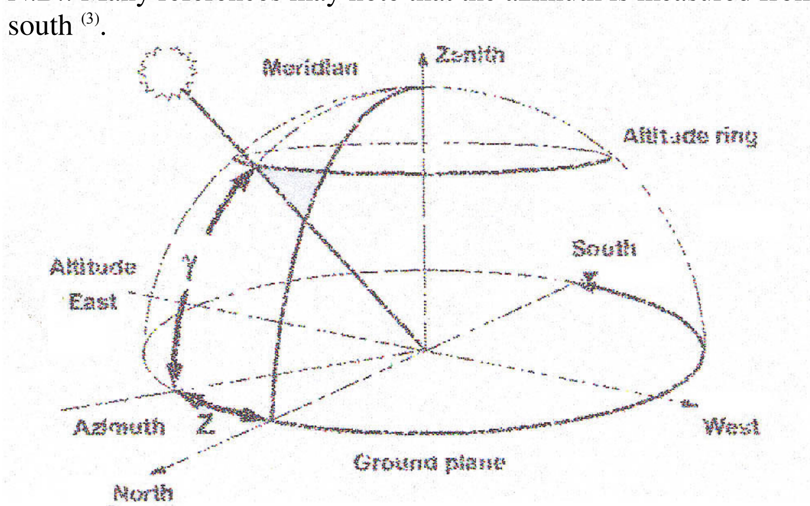


Fig. (2-1)
Solar Altitude and Solar Azimuth

(1) March, Andrews and Raines, Caroline, "Square One", www. Squ1.com,1/2003.
(2) March, Andrews and Raines, Caroline, "Square One", www. Squ1.com,1/2003.
(3) Such as: " Design with Climate" by Victor Olgyay.

(2-1-2) Methods of Detection of Solar Position

(2-1-2-1) Mathematical Calculations

- This method is a difficult one, where substitution in mathematical formulas to detect the solar position consumes a lot of time, however, these formulas can be used as a base for solar calculators and computer aided programs in which the role of the user is only to detect the latitude of the location in question, the time and the date.

(2-1-2-2) Graphical Charts

- A graphical or chart method was found to be easier to use, two of these methods are:
  - The cylindrical diagrams.
  - The stereographic sun path diagrams.

(A) The Cylindrical Diagrams

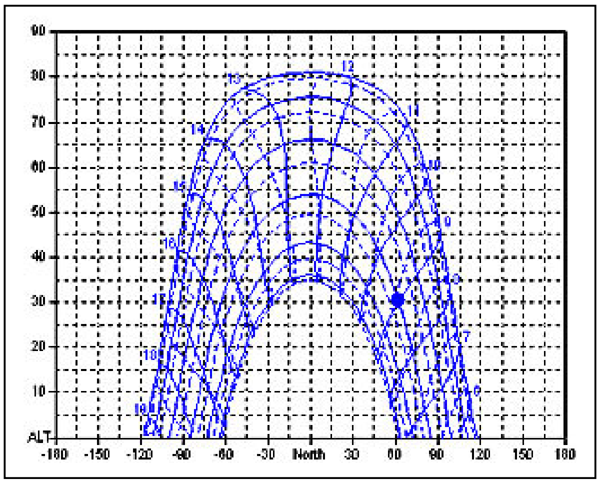


Fig. (2-2)
The Cylindrical Sun Path Diagrams
March, Andrews and Raines, Caroline, "Square One", www. Squ1.com

(a) Components of the Cylindrical Diagram

- Like most of the graphical methods, for each latitude there is a special chart, this kind of charts is found to be very easily understood and used by non specialists; it is a two dimensional graph of the sun position in Cartesian co-ordinates where the x-axis represents the azimuth angle while the y-axis represents the altitude angle.

- The long curves represent the solar position for the 21st day of each month (solid lines refer to January → June whilst the dotted lines for July → December).

- The short curves intersecting with the long curves refer to the hour of the day.

(b) How to Use the Cylindrical Diagrams

1- Detect the date required from the date curves previously mentioned.
2- Locate the required hour line on the diagram.
3- Find the intersection of the two lines.
   N.B. Dotted lines of the date intersect with dotted lines of the hours and similarly for solid lines.
4- Read the equivalent X & Y values to that point representing azimuth and altitude angles respectively.

(c) Advantages and Disadvantages of the Cylindrical Diagrams (1)

1- Advantages:
   a- Easy to use.
   b- Quick results.
   c- For each latitude there is a special diagram.
2- Disadvantages:
   a- Gives no further information other than altitude and azimuth.
   b- Couldn't be used for other applications if compared to stereographic diagrams.

(1) March, Andrews and Raines, Caroline, "Square One", www. Sq1.com, 1/2003.

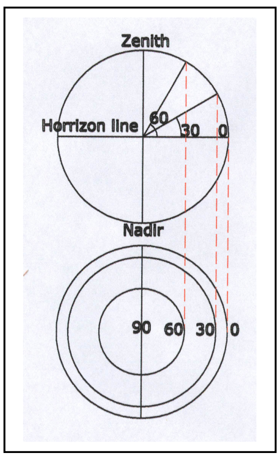
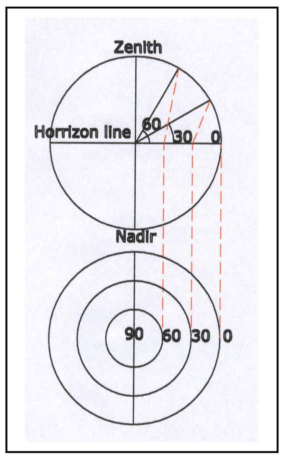
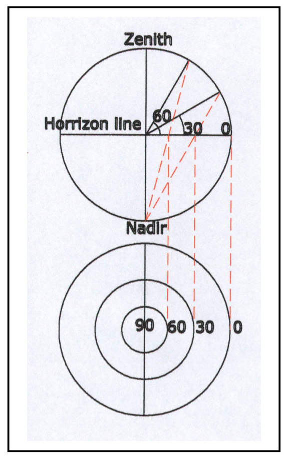
(B) The Stereographic Diagrams

(a) Evaluation With Respect to Equidistant and Orthographic Diagrams

- This category of sunpath diagrams includes two kinds other than the stereographic projection method, which are the equidistant, and the orthographic projection.

- The major difference between these methods concerns the way of plotting the altitude concentric circles.

- Table [2-1] illustrates this point of comparison between the three methods [1]:

<table>
<tr><th>The Orthographic Projection</th><th>The Equidistant Projection</th><th>The Stereographic Projection</th></tr>
<tr>
<td>
</td>
<td>
</td>
<td>
</td>
</tr>
</table>

(1) By the researcher after " Markus, T.A., and Morris, E.N. "Building, Climate and Energy", p.174, 1980" and " Olgyay, Victor, "Design with climate", p.36, 1963."

- "In the equidistant projection method, the altitude angles appear on the diagram equally spaced, this characteristic assures equal readability for high or low angles and makes plotting easy "(1).

- However the stereographic diagrams have a very good advantage as they could be linked to a photograph of the sight taken by a fish eye lens looking straight up towards the zenith of the sky, thus we find that it's the most used type in many scientific references and other applications.

- "For the stereographic projection, any point on the surface of the hemisphere is connected to the sphere's nadir equivalent to viewing the inside surface of the upper hemisphere from the nadir as the eye's position. These connecting, or sight lines cut the equatorial plane of the sphere; this plane can represent the horizon. Onto this plane, at the intersection of the site lines every point on the surface of the hemisphere can be projected. This yields a two dimensional projection with the horizon forming the outer circle and the zenith the center of the hemisphere's surface. On such projection, the paths of the sun can be plotted exactly as it would appear to pass over the imaginary sky hemisphere." (2)

- As a result of choosing the desirable method of projection, the sunpath can be easily estimated by plotting the altitude and azimuth for hourly readings, then joining them together by a smooth curve.

- It is not desirable to draw the sunpath diagrams from scratch, as they are already available for all latitudes; however, it is very useful to understand their basics.

(1) Olgyay, Victor, "Design with climate", p.36, 1963.
(2) Markus,T.A., and Morris, E.N. "Building, Climate and Energy", p.173, 1980.

(b) Components of the Stereographic Diagrams:

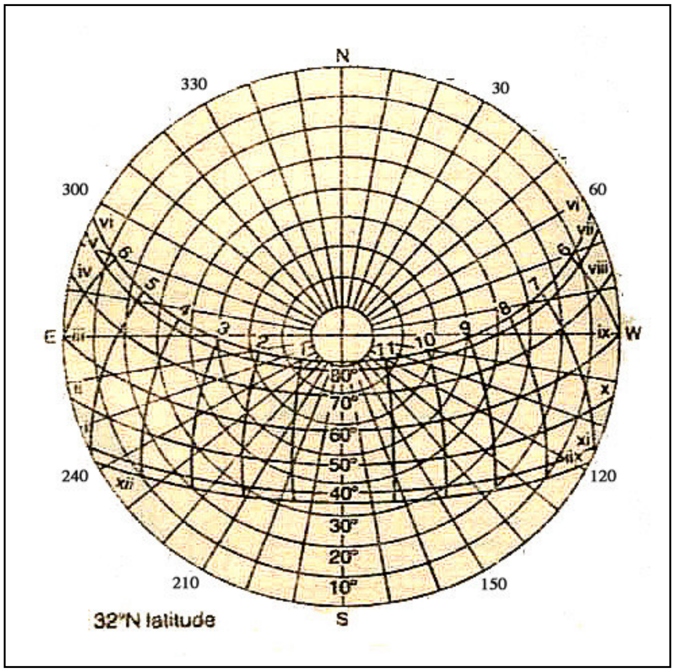


Fig. (2-3)
The Stereographic Sun Path Diagrams
Jones, Vincent, "Ernst Neufert – Architect's Data", 1985 p.34

1- Azimuth Angles
The azimuth angles run around the edge of the diagram, where it is measured in a clockwise from true north.

2-Altitude Circles
They are represented by concentric circles in 10° increments from 0° to 90°

3- Date Lines

Date lines represent the path of the sun in the sky dome at a particular date, they start on the eastern side of the graph (sunrise) and run to the western side (sunset), there are 12 lines each representing the 21st day of each month, the first 6 months are shown in solid (January-June) while the last six months are shown as dotted (July-December).

4-Hour lines

The hour lines represent the position of the sun at a specific hour of the day, at the point of their intersection with the date lines.

(c) How to Use the Diagram

1- Indicate the appropriate day – hour intersection to get the target point.

2- Draw a line from the center of the diagram (zenith point) passing through the point and intersecting with the border of the diagram at its azimuth angle.

3- Draw a circle from the center of the diagram through the point to intersect the y axis calibration at the point's altitude angle.

(d) Advantages and Disadvantages of the Stereographic Diagrams

1-Advantages:

- a- Quick results.
- b- For each latitude there is a special diagram.
- c- Can be used in several architectural practical applications.

2-Disadvantages:

- a- Readings require more steps than those of the cylindrical diagrams.

(e) Applications on Stereographic Diagrams

1- The Solar Window.

Fig. (2-4)
The Fish Eye Camera
http://www.pge.com/003_save_energy/003c_edu_train/pec/toolbox/tll/app_notes/arch_site.shtml

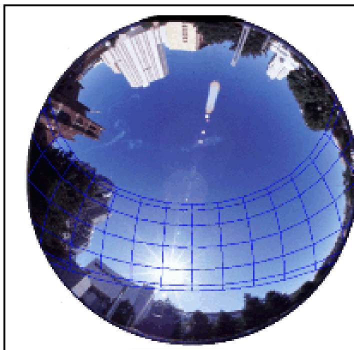


Fig. (2-5)
Solar Window
http://www.pge.com/003_save_energy/003c_edu_train/pec/toolbox/tll/app_notes/arch_site.shtml

- One of the most important properties of the stereographic Diagrams, the ability to link them to a photograph of the site taken by a fish eye camera.
- Fig.(2-4) shows the fixation of the camera to take the needed panoramic shot of the site.
- Fig.(2-5) shows the appropriate sun - path stereographic diagram of the latitude after being linked to the taken shot.
- The lines will represent the actual imaginary paths of the sun across the sky.
- Any obstruction of these paths by buildings or by vegetation gives us a complete data about the times of the day around the year at which the sun is blocked indicating times of shading.
- This method is very useful in case of external landscape shading devices and pergolas, where a complete control of shading can be achieved.

2- <u>The Shading Mask.</u>

- The sun path diagrams (either of the three types) could be used to design vertical and horizontal shading elements, where the horizontal line of the graph represents the plane of the window, while the shading elements are drawn in terms of altitude and azimuth relative to the center of the diagram.

- Similarly as the previous application, the obstruction of the shading elements projection to the sunpath lines indicate the times of shading throughout the year.

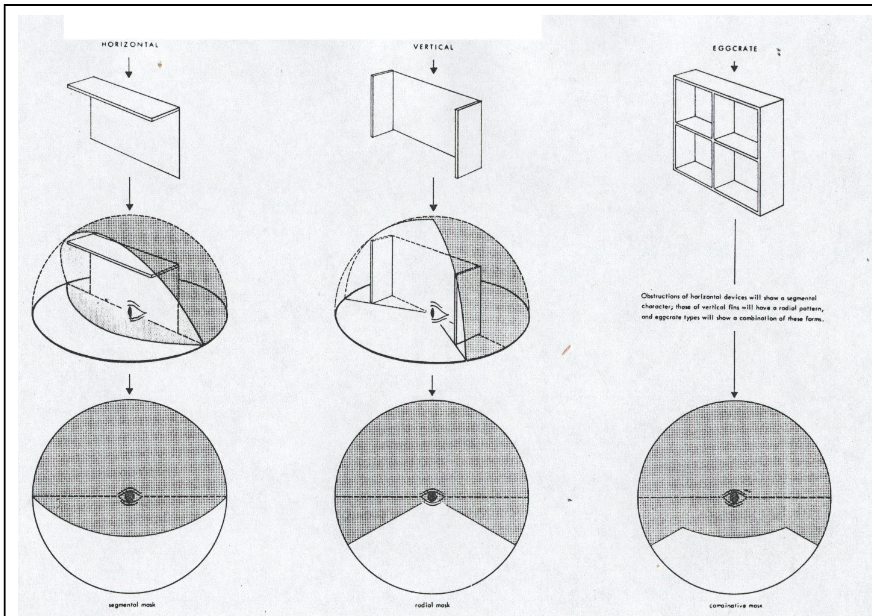


Fig. (2-6)
The Shading Mask
Olgyay, Victor, “Design with climate”, p.81, 1963

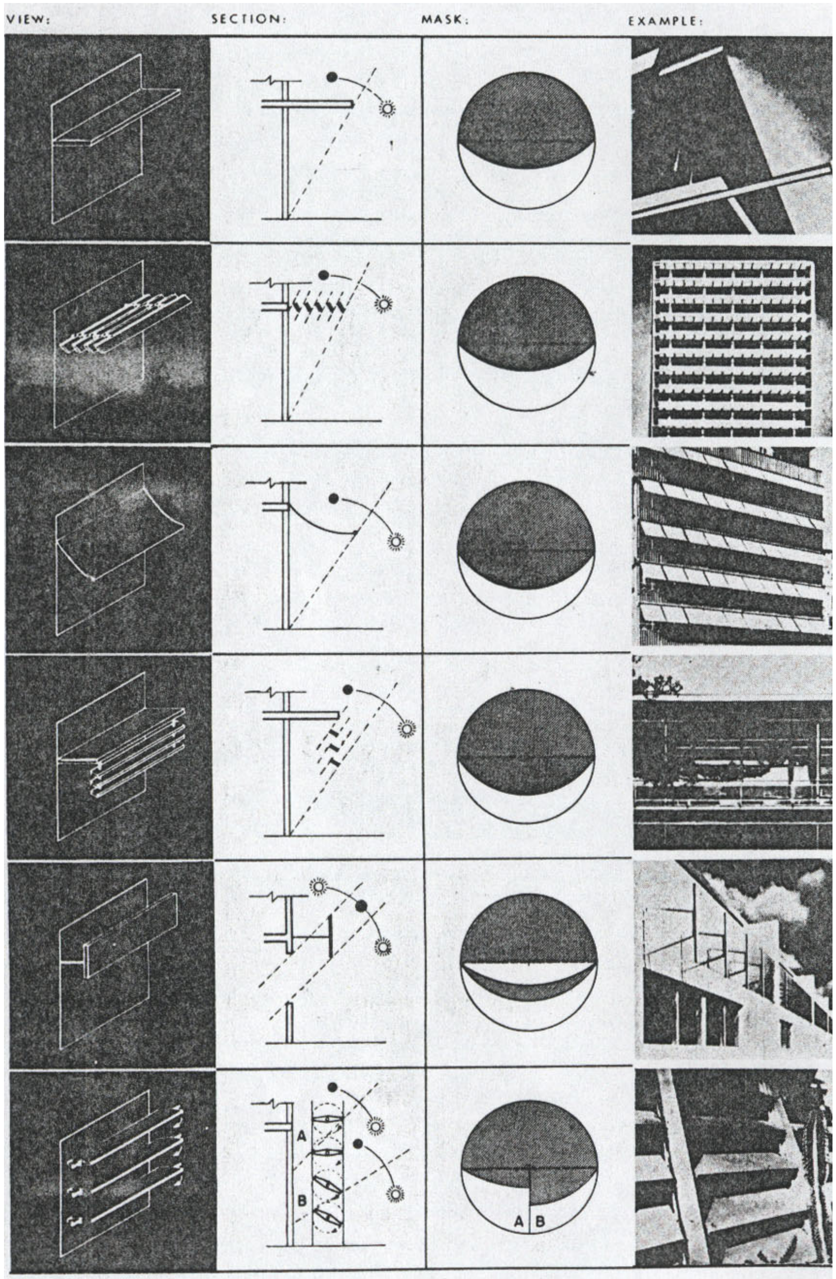


Fig. (2-7)
Shading Mask for Different kinds of Horizontal Shades
Olgyay, Victor, "Design with climate", p.82, 1963

(2-1-2-3) Computer Aided Programs

(A) Solar Calculators

- A further progress in the field of solar angle calculation is the computer aided programs which are specified to calculate the altitude and azimuth angles of the sun if supplied with the needed Data.

- The output may include other information like the time of sunrise, sunset and the solar declination angle.

- The following Interface, proposed by the NOAA [(1)], represents one of these calculators, where the latitude, longitude, date and time are supplied in the input to get the needed information.

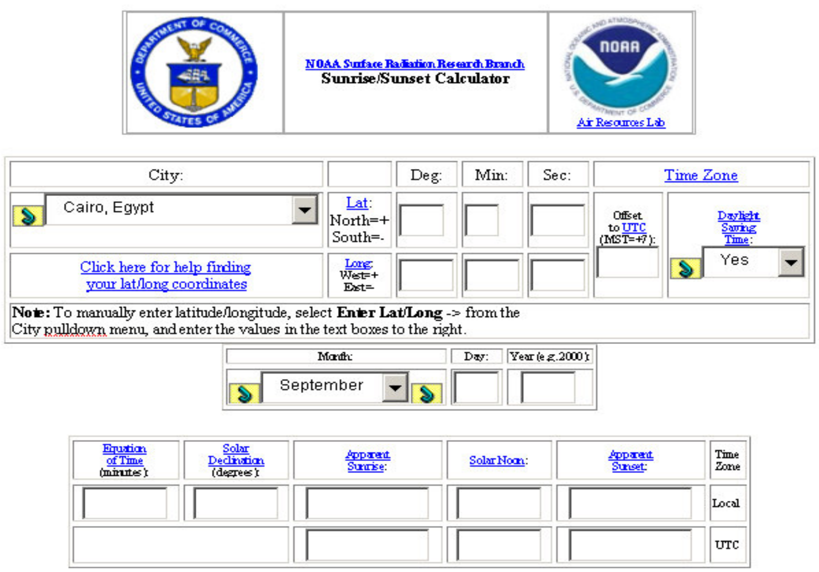


Fig. (2-8)
Solar Calculator, by NOAA
http://www.srrb.noaa.gov/highlights/sunrise/azel.html

(1) National Oceanic and Atmospheric Administration

(B) Shading Mask Simulator [(1)]

- This example is one of numerous programs dealing with sunpath diagrams.

- It is an educational program developed by (Oh and Harbel) 1996, Texas A & M university, which is based on MS windows so as to fast track the learning of the sunpath diagram and shading mask protractor.

- The figure below shows the user interface of the program; the combined sunpath diagram and the shading protractor can be seen in the upper right quadrant.

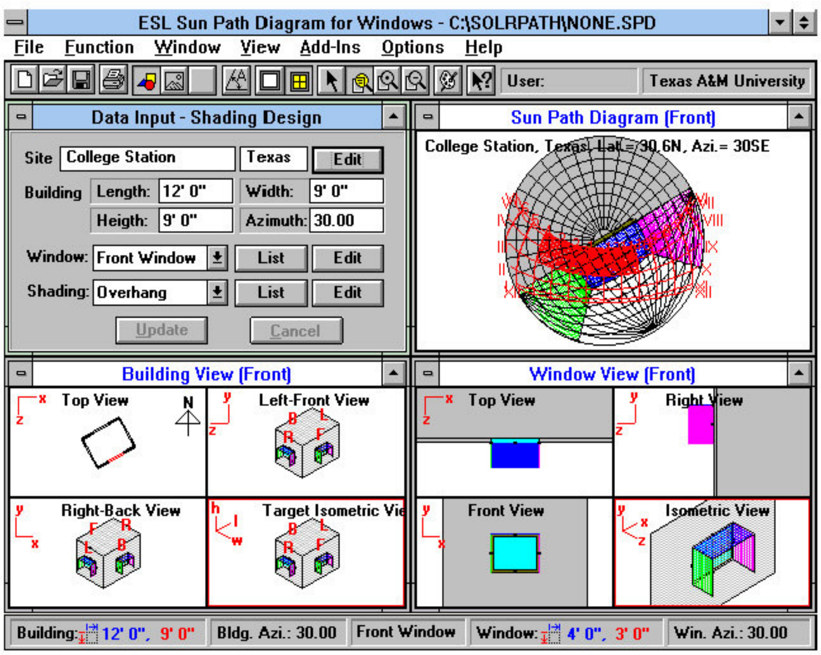


Fig. (2-9)
Opening Screen for the MS Windows Solar Shading Analysis Program
www.hvav.okstate.edu/pdf/ bs97/papers/p203.pdf

(1) www.hvav.okstate.edu/pdf/ bs97/papers/p203.pdf – accessed 1/2003

- All data entry is made in the data input quadrant to its left; the dimensions of the building, its orientation, its location in terms of latitude and longitude, the date-time of the calculations and the dimensions of the openings.

- The lower part shows the modifications to the shading devices and their dimensions

- The data input portion leads to sub menus concerning the dimensions of the shading device, and the solar target time; the times of the year planned to block the sun (fig. (2-10) and (2-11)).

- ***Briefly***, despite of the profession of any of the computer programs concerning this branch of science, it reflects sincerely the new potentials and advantages as compared with the traditional manual calculation methods, or even charts, saving more time and simplifying the concepts for non-specialists.[1]

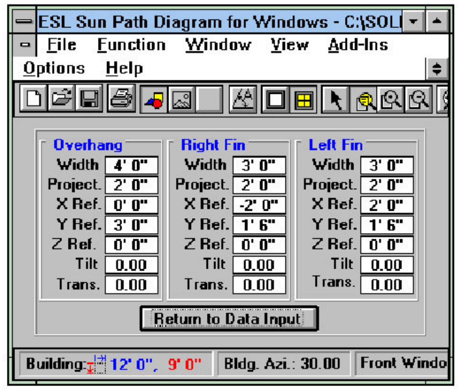


Fig (2-10)
Shading Data Menu
www.hvav.okstate.edu/pdf/
bs97/papers/p203.pdf

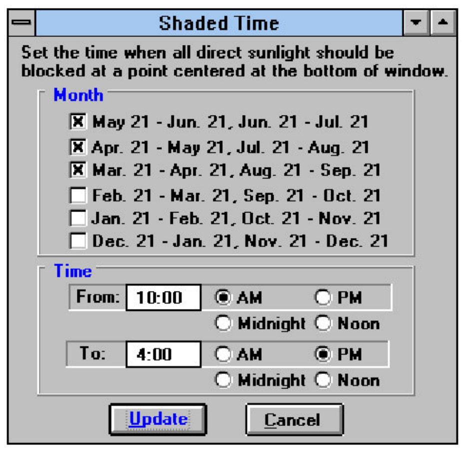


Fig (2-11)
Solar Target Time
www.hvav.okstate.edu/pdf/
bs97/papers/p203.pdf

(1) Review Chapter V

(2-2) Magnitude of Solar Radiation

(2-2-1) The Solar Constant

- The solar radiations emitted from the sun include a wide band of electro-magnetic waves having different wavelengths and frequencies due to different rates of energy loss during the journey of the radiations from the core of the sun to the corona.

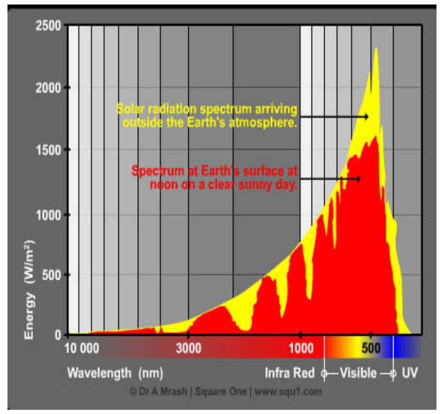


Fig. (2-12)
Solar Insolation Components
March, Andrews and Raines, Caroline, "Square One", www. Squ1.com

- Fig.(2-12) shows the variation of these waves within the solar insolation, obeying the laws of a black body emissions when heated to 5900°K.

- The amount of solar radiation reaching the earth outside the atmosphere was assumed to be a constant value despite of the changing distance between the sun and the earth due to the elliptical orbit of the earth around the sun.

- This value is well known as the solar constant, which was assumed to be 1353 W/m^2.

- " The rate at which the solar radiation strikes the earth's upper atmosphere is expressed as the "Solar Constant", this is the average amount of energy received in a unit time on a unit of area perpendicular to the sun's direction at a mean distance of the earth from the sun: 92,960,000 miles, approximately 150,000,000 km ".[(1)]

---

(1) Office of Energy Efficiency and Renewable Energy, "EREC Brief, Solar Radiation for Energy: A Premier and Sources of Data", www.eren.doe.gov /consumerinfo /refbreifs/ vi38.html, p.2, accessed 10/2002.

- "The ultra violet (UV) radiations make up a very small part of the total energy content of the insolation, roughly 8-9%, the visible range with a wavelength of 0.35 to 0.78 mm presents 46-47% of the total energy received from the sun, the final 45% of the sun's total energy is near the infra red range of 0.78 mm to 5 mm".[1]

(2-2-2) The Atmospheric Effect on Insolation

- As the solar radiation penetrates the atmosphere, some of it is absorbed and scattered (25%) by air molecules, water vapor, small airborne particles and aerosols.

- Another part is reflected directly back into space (20%) by clouds, the rest arrives directly to the earth's surface.

- Once radiation hits the ground it is reflected by different percentages according to the kind of terrain varying from (5 – 10 %) for dense forest vegetation to (95%) for snow.

- "It is the scattered component that makes the sky look bright and provides ambient diffuse day lighting in buildings, without it the sky would look as black as it does at night with the sun being a very large and bright star occasionally passing through it".[2]

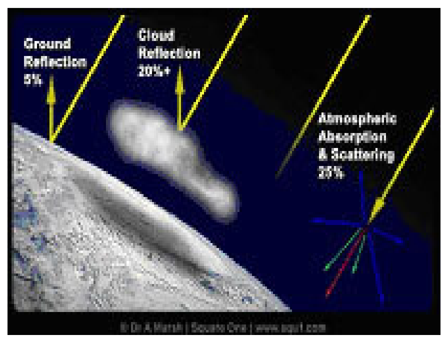


Fig (2-13)
Solar Insolation Scattering
March, Andrews and Raines, Caroline, "Square One", www. Squ1.com

(1), (2) March, Andrews and Raines, Caroline, "Square One", www. Squ1.com,accessed 1/2003

(2-2-3) Direct, Diffuse and Reflected Irradiation

- The incident solar radiation is divided into several portions; either reflected, scattered or passed directly to the ground's surface.

- Accordingly, the actual solar radiation falling on a surface at the ground's plane (vertical, horizontal or inclined) is the sum of the contributions of all the forms of radiation (direct, diffuse or reflected).

- This part will study the basics related to this branch as a starting point to calculate the heat gains of a building due to solar radiation.

(2-2-3-1) Radiation Units (1)

Radiation quantities are generally expressed in terms of either:

(a) Irradiance.
(b) Radiant Exposure.

(A) Irradiance:
It is a measure of the rate of energy received per unit area. It has units of Watts/Square meter (W/m^2),
where 1 Watt = 1 Joule/sec.

(B) Radiant Exposure:
It is a time integral or the sum of irradiance received by a surface within a time period. It has units of Joules/Square meter (J/m^2).

(1) Bureau of Meteorology, Australia, “Solar Radiation Definitions”, http/www.bom.gov.au , p.p.1,2, accessed 10/2002

(2-2-3-2) Direct Solar Irradiance (I_D)

(A) Definitions:

(a) Direct Solar Irradiance: [1]
It is a measure of the rate of solar energy arriving at the earth's surface from the sun's direct beam; it has units of W/m^2.
The direct radiation is so intense, and hence it is described as (shadow producing radiation)

(b) Direct Solar Exposure: [2]
It is the total amount of energy received by a surface due to direct solar irradiance within a certain period of time; it has units of J/m^2.

(B) Factors Affecting Direct Solar Irradiance: [3]

(a) Air Mass:
The solar constant received outside the earth's atmosphere is partially scattered, reflected whilst the rest reaches the ground directly (direct radiation).

The intensity of the direct component decreases when it penetrates a longer path through the atmosphere.

The path length of the solar radiation through the atmosphere is defined as the air mass.

The air mass depends upon:

- The solar altitude.
- The altitude above the sea level.

(1),(2) Bureau of Meteorology, Australia, “Solar Radiation Definitions”, http/www.bom.gov.au , p.2, accessed 10/2002
(3) Markus,T.A., and Morris, E.N. “Building, Climate and Energy”, pp.184 -186, 1980.

Table [2-2] gives values of air mass (m) as a function of the solar altitude.

(m)	1	1.5	2	3	4	5	6
Solar Altitude (A)	90	42	30	20	14.5	11.5	9.6

- Fig (2-14) shows the relation between solar altitude and the air mass (m); the shorter the path of the rays the smaller the value of the air mass (m).

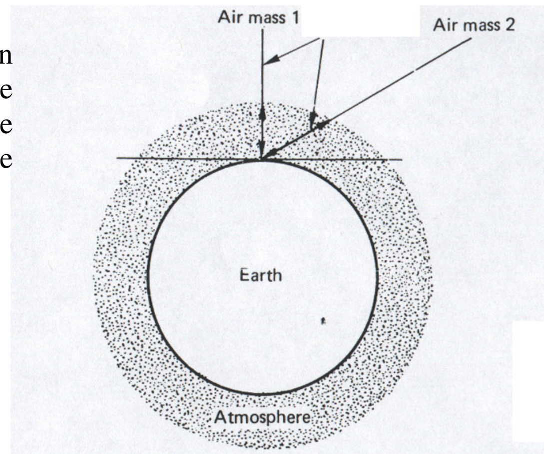


Fig (2-14)
Air Mass
Markus,T.A., and Morris, E.N. "Building, Climate and Energy", p.184, 1980.

(b) Turbidity

- It is a property of the atmosphere describing the concentration of water vapor, aerosols responsible for radiation scattering.
- Fig (2-15) after (Rogers and Souster) shows the value of the incident solar radiation (I_{DN}) with respect to the water vapor concentration and the air mass.

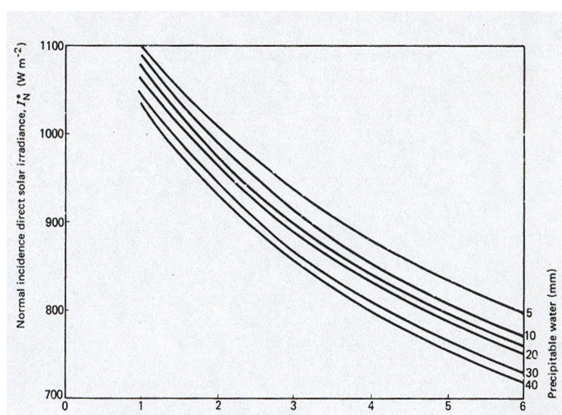


Fig (2-15)
Variation of I_{DN} with respect to water vapor content
Markus,T.A., and Morris, E.N. "Building, Climate and Energy", p.185, 1980.

Table[2-3] gives the values of direct solar irradiation (I_{DN}) with respect to air mass (m) and water vapor content in the atmosphere:[1]

Precipitate water (mm)	Air Mass (m)						
	1	1.5	2	3	4	5	6
	Solar Altitude (A)						
	90°	42°	30°	20°	14.5°	11.5°	9.6°
5	1100	1055	1010	940	885	835	800
10	1090	1035	990	915	860	810	775
15	1080	1020	975	900	845	800	760
20	1065	1010	960	890	835	790	750
30	1050	990	945	870	820	770	730
40	1035	980	930	860	805	755	720

(C) Direct Solar Irradiance Calculation [2]

From the previous Graph and table, the values of the incident direct solar irradiance (I_{DN}) can be calculated with respect to the solar altitude (A). This piece of information is very important to calculate all other forms of radiation components (either direct, diffuse or reflected) .

(a) For Horizontal Surfaces

$$\mathbf{I_{DH} = I_{DN} \sin A} \quad \text{-------- \{2-1\}}$$

Where $\mathbf{I_{DH}}$ = Direct solar irradiance for horizontal surfaces.
$\mathbf{I_{DN}}$ = Incident direct solar irradiance.
A = Solar altitude angle

(1) Markus,T.A., and Morris, E.N. “Building, Climate and Energy”, p.186, 1980.
(2) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design", P.50,1998.

(b) For Vertical Surfaces

First, we need to calculate the bearing angle of the sun, which is the difference between the orientation of the wall and the solar azimuth (Z).

$$\mathbf{b = Z - Z_B} \qquad \text{-------- \{2-2\}}$$

Where **b** = bearing angle.
Z = solar azimuth.
$\mathbf{Z_B}$ = building orientation

Then, the incidence angle of the sun with respect to the wall (O) can be calculated.

$$\mathbf{\cos O = \cos A \times \cos b} \qquad \text{-------- \{2-3\}}$$

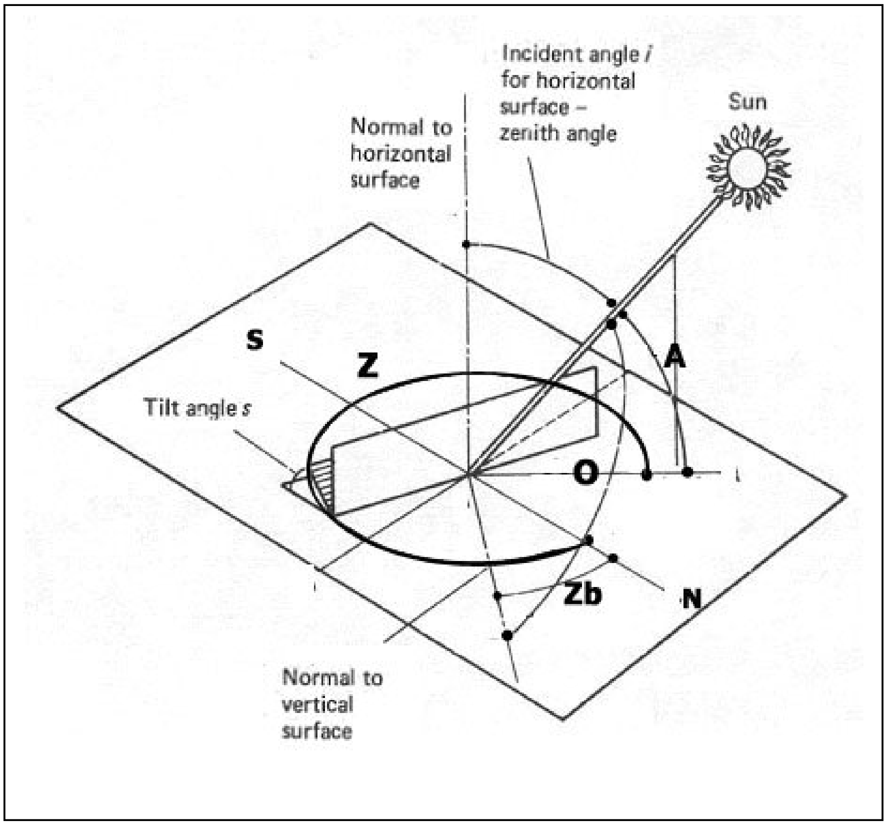
Finally, the direct solar irradiation ($\mathbf{I_{DV}}$) is given by the formula

$$\mathbf{I_{DV} = I_{DN} \cos O} \qquad \text{-------- \{2-4\}}$$

Where I_{DV} = Direct solar irradiance for vertical surfaces.

N.B:

In case the Bearing angle |b| > 90, then I_{DV} = zero



A= Altitude angle, Z= Azimuth angle , Z_B= Building's orientation
b= Bearing angle, = Z-Z_B
O= Angle of incidence
S= Inclination angle of the surface

- *cos O = cos(A) cos(b) sin(S) + sin(A) cos(S).*
- *For vertical surfaces ; S=90,*
  Then, cos(O) = cos(A) cos(b).
- *For horizontal surfaces ; S=0,*
  Then, cos(O) = sin(A).

Fig (2-16)
Solar Angles with Respect to Vertical , Horizontal and Inclined Surfaces
By the Researcher after Markus,T.A., and Morris, E.N. "Building, Climate and Energy", p.172, 1980.

(2-2-3-3) Diffuse Solar Irradiance (I_d)

(A) Definitions: [1]

(a) Diffuse Solar Irradiance:

It is a measure of the rate of the incoming solar energy on a horizontal plan at the earth's surface resulting from scattering the sun beam allover the sky dome due to atmospheric constituents; it has units of W/m^2.

(b) Diffuse Solar Exposure:

It is the total amount of energy falling on a surface from all parts of the sky apart from the sun; the daily diffuse solar exposure is the total diffuse energy of the day.
N.B: typical values for daily exposure range from 1 to 20 MJ/m^2.

(B) Factors Affecting Diffuse Solar Irradiance:

The main factor affecting the intensity of the diffuse component of the solar radiation is the sky cover;

" During cloudy days, the ratio of the diffuse to direct radiation may be 1.00 (100%), while during clear days, it may reach only 0.15, however, the overall radiation received on a cloudy day (only diffuse) is much less than the overall radiation (direct plus diffuse) received on a clear day."[2]

"The amount of diffused radiation is very variable, depending upon the atmospheric haziness and cloudiness. It may range from about 5% of the total radiation on a clear day in an arid region to above 80% in an overcast day".[3]

(1) Bureau of Meteorology, Australia, “Solar Radiation Definitions”, http/ www. bom. Gov.au , p.p.1-2, accessed 10/2002.
(2) Olgyay, Victor, “Design with climate”,p.35, 1963
(3) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",P.55, 1998

(C) Diffuse Solar Irradiance Calculation [1]

(a) For Horizontal Surfaces (I_{dH}).

Given the solar incident direct solar irradiance (I_{DN}), the horizontal diffuse solar irradiance can be calculated after the equation:

$$\mathbf{I_{dH} = K \times I_{DN}} \quad \text{-------- \{2-5\}}$$

For clear sky conditions, K = 0.12

(b) For Vertical Surfaces (I_{dV}).

"Diffused sky radiation reaching a wall in an open field (I_{dV}) comes only from one half of the sky vault." [2]
"If (I_d) is assumed to be of uniform intensity over the sky hemisphere, then, the vertical surface values of diffuse sky irradiance (I_{dV}) will be one half of (I_{dH})."[3]

$$\mathbf{I_{dv} = I_{dH} / 2 = 0.5\, K \times I_{DN}} \quad \text{-------- \{2-6\}}$$

(2-2-3-4) Reflected Solar Irradiance (I_R)

(A) Definition:

Reflected Solar Irradiance:

It is a measure of the rate of solar energy reflected from the surrounding terrain and received by a vertical, or inclined surface, it has units of W/m^2.

(1) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design", P.56,1998.
(2) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design", P.56,1998.
(3) Markus,T.A., and Morris, E.N. "Building, Climate and Energy", p.188, 1980.

(B) Factors Affecting Reflected Solar Irradiance:

Despite of its being a function of both direct and diffuse solar irradiance, the main factor affecting the intensity of the reflected solar irradiance is the kind of terrain surrounding the building,
Table [2-4] shows different percentages of reflection due to the nature of the surface : (1)

Nature of surface	Estimated reflected % (r)
Bare ground, dry	10-25
Bare ground, wet	8-9
Sand, dry	18-30
Sand, wet	9-18
Mold, black, dry	14
Mold, black, wet	8
Rock	12-15
Dry grass	32
Green fields	3-15
Green leaves	25-32
Dark forest	5
Desert	24-28
Salt flats	42
Brick, depending on color	23-48
Asphalt	15
City area	10

(1) Olgyay, Victor, “Design with climate”, p.33, 1963

(C) Reflected Solar Irradiance Calculation [1]

For Vertical Surfaces (I_R).

$$I_R = I_{GH} \times r / 2 \quad \text{-------- } \{2\text{-}7\}$$

Where, r = Estimate reflected percentage according to kind of terrain
I_{GH} = Global horizontal irradiance.

(2-2-3-5) Global Solar Irradiance (I_G)

(A) Definition: [2]

It is a measure of the rate of total incoming solar energy for any surface due to the contribution of all forms of radiation.

(B) Global Solar Irradiance Calculation: [3]

(a) For Horizontal Surfaces (I_{GH}).

$$\mathbf{I_{GH} = I_{DH} + I_{dH}} \quad \text{-------- } \{2\text{-}8\}$$

(b) For Vertical Surfaces (I_{GV}).

$$\mathbf{I_{GV} = I_{DV} + I_{dV} + I_R} \quad \text{-------- } \{2\text{-}9\}$$

(1) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design", P.56,1998
(2) Bereau of Meteorology, Australia, "Solar Radiation Definitions", http/ www. bom. Gov.au , p.3, accessed 11/2002.
(3) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design", p.,57, 1998

(2-3) Conclusions

- The position of the sun in the sky dome is determined in terms of altitude and azimuth, where these angles are detected by manual calculations, graphical charts and diagrams, or by aided computer programs.

- Further applications using sun path diagrams can be made, to detect the times of the year of solar exposure for a spot within an urban space, or to design desirable shading devices for a certain façade.

- The solar altitude and azimuth is a very important piece of information to calculate the amount of solar radiation falling on a vertical/horizontal surface.

- The amount of solar radiation reaching outside the atmosphere is assumed to be constant around the year despite of the earth's elliptical orbit; nearly1353 W/m^2 , this amount, when penetrating the atmosphere, is partially scattered, absorbed, reflected directly again to space , or, reach the ground surface directly.

- The actual amount of solar radiation falling on any surface is the sum of contribution of the scattered component (direct radiation, diffuse radiation, and reflected radiation).

- The intensity of the direct solar radiation varies according to the air mass (depending on solar altitude), and turbidity.

- The intensity of the diffuse component depends upon the cloud cover of the sky.

- The intensity of the reflected component depends on the nature of the surrounding terrain.

- The aim of calculating the solar radiation falling on a surface is to estimate the amount of energy gained by the building from the sun.

CHAPTER III
Building Skin Parameters Affecting Thermal Heat Gains

Introduction

- The building skin is the external barrier which protects the occupants from the undesirable climatic conditions; the need of suitable shelter was a motive that made man search for suitable strategies concerning the design of that barrier.

- Many architectural features of the building skin affect its thermal performance with respect to solar radiation, and taking advantage of theses features helps us to shift the internal conditions if the building towards the human comfort zone. [(1)]

- This chapter will study these parameters, and how they affect solar heat gains, giving architectural examples of the practical application of each factor.

- **The building skin parameters affecting solar heat gains are:**

1. Building material.
2. Building glazing.
3. Shading strategies.
4. Building compactness.
5. Building color.
6. Building orientation.

---

(1) The human comfort zone: It is a group of climatic conditions causing minimum stress of the themogulatory system (temperature, humidity, radiation and air movement), with respect to activity of clothing, many charts defined the comfort zone, such as the bioclimatic chart by Victor Olgyay, and the standard effective temperature (SET) by Gagge et Al.
Shifting the internal conditions of the building into that zone is the main goal of Bioclimatic architecture.
For more details review
Markus, T.A. and Morris, E.N, "Buildings, Climate and Energy", 1980, P.P 33-84.
Olgyay, Victor, "Design with Climate", 1963 P.P 14-34.
Givoni, Baruch, "Climate Considerations in Buildings and Urban Design",1998 , P.P 3-46

- Although each factor of these parameters has its own individuality, one or more of them may have mutual effect on each other, accordingly, the design must be integrated to benefit from all the possible potentials.

- "There are significant interactions between the effects of these features, so that the quantitative effect of on one feature (e.g. Orientation) may greatly depend on the design details of other features (in this case the shading of the windows and the color of walls and roof)." [1]

(1) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.50

(3-1) Building Materials

- The amount of heat that flows through a building's skin due to temperature difference between the outside and the inside is a function of magnitude of that difference, in addition to the resistance to heat flow by the skin materials.

- Since heat flows from hot to cold, if the inside of the building is warmer than the outside, heat will flow through the building skin outwards and vice versa.

- Accordingly, the kind of material used in the external building's skin represents a vital factor in securing a suitable thermal environment inside the building.

- This part will study the performance of skin materials with respect to solar radiation and temperature difference between the outside and the inside.

(3-1-1) Definitions:

(3-1-1-1) Thermal Resistance (R-value):

It is a property of the building's skin material giving the number of hours needed for one Btu to flow through one square foot of that skin, given a temperature difference of 1 ºF, it has the units of (ft^2, ºF, hr / Btu), or in metric units, (m^2 ºk/W).[1]

(1) Brown, G.Z and Mark, Dekay "Sun, Wind and Light", 2000, P.46

(3-1-1-2) Thermal Conductance (U-value):

A) It is a property of the building's skin material giving the number of Btu's that will flow through one square foot of the building's skin in one hour, given a temperature difference 1 ºF, it has the units of (Btu/hr, ft^2, ºF) or in metric units, (W/ m^2 ºk) .[1]

B) It is the reciprocal of the thermal resistance (R).

i.e.:

$$\mathbf{U = 1 / R} \qquad \text{------- \{3-1\}}$$

N.B:

For buildings having different construction materials of their walls, U_{wall} represents the average opaque wall heat transmission coefficient for the total building opaque area, the average U_{wall} can be estimated using area weighting. [2]

i.e.:

$$\mathbf{U_{wall} = U_{wall\ 1}(A_{wall\ 1}/ A_{wall}) + U_{wall\ 2}(A_{wall\ 2}/ A_{wall}) \text{--+ } U_{wall\ n}(A_{wall\ n}/ A_{wall})}$$

----- {3-2}

(3-1-1-3) Heat Transfer Rate through Building's Walls ($\hat{U}_{wall}$):

It is a property of the building, describing heat transfer rate through its skin to allow the comparison between different sized buildings, it has the units of (Btu/hr, ft^2, ºF) or in metric units, (W/ m^2 ºk) .[3]

i.e.:

$$\mathbf{\hat{U}_{wall} = U_{wall} (A_{wall} / A_f)} \qquad \text{----- \{3-3\}}$$

where, $\mathbf{A_{wall}}$ = Opaque wall areas
$\mathbf{A_f}$ = Total floor area

(1) Brown, G.Z and Mark, Dekay "Sun, Wind and Light", 2000, P.46
(2) Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point", 1997, P. 10
(3) Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point", 1997, P. 9

(3-1-2) Building Skin Performance with Respect to Heat Flow:

(3-1-2-1) Methods of Heat Flow:

There are three methods of heat flow:

- By Conduction.
- By Convection.
- By Radiation.

A. Heat Flow By Conduction

It represents the method of heat flow through solid material, where is based on the molecule to molecule transfer of kinetic energy (one molecule becomes energized, and in turn energizes the adjacent molecules), hence heat energy is transformed into kinetic energy through solid materials, it is affected by the thermal resistance (R-value) of the solid material. [1]

B. Heat Flow By Convection

It represents the method of heat transfer through fluids (e.g. air or water), where the heat is transferred by the physical movement of the fluid's molecules from one place to another, it is affected by the temperature of the fluid and its movement. [2]

C. Heat Flow By Radiation

It represents the method of heat transfer through space by electromagnetic waves (radiant energy), it is not affected by air movement. [3]

"During the process of flow through a wall or a roof, the heat may change its mood of transfer; thus the solar energy reaching a wall in the form of short-wave radiation, is absorbed in the external space, and flows across the wall material by conduction", "finally, heat is transferred from the interior surface to the indoor air by convection and long-wave radiation respectively" [4]

---

(1), (2), (3) BuildingGreen..com, Environmental Building News, "Thermal Mass and R-value: Making sense of confusing issue", From EBN Volume 7, N04-April 1998, P.1,2
(4) Givoni,Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.114

(3-1-2-2) Temperature Difference and Modes of Heat Flow:

Choosing the most suitable building material depends upon the performance of these materials with respect to the surrounding environment, and the climatic conditions of the building's site, the following cases explains different moods of heat exchange with the surrounding medium.

A. Steady-State Heat Flow [1]

It is an imaginary or artificial state of heat flow through a wall in which both temperatures on the outer and inner surfaces of the wall are constant, having one of them warmer than the other, accordingly, heat will flow gradually through the wall towards the cooler side with an easily predicted rate depending upon the R-value of the wall.

B. Dynamic (Reversible) Heat Flow [2]

It takes place due to the fluctuation of the outside temperature above and below the indoor temperature, accordingly, using the thermal mass effect of the wall would be beneficial; materials having high heat capacity would lag the penetration of the heat flow inside the wall until the direction of the flow is reversed due to decrease of the outside temperature lower than that of the building, heat is withdrawn to the outside again, the efficiency of this operation depends on the R-value and the heat capacity of the material, (mass enhanced R-value).

C. Dynamic One Way Heat Flow

It takes place, incase the outside temperature fluctuates, but never crosses the indoor set point temperature (either higher or lower), in this case, the direction of heat flow never changes, but the thermal lag caused by the thermal mass and R-value (enhanced R-value) of the building material, is still beneficial by delaying the peak heating or cooling load to a time interval when it is not necessary to use mechanical equipments, especially in public buildings (i.e. office and commercial Buildings).

(1), (2), BuildingGreen..com, Environmental Building News, "Thermal Mass and R-value: Making sense of confusing issue", From EBN Volume 7, N04-April 1998, P.2,3 accessed 1/2003

(3-1-3) Architectural Examples Making Use of Building Materials

Using the building mass as a thermal shield have always been a design strategy used in buildings over ages, contemporary examples insure the success of that criteria.

(3-1-3-1) Concrete Mass - Faculty of Journalism:

Fig.(3-1)
Faculty of Journalism-exterior
Cerver, Francisco Asensio, "Architecture of Minimalism", 1997 P.78

Fig.(3-2)
Faculty of Journalism-interior
Cerver, Francisco Asensio, "Architecture of Minimalism", 1997 P.87

The faculty of Journalism [1], Pamplona, Spain by the architect Ignacio Vicens and José Antonio Ramos, 1996, shows an opaque building, using concrete as a thermal mass, the openings are slim, either vertical or horizontal (Fig.(3-1)).
The interior of the building was illuminated by borrowed daylight using patios (Fig.3-2)) and (Fig.(3-3)).

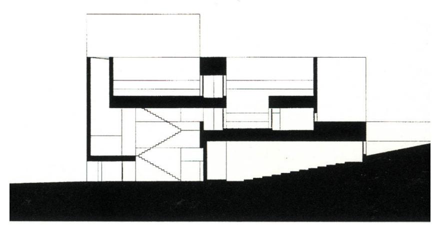


Fig.(3-3)
Faculty of Journalism-section
Cerver, Francisco Asensio, "Architecture of Minimalism", 1997 P.80

(1) Cerver, Francisco Asensio, "Architecture of Minimalism", 1997 P.P 76-87

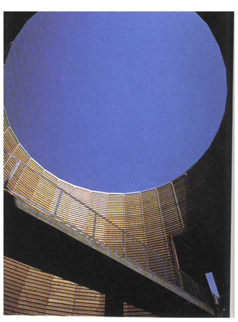
(3-1-3-2) Aluminum Insulated Mass – Communications Science Faculty:

Fig.(3-4)
Communications Science Faculty-operable louvers
Cerver, Francisco Asensio, "Architecture of Minimalism", 1997 P.66

The Communications Science Faculty, Barcelona, Spain by Varis architects who used insulated aluminum sheets for external walls, the opacity of the building can be changed where some of the horizontal aluminum panels are operable to admit desirable illumination and changing the overall Û value of the walls.(Fig.(3-4)).

(3-1-3-3) Wooden Mass – Museum of Wood:

The Museum of Wood, Mikata-gun, Hyogo, Japan by the architect Tadao Ando used timber planks in the exterior and courtyard walls, (Fig.(3-5)) and Fig.(3-6)), where the building Fabric, besides its solar control function, gives a homogenous integration with the surrounding forest.
"The buildings woodland location, its construction, and the elemental nature of the display, emphatically connect place, nature and resource."(1)



(left) Fig.(3-5)
Museum of Wood-court

(right) Fig.(3-6)
Museum of Wood-exterior

Jones, David Lloyd, " Architecture and the environment ", 1998 P.66

(1) Jones, David Lloyd, " Architecture and the environment ", 1998 P.66

(3-1-3-4) Stony Mass – Mit Rehan Villa:

- The Mit-Rehan villa, Sakkara, Egypt, by the architect Hassan Fathy (1980-1981) is one of the contemporary architectural examples making use of limestone as a protective shell of the building, the house is characterized by its massive solid walls (500 mm thick) and its reliance on a large thermal mass clustered around a courtyard to provide sufficient protection against the hot dry weather of the region.[1] (fig. (3-7))

Fig.(3-7)
Mit-Rehan Villa
http://arch.ced.berkeley.edu/vitalsigns/workup/two_houses/two_method.html

(3-1-3-5) Mud Brick Mass – The New Gourna Village:

- The village of New Gourna, which was partially built between 1945 and 1948, is possibly the most well known of all of Hassan Fathy's projects.
- Hassan Fathy designed the village using traditional Nubian building methods of mud-brick walls, vaults and simple domes. It includes housing, a mosque, and a cultural center.
- Besides its traditional taste, and giving the possibility of participation of the occupants in construction, the mud as a building material represented a suitable treatment to the external envelope of the buildings, small openings were used in the facades to resist severe hot weather.[2] (fig.(3-8))

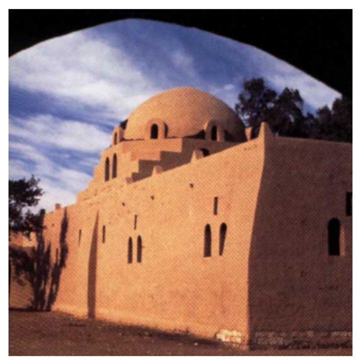


Fig.(3-8)
New Gourna Village - Mosque
http://www.geocities.com/egyptarchitect1/hasanfathi/ngourna/gmosque1.htm

(1)Vital Signs, “A Tale of Two Buildings” http://arch.ced.berkeley.edu/vitalsigns / workup /two _houses/two_ method.htm l- accessed 25/6/2003
(2) http://www.geocities.com/egyptarchitect1/hasanfathi/ngourna/gmosque1.htm-accessed 20/2/2003

(3-1-4) Building Material Efficiency with respect to Solar Radiation

The quantitative thermal performance of the building materials depends upon its U-value, where table [3-1a] illustrates different U values for some masonry and manufactured building materials. (1)

	Wall Material	U-value
1	25 cm solid brick - no finish	1.87
2	30 cm solid brick + plaster on lathe	1.22
3	12 cm solid brick - no finish	3.74
4	17 cm solid brick + plaster on lathe	2.44
5	Hollow clay tile 10cm	5
6	Hollow clay tile 15cm	3.7
7	Hollow clay tile 20cm	3
8	Poured concrete, 15 cm	1.75
9	Poured concrete, 20 cm	1.4
10	Poured concrete, 25 cm	1.19
11	Poured concrete, 30 cm	1.02
12	Hollow concrete blocks 20cm	5.6
13	Wood 2.5 cm	3.6
14	Wood 5 cm	1.8
15	Plywood 12mm	9
16	Mineral fibers batts 9cm	0.5
17	Mineral fibers batts 15cm	0.3
18	Stone 40 cm	1.15

The Housing & Building Research Centre in Egypt published a special code for energy efficient residential buildings including the standard values of thermal conductivities of typical building materials and insulation commonly used in Egypt.

Table [3-1b] shows these values for different building materials having different thickness: (2)

(1) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.121,122, and Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point", 1997, P. 10 & Newly Revised ASHRAE 90.1 Standard Addresses the Thermal Performance of Metal Building Envelopes, www.insulatemetalbuildings.com – accessed 14/12/2003

(2) Housing Building & Research Centre, Arab Republic of Egypt "Energy Efficiency Residential Building Draft Code (EERBC)", June 2003, p.85, p.86.

	Description	(k) (W/m^2 C)	Density (Kg/m^3)	Thermal Resistance for Different Thickness (mm) , (R-Value) (m2.°C/W)				
1- Bricks				120	150	200	250	380
1.1	Clay Bricks	0.6	1850	0.37	0.42	0.50	0.59	0.8
1.2	Solid Cement Bricks	1.4	2000	0.26	0.28	0.31	0.35	0.44
1.3	Heavy Sand Bricks	1.7	2000	0.24	0.26	0.29	0.32	0.39
1.4	Light Sand Bricks	0.35	650	0.51	0.6	0.74	0.88	1.26
1.5	Clay & Hollow	0.6	1790	0.37	0.42	0.5	0.59	0.8
1.6	Cement & Hollow	1.6	1140	0.25	0.26	0.3	0.33	0.41
2-Tiles				10	20	30		
2.1	Cement Tiles	1.4	2100	0.18	0.18	0.19		
2.2	Ceramic Tiles	1.6	2000	0.18	0	0		
2.3	PVC	0.16	1350	0.23	0	0		
2.4	Rubber Tiles	0.4	1700	0.2	0	0		
2.5	Mosaic Tiles	1.6	2450	0.18	0.18	0.19		
3-Woods				10	20	30	40	50
3.1	Beech	0.17	700	0.23	0.29	0.35	0.41	0.46
3.2	Spruce	0.10	415	0.27	0.36	0.46	0.55	0.65
3.3	Oak	0.16	770	0.23	0.3	0.36	0.42	0.48
3.4	Mahogany	0.15	700	0.23	0.3	0.36	0.43	0.49
3.5	Pitch Pine	0.14	660	0.24	0.31	0.38	0.46	0.53
3.6	Plywood	0.14	530	0.24	0.31	0.38	0.46	0.53
3.7	Chip Board	0.17	400	0.23	0.29	0.35	0.41	0.46
Gypsum & Cement Materials				20	30	40	50	60
4.1	Gypsum	0.15	320	0.3	0.37	0.44	0.5	0.57
4.2	Gypsum Boards	0.39	950	0.22	0.25	0.27	0.3	0.32
4.3	Portland Cement	0.17	1335	0.28	0.34	0.4	0.46	0.51
Stones				120	150	200	250	380
5.1	Sand Stone	1.6	1800	0.25	0.26	0.3	0.33	0.41
5.2	Lime Stone	0.79	1600	0.32	0.36	0.42	0.49	0.65
Insulation				20	40	60	80	100
6.1	Expanded Polystyrene	0.034	35	0.76	1.35	1.93	2.52	3.11
6.2	Expanded Polystyrene	0.03	30	0.84	1.5	2.17	2.84	3.5
6.3	Polystyrene Beads	0.045	15	0.61	1.06	1.5	1.95	2.39
6.4	Polyurethane	0.026	30	0.94	1.71	2.48	3.25	4.02
6.5	Perlite Loose	0.055	120	0.53	0.9	1.26	1.62	1.99
6.6	Vermiculite Loose	0.065	100	0.48	0.79	1.09	1.40	1.71
6.7	Vermiculite Cement	0.22	650	0.26	0.35	0.44	0.53	0.62
6.8	Celton	0.17	480	0.29	0.41	0.52	0.64	0.76

(3-2) Building Glazing

- The function of windows in any building is to admit daylight in, however, the entrance of solar radiation inside the building may cause undesired heating effect.

- The different ratios of light to heat transmissions characterizing different types of glazing are achieved by modifying the amounts of different ranges of solar spectrum, passing through the window pane.

- This part will study different kinds of glazing showing their performance with respect to solar radiation.

(3-2-1) Definitions:

(3-2-1-1) The Shading Coefficient (Sc):
It is the ratio of the total solar transmittance of a given glazing type to that of a single pane of clear glass. (1)

i.e.:

$$Sc = \frac{\text{Solar Transmittance of a given Glazing}}{\text{Solar Transmittance of a Single Pane Clear Glazing}}$$

------- {3-4}

(3-2-1-2) The Ke Factor:
It is an absolute numerical factor, showing the ratio of visible transmittance to the shading coefficient. (2)

i.e.:

$$Ke = \frac{\text{Visible Transmittance of a given Glazing}}{\text{Shading Coefficient of that glazing}}$$

------- {3-5}

N.B. In addition to Sc and Ke, the U and R values can be used to classify the glazing type with respect to its performance regarding solar radiation.(3)

---

(1) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.58
(2) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.58
(3) Refer to chapter III, (3-2-3)

(3-2-2) Glazing Performance with respect to Solar Radiation:

(3-2-2-1) Reflection, Absorption and Transmittance:

- When solar radiation hits a window glass, it is divided into three fractions: (Fig. (3-9))

The first part is reflected outwards without any effect on the building's temperature.
The second part is absorbed by the window pane itself, rising its temperature, leading to the emission of long wave infra red radiation, half of this radiation is radiated towards the inside of the building, and the other half towards the outside.
The third portion is transmitted through the glazing into the building.

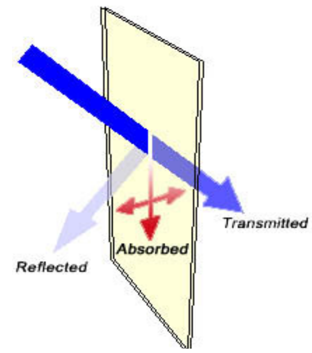


Fig.(3-9)
Fractions of Solar Radiation with Respect to Window Pane
www.squ1.com

- The relative proportion of the three components depends upon:

- The type of glass.
- The angle of incidence of radiation"[1]

- Fig.(3-10) shows the proportions of reflection, absorption and transmission for a single sheet of ordinary glass with respect to angle of incidence of solar radiation.

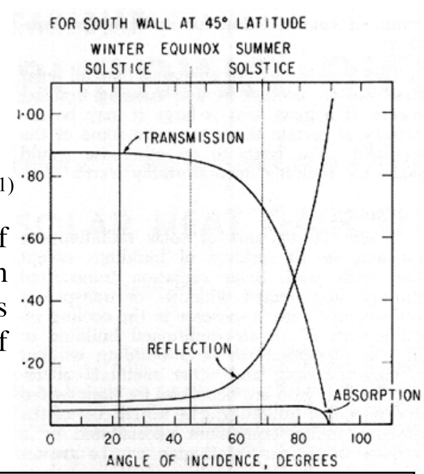


Fig.(3-10)
Incidence Angle and Fractions of Solar Radiation with Respect to Window Pane
D. G. Stephenson, Canadian building digest, CBD-39. "Solar Heat Gain Through Glass Walls",2002, p.2

(1) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.58

(3-2-2-2) Green House Effect:

- One of the most significant properties of the glass is its opacity towards the long wave radiation from the inside, leading to the green house effect, which causes excessive rise in the room temperature that becomes very effective in the absence of heat loss by convection with the surrounding ambient air. (Fig.(3-11))
- This property is treated using special kinds of glazings so as to limit the undesirable effects causing human uncomfortable conditions. (1)
  However, the green house effect was used by the scientists and engineers in thermal power plants, working on the principle of thermodynamics (Fig.(3-12)).
- Architects also forced many strategies making use of the green house property, one of these strategies is the double wall glazing, used in the Hooker Building, Buffalo, New York, 1981 where the trapped air between the two glazed elevations rise in temperature, and finds its way out through special vents carrying heat away, to be replaced from the bottom with cool fresh air, thus reducing cooling loads.(2) (Fig.(3-13))

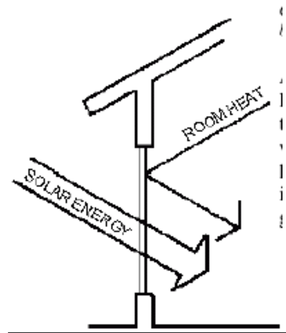


Fig.(3-11)
Green House Effect
Pacific Energy Center
Factsheet: Energy-Efficient
Window Glazing Systems
http://www.pge.com/pec

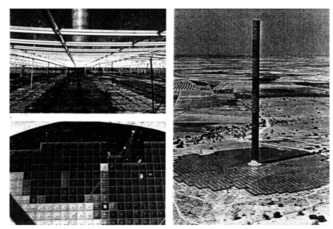


Fig.(3-12)
Solar Power Plants
Behling, Sophia & Stephen,
"The Evolution of Solar
Architecture"1996 , p.197

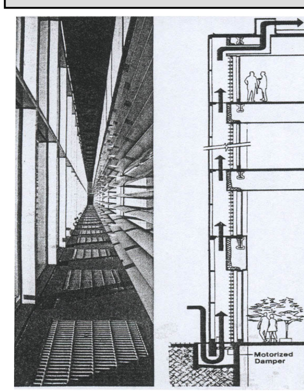


Fig.(3-13)
The Hooker Building
Behling, Sophia & Stephen,
"The Evolution of Solar Architecture"1996
p.202

(1) Refer to chapter 3 (3-3)
(2) Behling, Sophia & Stephen, "The Evolution of Solar Architecture"1996 , p.202

(3-2-3) Kinds of Glazing:

- Proper glazing selection can reduce a building's energy use throughout the year, electric lighting requirements can be reduced by designing windows to take advantage of natural daylight. For buildings with significant cooling loads, special glazings can reject excessive summer solar heat.

- The solar spectrum can be divided into three components: (1)

    - The ultraviolet radiation; having wave length below 0.4 microns.
    - The visible spectrum; having wave length from 0.4 to 0.7 microns.
    - The infrared radiation; having wave length from 0.7 up to 2.5 microns.

  "About 45 percent of the solar radiation energy is at its visible wavelengths; the rest is invisible. To minimize cooling loads, it is desirable to transmit as much visible energy as desired for application, while rejecting the rest of the solar radiation. Such a window has a high visible transmittance and a low shading coefficient." (2)

- The efficiency of the glazing can be improved by applying more than one layer of glass panes, double and triple glazing filled with grasses, such as and argon krypton, improve the window's thermal resistance.

- The glazing could be broadly classified into two groups:

    - Static selective glazing.
    - Dynamic selective glazing (Switchable glazing).

---

(1) Refer to chapter 2
(2) Pacific Energy Center, "Energy Efficient Window Glazing Systems", a Pacific Energy Center factsheet, 2002, P.1, www.pge.com.pec – accessed 20/2/2003

(3-2-3-1) Static Selective Glazing:

(A) Definition

These are kinds of glazings, having static selective property with respect to solar radiation, with fixed proportions according to the needs of the architectural design.

(B) Kinds of Static Selective Glazing:

a. Tinted Glazing: [1]

It is sometimes called absorbing glass, having energy absorbing material within it, lowering the shading coefficient and giving a tint, generally bronze, gray, blue or green.

b. Reflective Glazing: [2]

It has better shading coefficient than tinted glazing, because it reflects rather than it absorbs most of the infra-red heat, the reflective layer is made of thin layers of metals or metallic oxides.

c. Applied Films: [3]

It is a multilayer adhesive which is attached to the inner surface of the glazing, darkening it and giving it a mirror like appearance (Fig.(3-14)).

d. Low-E Glazing: [4]

It is produced by coating the glass with a layer of selective low emissive long wave radiation, which reduces radiant heat loss from the glazing.

e. Spectrally Selective Glazing: [5]

"Tinted glazing and some low-E glazing types are spectrally selective to a small degree, the new generations of spectrally selective glazing are designed to exaggerate the difference between the visible and the infrared radiation." (Fig.(3-15)).

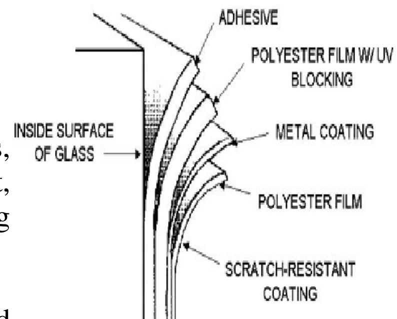


Fig.(3-14)
Applied Films
Pacific Energy Center, "Energy Efficient Window Glazing Systems", a Pacific Energy Center factsheet, 2002, P.2, www.pge.com.pec org

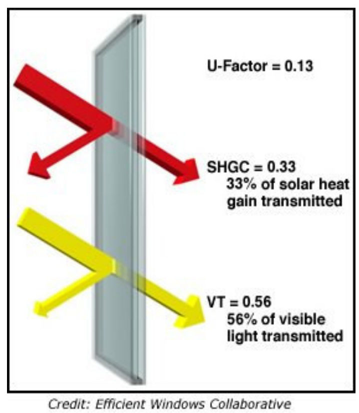


Fig.(3-15)
Spectrally Selective Glazing
http://www.advancebuildings.org

(1),(2),(3) Pacific Energy Center, "Energy Efficient Window Glazing Systems", a Pacific Energy Center factsheet, 2002, P.2, www.pge.com.pec, accessed 20/2/2003.
(4) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.60
(5) "Spectrally-Selective Glazings", http://www.advancebuildings.org ,accessed 2/2003.

(C) Advantages and Disadvantages of Static Selective Glazing: [1]

a. Advantages:

- Tinted, reflective and spectrally selective glazing can all reduce solar heat gains significantly.

- Spectrally selective glazing let in most visible light, providing the greatest day lighting opportunity.

- Tints and reflective glazing can give the building a pleasing appearance.

- Applied films reduce solar heat, glare and U.V., they are also available in non-scratchable new generations.

b. Disadvantages:

- Tints alone achieve a modest shading coefficient, because some of the heat absorbed eventually, is transferred into the space in the form of long wave infrared heat radiations.

- Reflective glazing may cause increased lighting requirements because of its very low light transmittance.

- Spectrally selective glazing can produce problems with glare, particularly in rooms with computer screens.

(1) March, Andrews and Raines, Caroline, "Square One", www. Squ1.com, accessed 10/2002

(3-2-3-2) Dynamic Selective Glazing (Switchable Glazing): [1]

(A) Definition

These are window glazings with optical/solar properties that vary according to voltage, light or heat.

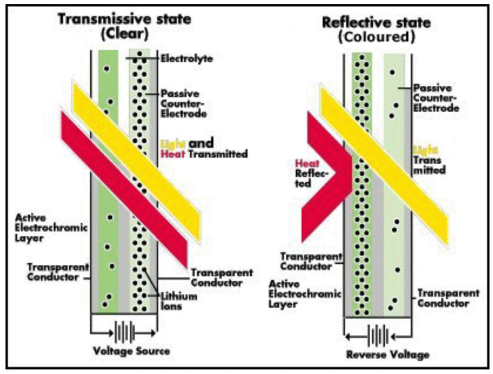


Fig.(3-16)
Switchable Glazing
http://www.advancebuildings. org

(B) Description of Switchable Glazing:

- This is a new generation of smart glazing, used in office, retail, foodservice and institutional buildings.
- Switchable glazings have two states; colored and bleached. In the colored state, light and solar heat are reflected from the window. In the bleached state, they are transmitted through the window. (Fig (3-16))
- This kind of glazing is based on the technology of photochromic, thermochromic or electrochromic performance, where computer simulation results recommended the electrochromic-based technology type.

(C) Advantages and Disadvantages of Switchable Glazing:

a. Advantages:

- Reducing cooling loads.
- Reducing glare.
- Increasing visual comfort and privacy.

b. Disadvantages:

- High cost.
- No residential switchable glazing is available.
- Having a lifetime of stability in performance after which they should be exchanged.

---

(1) "Switchable glazing" http://www.advancebuildings.org, accessed 2/2003

(3-2-4) Glazing Efficiency with respect to Solar Radiation:

The quantitative thermal performance of the glazing depends upon its U-value in addition to its shading coefficient. Table [3-2] illustrates these values for a number of single and double glazing types [1]

	type	U	Sc
1	**Single clear**	6	0.82
2	**Single-reflective-bronze**	6	0.2
3	**Single-tinted-bronze**	6	0.57
4	**Single-tinted-green**	6	0.56
5	**Single low-E (bronze)**	4.6	0.42
6	**Single low-E (clear)**	4.6	0.66
7	**Single low-E (green)**	4.6	0.41
8	**Double clear**	3	0.65
9	**Double-tinted (bronze)**	3	0.48
10	**Double-tinted (green)**	3	0.46
11	**Double-tinted (gray)**	3	0.45
12	**Double, Reflective**	3	0.16
13	**D. low-E, clear**	2.3	0.45
14	**D. low-E,(bronze)**	2.3	0.35
15	**D.low-E, (green)**	2.3	0.37
16	**D. low-E (gray)**	2.3	0.34

(1) Brown,G.Z and Dekay, Mark, "Sun, Wind and Light",2000, p.48.

(3-3) Shading Strategies

- The shading strategies are one of the most important methods to overcome the undesired direct solar radiation, which increases the building internal temperature, especially in hot arid regions.

- "The control of the solar radiation is an important part of the building's design. In a relatively hot climate it represents one of the most significant sources of potential summer heat gains. Even in a relatively cold climate, direct solar radiation can be a source of extreme local discomfort, equivalent to 1000 W. electric bar radiation for every square meter of exposed window".[1]

- The use of appropriate shading method is very important, especially within air conditioned buildings, where proper shading greatly reduces what is essentially a needless waste of energy, trying to cool a space with large areas of unprotected glazing.

- There are two main kinds of shading; external shading and internal shading. For the external shading,, there is a further classification into fixed and operable shading devices.

- This part will study these kinds of shading devices, showing their performance with respect to heat gain.

(1) March, Andrews and Raines, Caroline, "Square One", www. Squ1.com,accessed 10/2002

(3-3-1) Internal Shading Devices:

Although both internal and external shades are effective in solar control, however, external shading is better because they block the solar radiation before passing through glazing, on the other hand internal shading devices block them after passing through the glazing.

(3-3-1-1) Performance of Internal Shading Devices: [1].

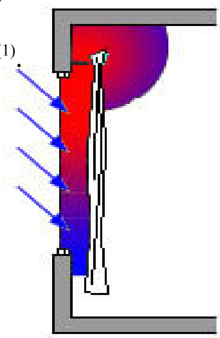


Fig.(3-17)
Performance of curtains as internal shading devices
March, Andrews and Raines, Caroline, "Square One", www. Squ1.com

- According to the behavior of the glass with respect to solar radiation the heat gained by the curtain will be emitted as long wave radiation, half to the room, and the other half towards the space between the glass pane and the curtain.
- Since the glass is opaque to the long wave radiation from the inside, the heat will be trapped at that space, rising the air temperature between the curtain and the window.
- Cooler air will be withdrawn from the bottom of the curtain to replace the hot air at that zone, which in return finds its way out towards the ceiling, rising the temperature of the space as a whole (Fig.(3-17)).
- There are two methods to improve the performance of internal shades:
  a. Using long curtains extending down to rest on the floor, thus blocking the previous air circulation.
  b. Using double glazed unit with vents at the top and the bottom of the external leaf (Fig.(3-18))

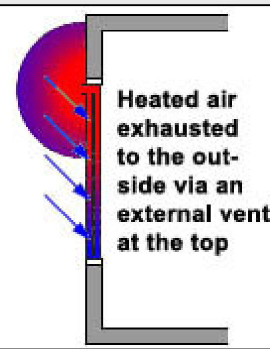


Fig.(3-18)
Double Glazed Unit with Vents
March, Andrews and Raines, Caroline, "Square One", www. Squ1.com

(1) March, Andrews and Raines, Caroline, "Square One", www. Squ1.com,accessed 10/2002

(3-3-1-2) Kinds of Internal Shading Devices: [(1)].

Fig.(3-19)
Curtains and Drapes
www.squ1.com

a. Curtains and Drapes:
Curtains and drapes made of tightly woven, light-colored, opaque fabrics reflect more of short-wave solar radiation back out the window than they let through.
The tighter the curtain is against the wall, the better it will prevent heat gain.
Two layers improve the effectiveness of the draperies insulation when it is either hot or cold outside.(fig.(3-19))

Fig.(3-20)
Venetian Blinds
www.squ1.com

b. Venetian Blinds
Although they are not as effective as drapes, they can be adjusted to control light and air movement while reflecting some of the heat.
Some newer blinds are coated with reflective finishes on the side facing the window to increase their effectiveness. (fig.(3-20))

Fig.(3-21)
Cellular Shades
www.squ1.com

c. Cellular Shades
This kind of shading is constructed from two layers of material with an air gap between them, this allows them to be raised and lowered easily, increasing the overall window resistance.
When fully drawn, these shades block the majority of natural light, and restrict air flow. (fig.(3-21))

d. Roller Blinds
Opaque roller blinds are simply a thin sheet of material that unrolls down behind the window to reduce direct sun penetration.

(1) March, Andrews and Raines, Caroline, "Square One", www. Squ1.com,accessed 10/2002

(3-3-2) External Shading Devices:

This is a more efficient tool widely used by architects as an integral part in their façades, it was recommended by the masters of architecture especially by Le Corbusier who was popular for his "Brise Soleils".[1]

External shading devices can be divided broadly into two types:

- Fixed shading.
- Operable shading.

(3-3-2-1) Fixed External Shading:

- This kind of shading is characterized by its being a part of the building mass, accordingly, it needs no adjustment or maintenance by users.

- This kind of shading is designed using the shading mask method previously mentioned in “Chapter II” [2], where they are plotted on the sun path stereographic diagram detecting times and dates of blocking and admitting sun rays inside the building space.

- Mainly, there are 3 kinds of fixed external shading:
  - A. Horizontal shading.
  - B. Vertical shading (fins).
  - C. Overhang shading.

- Where it is desirable to use horizontal shading for the southern façades (in the northern hemisphere), and vertical fins for the eastern and western façades.

---

(1) Refer to Chapter (1) (1-8-1)
(2) Refer to Chapter II (2-1-2-2)

Fig.(3-22)
Vice Chancellor's Office
Jones, David Lloyd, " Architecture and the environment ", 1997

A. Horizontal Shading:

The horizontal shading is recommended in case of southern facades, (northern facades in the southern hemisphere) , where the sun path in the sky is high enough to make them cast their shadows effectively most of the time of exposure to direct solar radiation.

Example: Vice Chancellor's Office, Martinique, French West Indies, 1994, by the architects Christian Hauvette and Jerome Nouel. (fig.(3-22))

B. Vertical Shading:

The vertical shading is recommended in case of eastern and western facades, as the sun path in the sky is still low enough to make the vertical shading more effective than horizontal shading, where they can have certain inclination with respect to the building's façade to block the sun and admit the desirable illumination.

Example:. Office building, Athens, Greece., Architects: A. N. Tombazis and Associates,1998

"The main design feature is the building's east facade, which is shaded by vertical glass silk-screen-printed panels providing a shading coefficient of 70%. The blinds rotate automatically in response to solar radiation, thus protecting the building from unwanted heat gains, but providing adequate day lighting throughout the day." [1] (fig.(3-23))

Fig.(3-23)
AVAX S.A. Headquarters, Athens, Greece.
http://www.jxj.com/magsandj/rew/2001_06 urban_reality.html

(1)Renewable Energy World, "Urban reality- solar design and refurbishment", http://www.jxj.com/magsandj/rew/2001_06/urban_reality.html- accessed 19/2/2004

C. Integrated Horizontal and Vertical Shading:

In some cases, an integrated shading system consisting of both horizontal and vertical devices may be needed, specially in case of inclined surfaces, or in case the building is oriented towards south east, or south west.

Examples:

- Spring Lake Park Visitors' Center, Santa Rosa, California, USA, 1992, by the architect Obie G. Bowman. (fig.(3-24),(3-25))
- Millowners' Association Building, Ahmedabad, India,1952 , Le Corbusier (fig(3-26)

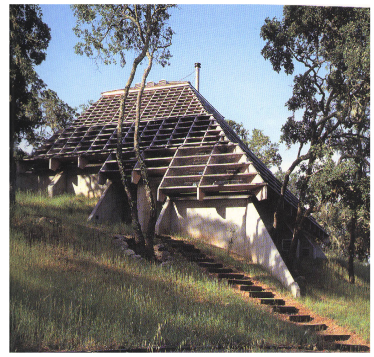


Fig.(3-24)
Spring Lake Park Visitors Center (exterior)
Jones, David Lloyd, " Architecture and the environment ", 1997

Fig.(3-26)
Millowners' Association Building
http://www3.bk.tudelft.nl/scripts/architectuur/agram/fcard.asp

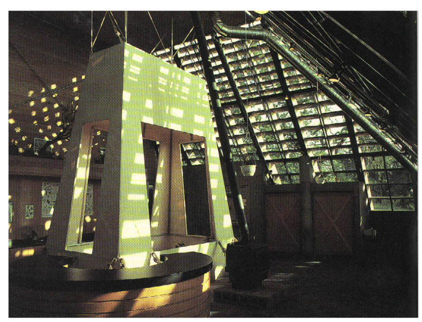


Fig.(3-25)
Spring Lake Park Visitors Center (interior)
Jones, David Lloyd, " Architecture and the environment ", 1997

D. Overhang Horizontal Shading:

- "During the summer at temperate latitudes, or year round at tropical latitudes, sun is high enough in the sky for much of the day, that horizontal overhead shading devices are more effective at shading outdoor space than vertical ones or from building mass".(1)
- Because sun changes its position throughout the day, the overhang shading must be larger than the outdoor room.

Examples:

a. Hiss Residence, Sarasota, Florida, designed by Paul Rudolph using the previous shading strategy where the overhang shading extends over the whole building, (fig.(3-27)).

b. The Roof –Roof house, Malaysia by the architect Ken Yeang, makes use of an overhang shade covering the original roof to reduce solar heat gains, (fig.(3-28)).

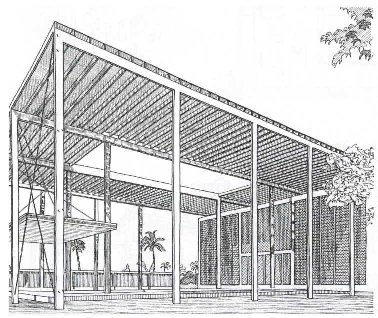


Fig.(3-27)
Hiss Residence
Brown, G.Z and Mark, Dekay "Sun, Wind and Light", 2000, P.142

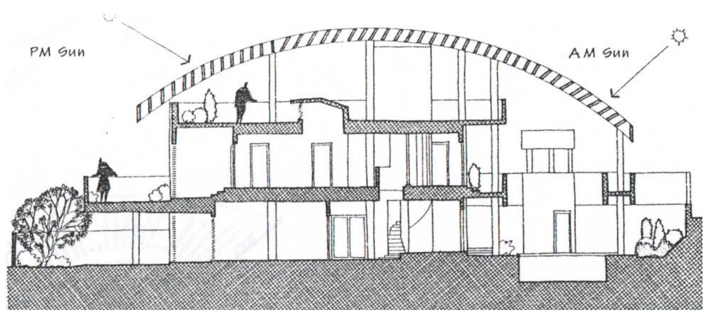


Fig.(3-28)
Roof-Roof House
Brown, G.Z and Mark, Dekay "Sun, Wind and Light", 2000, P.165

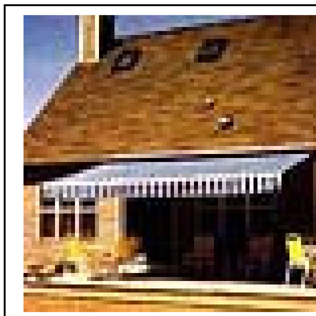
(1) Brown, G.Z and Mark, Dekay "Sun, Wind and Light", 2000, P.142

(3-3-2-2) Operable External Shading:

- This kind of shading devices has the advantages of the internal shading devices, being interactive with the occupants and adjustable according to their needs, also they block the solar radiation before entering through the window pane as in the case of fixed external shading devices, however, they need continuous maintenance to keep their performance and appearance in good condition.
- Exterior shading devices include awnings, shutters, rolling shutters, and louvers.

A. Awnings:[1]

- Awnings are effective because they completely block direct sunlight. They are usually made of fabric or metal and are attached above the window and extend down and out. A properly installed awning can reduce heat gain by up to 65% on south-facing windows and 77% on eastern windows. A light-colored awning also reflects sunlight so, it can help to reduce radiant temperatures immediately outside the window.



Fig(3-29)
Awnings as external operable shading device
www.squ1.com

- Maintaining a gap between the top of the awning and the side of the building helps vent accumulated heat from under a solid-surface awning. In a climate with cold winters, it may be desirable to remove awnings for winter storage, or to install retractable ones to maximize winter heat gains.

- One disadvantage of awnings is that they can block the view from inside, particularly on the east and west sides. However, slatted awnings do allow limited viewing through the upper parts of windows.

(1) March, Andrews and Raines, Caroline, "Square One", www. Squ1.com,accessed 10/2002.

B. Shutters:[1]

Shutters are movable wooden or metal coverings that, when closed, keep sunlight out. Shutters are either solid or slatted with fixed or adjustable slats. Besides reducing heat gain, they can also provide privacy and security. Some shutters help insulate windows when it is cold outside.
This method is widely spread in Egypt, where it gained popularity due to its economical cost and effectiveness.

Fig.(3-30)
Shutters as external operable shading device
www.squ1.com

C. Roller Shutters:[2]

Roller shutters have a series of horizontal slats that run down along a track. These are the most expensive shading options, but they work very well and provide excellent security. Many exterior rolling shutters or shades can be conveniently controlled from the inside. The disadvantage, however, is that they block all light and view when fully extended.

Fig(3-31)
Roller Shutters as external operable shading device
www.squ1.com

D. Louvers:[3]
Louvers are attractive because their adjustable slats control the level of sunlight entering the building and, depending on the design, can be manually adjusted from inside or outside. The slats can be vertical or horizontal. Louvers remain fixed and are attached to the exteriors of window frames. Careful attention to the louver angle can allow significant winter sun penetration whilst still excluding all sun in summer.

Fig(3-32)
Louvers as external operable shading device
www.squ1.com

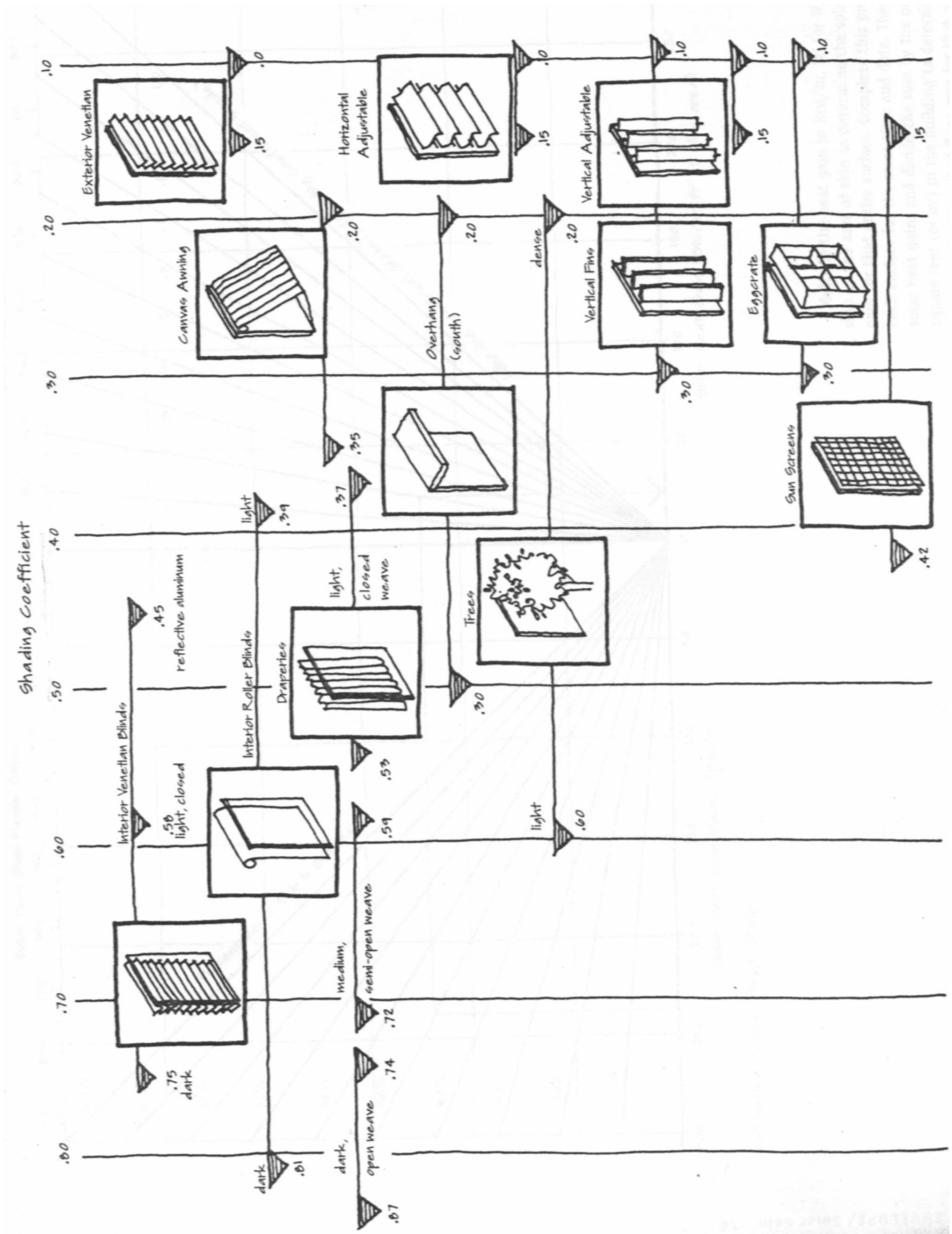
(1),(2),(3) March, Andrews and Raines, Caroline, "Square One", www. Squ1.com,accessed 10/2002

(3-3-3) Shading Efficiency with respect to solar radiation:

- The efficiency of a shading device regarding its quantitative thermal performance is measured by its shading coefficient (Sc) [(1)] .
- Table[3-3] shows the shading coefficients(Sc) for a number of external and internal shading devices.[(2)]

		Shading type	Sc
External Shading	1	Exterior Venetian	0.1
	2	Horiz. Adjustable	0.1
	3	Vertical Adjustable	0.1
	4	Vertical Fins	0.3
	5	Eggcrate (narrow)	0.1
	6	Eggcrate (Wide)	0.3
	7	Canvas Awning (light)	0.2
	8	Canvas Awning (Dark)	0.35
	9	Mashrabia (narrow)	0.15
	10	Mashrabia (wide)	0.42
	11	Overhang	0.2
	12	Trees (dense)	0.2
	13	Trees (medium)	0.4
	14	Trees (light)	0.6
Internal shading	15	Venetian Blinds(ref.)	0.45
	16	Venetian Blinds(light)	0.58
	17	Venetian Blinds(dark)	0.75
	18	Roller Blinds (light)	0.39
	19	Roller Blinds (medium)	0.6
	20	Roller Blinds (dark)	0.81
	21	Draperies (light)	0.4
	22	Draperies (medium)	0.65
	23	Draperies (dark)	0.8

(1) After Brown, G.Z and Dekay Mark, "Sun, wind and Light", 2000, P. 49, and Olgyay, Victor, "Design with Climate", 1963, p.p. 67 - 71
(2) Brown, G.Z and Dekay Mark, "Sun, wind and Light", 2000, P. 49



Fig(3-33)
Shading coefficients for different internal and external shading devices
Brown, G.Z and Dekay Mark, "Sun, wind and Light", 2000, P. 49

(3-4) Building Compactness

- The main impact of the layout from the indoor climate point of view is its effect on the envelope's surface area, relative to the floor's area, or the space volume, and hence, the rate of heat exchange of the building with the outdoors, also, the building's potential for natural ventilation and natural illumination.[1]

- This research is interested in the effect of the building's layout on the rate of heat gains from the external envelope.

- The more compact the building's plan, the smaller the exposed surface area of the walls or the roof, for a given volume or floor area of the building, as a result, the heat exchange with the surrounding environment is decreased.

- In case of air conditioned buildings, a smaller exposed surface area of the building, the less energy needed for cooling or heating.

- A very significant feature that accompanies the compact plans in many cases is the presence of courtyards or patios for the sake of borrowed daylight through glazing without being exposed to direct solar radiation.

- On the other hand, a loose elongated layout may be needed in some cases. "Long east-west plan arrangements increase winter-sun facing skin available to collect solar radiation" [2]

- This part will study different architectural examples for compact and elongated layouts.

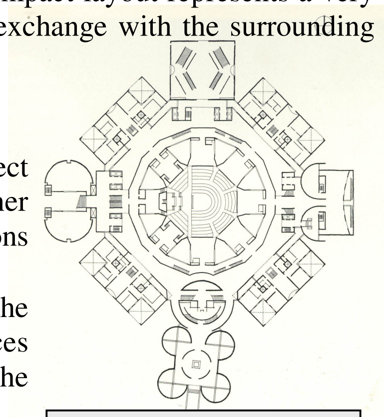
(1) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.50
(2) Brown, G.Z and Mark, Dekay "Sun, Wind and Light", 2000, P.153

(3-4-1) Compact Layout and Decreasing Heat Exchange:

For both hot and cold conditions, a compact layout represents a very effective design strategy that limits heat exchange with the surrounding environment.

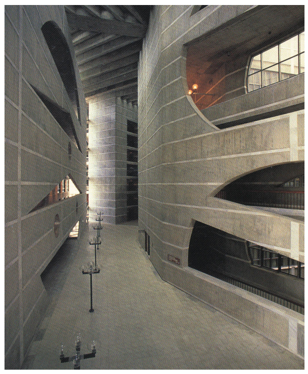
(3-4-1-1) National Assembly Building Dacca, Bangladesh, Louis Khan, 1979: [1]

- The compact layout of the project reflects the awareness of the designer with the severe hot climatic conditions of Bangladesh. (Fig (3-34)).
- This compactness, together with the nearly opaque building mass reduces greatly heat exchange with the surroundings (Fig (3-35)).
- The pedestrian paths inside the buildings are completely shaded and trapped between the masses of the building, where they are illuminated by borrowed sunlight, (Fig (3-36)).



Fig(3-34)
National Assembly Building (plan)
Steele, James "Architecture for Islamic Societies Today", 1994, P.P 127-137

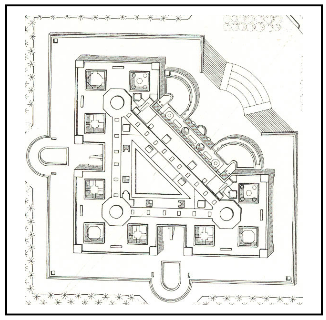
Fig(3-35)
National Assembly Building (Exterior)
Steele, James "Architecture for Islamic Societies Today", 1994, P.P 127-137



Fig(3-36)
National Assembly Building (Interior)
Steele, James "Architecture for Islamic Societies Today", 1994, P.P 127-137

(1) Steele, James "Architecture for Islamic Societies Today", 1994, P.P 127-137

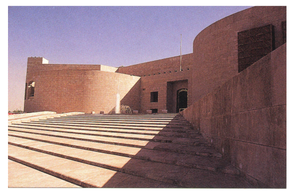
(3-4-1-2) Ministry of Foreign Affairs, Riyadh, Saudi Arabia, Hennings Larsen, 1984: (1)



Fig(3-37)
Ministry of Foreign Affairs (plan)
Steele, James "Architecture for Islamic Societies Today", 1994,.P 120

- This is another architectural example making use of compact plan strategy together with a traditional feature of the Islamic architecture, which are spread all over the building (9 courtyards) (Fig(3-37)), these shaded courtyards are used to illuminate internal spaces, where the external façade is completely opaque (Fig(3-38)).

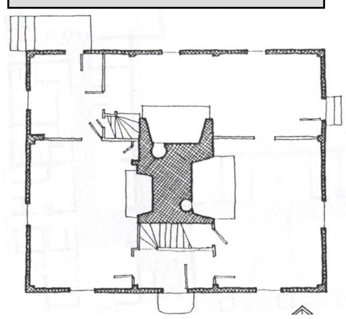
- This main triangular entrance space is covered and surrounded by the other spaces for further insulation.



Fig(3-38)
Ministry of Foreign Affairs (exterior)
Steele, James "Architecture for Islamic Societies Today", 1994, P 117

(3-4-1-3) Old Ogden House, Fair Field, Connecticut: (2)

- This example differs from the previous two buildings, because it uses the same strategy of compact plan, but in this case for cold climate.
"Rooms are contracted into a compact form, in which they are surrounded by a central heat source, when the house fronts the south; it has the large windows to collect the sun, the kitchen is on the coldest north side". (Fig(3-39))



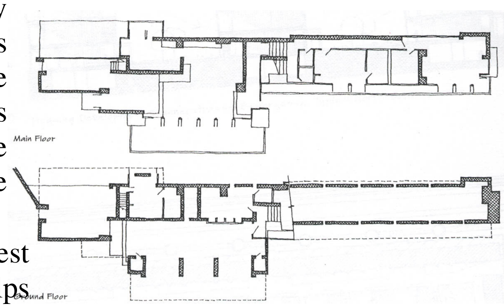
Fig(3-39)
Old Ogden House (plan)
Brown, G.Z. and Dekay Mark, "Sun, wind and Light", 2000, P.145

(1) Steele, James "Architecture for Islamic Societies Today", 1994, P.P 117-123
(2) Brown, G.Z. and Dekay Mark, "Sun, wind and Light", 2000, P.145

(3-4-2) Elongated East-West Plan for Solar Radiation Collection:

(3-4-2-1) Lloyd Lewis House, Illinois, Frank Lloyd Wright:

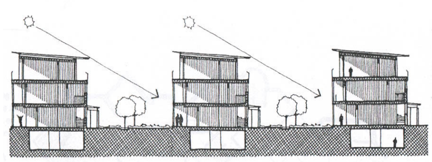
- The amount of south facing skin, and thus the opportunity for solar collection is increased by organizing the rooms along an east-west axis facing the south, whilst the circulation is located on the northern side.
- "The size of east and west façades is reduced, which helps to lower the unwanted solar heat gain in summer, when the sun rises further east and sets further west than it does in winter." (1) (Fig (3-40)).



Fig(3-40)
Lloyd Lewis House (plan)
Brown, G.Z., and Dekay Mark, "Sun, wind and Light", 2000, P.153

(3-4-2-2) Housing Development, Brunnerstrasse, Vienna, Austria: (2)

The buildings are organized in the form of twelve fingers of three storey south facing row houses (Fig(3-41)). The south facing units are heated by the combination of direct solar heat gain and sunspaces.



Fig(3-41)
Brunnerstrasse Housing (section)
Brown, G.Z., and Dekay Mark, "Sun, wind and Light", 2000, P.154

(1) Brown, G.Z., and Dekay Mark, "Sun, wind and Light", 2000, P.153
(2) Brown, G.Z., and Dekay Mark, "Sun, wind and Light", 2000, P.154

(3-5) Building Color

- The color of the building represents a very effective factor in the process of heat gain from solar radiation.

- Any colored surface tends to absorb a fraction of the visible spectrum and reflects the rest, this process differentiates one color from another due to different percentages of absorption and reflection, which gives each color its unique appearance to the eye.

- Besides its visible effect, the shortwave visible spectrum has a heating effect on the surfaces that they fall on, depending upon the percentages of their absorbance by these surfaces, the light energy of the spectrum is changed into kinetic energy gained by the molecules of the surface rising its temperature.

(3-5-1) Definitions

(3-5-1-1) Absorptivity (a)

It represents the absorbed fraction of the visible radiation falling on a surface.

(3-5-1-2) Reflectivity (r)

It represents the reflected fraction of the visible radiation falling on a surface. i.e : a = 1/r

N.B: The solar energy absorbed at the external surface is represented by the sol-air temperature T_{sa}

$$\mathbf{T_{sa} = T_a + (a \times I / h_o) - LWR} \qquad \text{---------- \{3-4\}}$$

(Ta = ambient air temp. , a= surface absorptivity, I= striking radiation, ho= external surface heat transfer coefficient (20 in metric units) , and finally, LWR= temperature drop due to long wave radiation) [1]

(1) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.132

(3-5-2) Building Color Performance with Respect to Solar Radiation

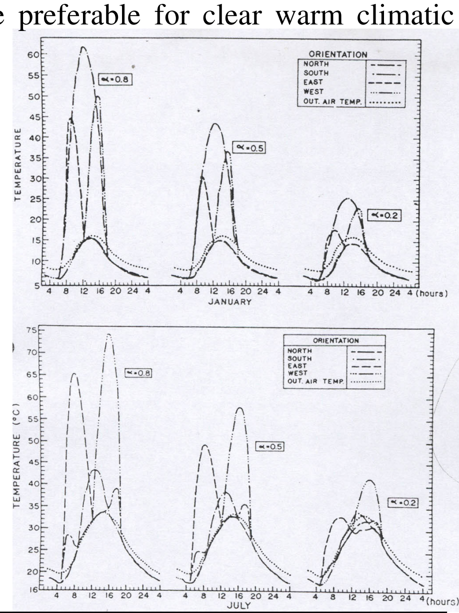
- According to the previous definitions, it is obvious that direct exposure, to solar radiation affects greatly the role of the color in the solar heat gain of the building.

- The relation between the color of the wall and its orientation is very vital, depending upon the sun path in the sky dome, which declares whether the surface in question is subjected to direct, or indirect solar radiation.

- Another important factor that affects the architectural decision concerning the color of the building is the sky cover; for overcast conditions, dark colors are preferred for maximum heat absorbance, whilst white and light colors are preferable for clear warm climatic conditions.

- Fig (3-42) shows the external surface temperatures for different wall orientations in January and July; three levels of absorptivity are assumed (0.8, 0.5, 0.3) representing dark, medium and light colors respectively.

- N.B: in case of white walls, the effect of orientation is very small, as most of the impinging radiation is reflected away in contrast to dark colors, where the effect of orientation is very clear.



Fig(3-42)
External Walls Temperatures For Different orientations with respect to their colors
(a) in January (b) in July
Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.85

(3-5-3) Architectural Examples Using Color as a Strategy for Different Climatic Conditions

(3-5-3-1) Dark Colors in Cold Climates

"In cold climates, the surface temperature of the external walls and roof can be increased with the use of dark exterior materials. Since heat flow through buildings is proportional to the temperature difference between the outside and the inside, raising the external temperature by increasing the solar radiation absorbed reduces envelope heat loss".[1]

Fig(3-43)
Tegnestuen Vandkusten, Housing Project - Denmark
http://www.dcue.dk

Many projects designed by "The Tegnestuen Vandkusten" made use of this property, where most of their projects in Denmark had black exteriors.

Fig(3-44)
Tegnestuen Vandkusten, Housing Project - Denmark 1991-92
http://www_tagpapoplys_dk-images-tagpapogarkitektur-figur8_jpg.htm

Fig(3-45)
Tegnestuen Vandkusten, Housing Project - Denmark . 1987-90
http://www_tagpapoplys_dk-images-tagpapogarkitektur-figur5_jpg.htm

(1) Brown, G.Z., and Dekay Mark, "Sun, wind and Light", 2000, P.220

(3-5-3-2) Light Colors in Hot Climates

In hot climates, the sun path in the sky dome is high in summer, thus making the direct heat gains from roof, east and west very high as compared by north and south facades, where in winter, heat gains are sometimes needed from north and south when the sun path in the sky dome is lower, slightly darker colors are recommended.

A unique architectural application to this is the Sangath studio, Ahmedabad, India, by the architect Balkrishna Doshi; "the vaulted roofs were made of two layers of ferro-cement with hollow clay tile between and furnished with broken white glazed ceramic tiles, which has a high reflectance and a high emittance, so, it absorbs only a small fraction of the insolation, and freely releases what it absorbs"[(1)] (fig(3-46))

Fig(3-46)
Sangath studio, Ahmedabad, India, Balkrishna Doshi
http//www.indiabuildnet.com/arch/sangath.htm

It was also very common to use light and white colors in buildings of Mediterranean and Arabian cities, where the white stucco as a traditional finish was popular to scatter the reflected component of the solar radiation falling on the building.

(1) Brown, G.Z., and Dekay Mark, "Sun, wind and Light", 2000, P.221

(3-5-4) Color Efficiency with Respect to Solar Radiation:

The efficiency of the building's color with respect to solar radiation is judged through its reflectivity and absorptivity.
Table [3-4] illustrates the previous points for different building materials according to their colors [(1)]

	Color	Absorptivity a	Reflectivity r
1	Whitewash, new	0.15	0.85
2	White, dirty	0.3	0.7
3	White paint	0.2	0.8
4	light (Gray, Green, Brown)	0.45	0.55
5	Dark (Gray, Green, Brown)	0.75	0.25
6	Black paint	0.85	0.15
7	Aluminum foil, polished	0.05	0.95
8	Aluminum foil, oxidized	0.15	0.85
9	Aluminum paint	0.5	0.5

(1) Givoni, Baruch,"Climate Considerations in Buildings and Urban Design",1998, P.85

(3-6) Conclusions

- The building skin is the external barrier which protects the occupants from the undesirable climatic conditions, the need of suitable shelter was a motive that made man search for suitable strategies concerning the design of that barrier.

The building skin parameters affecting solar heat gains are:

- Building materials.
- Building glazing.
- Shading strategies.
- Building layout.
- Building color.
- Building orientation.

- The amount of heat that flows through a building's skin due to temperature difference between the outside and the inside is a function of magnitude of that difference, in addition to the resistance to heat flow by the skin materials, accordingly, the kind of material used in the external building's skin represents a vital factor in securing a suitable thermal environment inside the building.

- The Thermal Conductance (U-value) is a property of the building's skin material giving the number of Btu's that will flow through one square foot of the building's skin in one hour, given a temperature difference 1ºF, it has the units of (Btu/hr, ft^2, ºF) or in metric units, (W/ m^2 ºk).

There are three methods of heat flow through the external envelope:

- By Conduction.
- By Convection.
- By Radiation.

- The Shading Coefficient (Sc), is the ratio of the total solar transmittance of a given glazing type to that of a single pane of clear glass, it describes the performance of the glazing with respect to solar radiation.

i.e.:

$$Sc = \frac{\text{Solar Transmittance of a given Glazing}}{\text{Solar Transmittance of a Single Pane Clear Glazing}}$$

- When solar radiation hits a window glass, it is divided into three fractions**;** the first part is reflected outwards without any effect on the building's temperature. The second part is absorbed by the window pane itself, rising its temperature, leading to the emission of long wave infra red radiation, half of this radiation is radiated towards the inside of the building, and the other half towards the outside, the third portion is transmitted through the glazing into the building.

- Proper glazing selection can reduce a building's energy use throughout the year, electric lighting requirements can be reduced by designing windows to take advantage of natural daylight. For buildings with significant cooling loads, special kinds of glazing can reject excessive summer solar heat.

- The shading strategies are one of the most important methods to overcome the undesired direct solar radiation, which increases the building internal temperature, especially in hot arid regions, the use of appropriate shading method is very important, especially within air conditioned buildings, where proper shading greatly reduces what is essentially a needless waste of energy, trying to cool a space with large areas of unprotected glazing.

- There are two main kinds of shading; external shading and internal shading. For the external shading, there is a further classification into fixed and operable shading devices

- Although both internal and external shades are effective in solar control, however, external shading is better because they block the solar radiation before passing through glazing, on the other hand internal shading devices block them after passing through the glazing.

- The efficiency of a shading device is measured by the shading coefficient (Sc).

- The more compact the building's plan, the smaller the exposed surface area of the walls or the roof, for a given volume or floor area of the building, as a result, the heat exchange with the surrounding environment is decreased.

- The term layout refers to the compactness of the building's plan, the main impact of layout from the indoor climate point of view is its effect on the envelope's surface area, relative to the floor's area, or the space volume, and hence, the rate of heat exchange of the building with the outdoors, also, the building's potential for natural ventilation and natural illumination.

- A very significant feature that accompanies the compact plans in many cases is the presence of courtyards or patios for the sake of borrowed daylight through glazing without being exposed to direct solar radiation.

- The color of the building represents a very effective factor in the process of heat gain from solar radiation, using light colors in hot climates and dark colors in cold climates is a well known inherited strategy.

- The efficiency of the building's color with respect to solar radiation is judged through its reflectivity and absorptivity.

CHAPTER IV
Balance Point Temperature and the Evaluation of the Building's Thermal Performance

Introduction

- The evaluation of the thermal performance of a building needs a quantitative dynamic method, whereas the thermal flow through the building takes place in a dynamic way, depending upon the activities, lighting, and equipment on one hand, and the solar impact on the other hand, having the building's envelope in between as a heat flow regulator.

- The aim of using such an evaluating tool is to help the architect to manipulate the building's envelope parameters (1) in the schematic design phase, guiding him to choose the most suitable group of alternatives that contribute together forming the external shell of the building.

- "A mechanical engineer uses balance point information to determine the magnitude of heating and cooling loads in order to size the equipment, for the architect, the balance point concept and understanding of energy flows that it involves provides a way to anticipate those demands and minimize, or eliminate them through insightful design" (2).

- The evaluating method used in this chapter will represent the main frame of the user interface proposed in chapter V of the research.

- Whilst chapters II and III discussed the external heat source in the form of solar radiation, and the building's envelope as the second phase of energy flow through the building, this chapter draws light on the third phase inside the building, where the contribution of all heat forces acting on it externally and internally, results a certain internal condition.

---

(1) Refer to chapter III "Building Skin Parameters Affecting Solar Heat Gains"
(2) Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point", 1997, P. 28

(4-1) Building Balance Point Definitions

- It is the outdoor air temperature required for the building's indoor temperature to be comfortable without the use of any mechanical heating or cooling.[(1)]

- It is the outdoor air temperature at which the heat generated inside the building balances the building's heat losses to maintain a desired indoor temperature. [(2)]

- It is the ambient (or outdoor) air temperature which causes building heat transfer across the enclosure to balance building heat gains at a desired indoor temperature. [(3)]

N.B: The researcher agrees with the previous three definitions where the balance point temperature can be described as the external ambient temperature that causes balance between thermal gains and losses at a desired indoor temperature without the need of any mechanical heating or cooling, where it can be described quantitatively according to the equation: . [(4)]

$$T_B = T_{thermostat} - [\ (Q_{IHG} + Q_{Sol}) / \hat{U}_{bldg}\ ] \qquad \{4\text{-}1\}$$

Where:

T_B = building balance point

$T_{thermostat}$ = desired inside temperature

Q_{IHG} = internal heat gains

Q_{Sol} = solar heat gains.

$\hat{U}_{bldg}$ = overall Û value of the building's envelope

---

(1) Utzinger, Michael & Wasley, James"Vital Signs, Building Balance Point, 1997, P.2

(2) Brown, G.Z and Mark, Dekay "Sun, Wind and Light", P.67, 2000

(3),(4) Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point", 1997, P. 7

(4-2) Factors Affecting Balance Point Temperature

- Balance point temperature represents the overall result describing the thermal condition of the building as a result of all heat forces acting on it , thus it is affected by these forces in addition to other factors describing the performance of the building in its location.

- According to the equation {4-1}, these factors were found to be:
  1- Solar radiation.[1]
  2- Building envelope.[2]
  3- Internal heat gains.

(4-2-1) Internal Heat Gains

- The internal heat gains of any building depend in the first order on its function and program, where it is the sum of the heat generated due to occupants' metabolism, lighting, and equipments respectively.

i.e:

$$Q_{IHG} = Q_{People} + Q_{Lights} + Q_{Equipments} \quad \text{---------} \quad \{4\text{-}2\}$$

Where:

Q_{IHG} = internal heat gains
Q_{People} = heat gains due to occupants' metabolism.
Q_{Lights} = heat gains from lighting
$Q_{Equipments}$ = heat gains from equipments

- For example, an office building having too many occupants, lighting and equipments produces much more internal heat than that of a residential building, where the role of the building's envelope in the latter is superior over the internal heat gains in its thermal balance process, moreover, the time interval of the day at which the building is operated is a very important point to judge the dynamic internal heat gains over the course of the day.

(1) Refer to chapter II "Solar Radiation and External Thermal Force Acting on the Building"
(2) Refer to chapter III "Building Skin Parameters Affecting Solar Heat Gains"

(4-2-1-1) Internal Heat Gains from Occupancy

- The metabolic energy of people can contribute substantially to the amount of heat generated in the building, this heat may increase the cooling requirements in a hot climate or in a building that has a cooling load due to other sources of internal heat gain, or it may decrease the heating requirements of a building in a cold climate.

- The amount of heat generated by people is a function of sex, age and activity,

- The total heat gains from people is found by multiplying the occupant density of the building by the rate of heat gain per person, where the occupant density may be determined for either peak or average conditions representing maximum requirements and normal conditions for the capacity of systems respectively.[1]

i.e:

$$\frac{Q_{People}}{\text{Unit area}} = Q_{Person} * \text{Density } \rho \qquad \text{----------} \quad \{4\text{-}3\}$$

Table [4-1] illustrates different metabolic rates for different degrees of activity [1]

Activity	Building type	Btu/hr	Watts
Seated at rest, very light work	Theatre	225-245	66-72
Office work, walking slowly	Office, Hotel, Residential	250	73
Light bench work, eating	Restaurant	275	81
Moderate dancing	Dance Hall	305	89
Walking fast, moderately heavy work	Factory	375	110
Heavy work, lifting	Factory, Bowling alley	580-635	170-186
Athletics	Gymnasium	710	208

(1) Brown, G.Z and Mark, Dekay "Sun, Wind and Light", P.39, 2000

(4-2-1-2) Internal Heat Gains from Lights

- To have an accurate estimation of the amounts of heat generated from lights, there must be a complete survey to the number of lamps, their kinds, and their power ratings within the building, which may be different for buildings having the same function.

- Since the balance point method is used in the schematic phase of the design, all these details are not necessary, where a rough estimation is recommended for quick calculation and time saving.

- Fig.(4-1) shows typical lighting levels (Q_{light}) for different kinds of buildings, where light power densities are given on a scale in Btu/hr ft^2 or in Watts/m^2 to help non-specialists.

- However, a further correction to these figures must be done as a result of the contribution of natural daylight, depending upon the percentage of the voids' areas to that of the overall building's area.

i.e:

$$F_{daylight} = A_{Glz} \times 2 / A_f$$ [1] --- {4-4}

- Where the equation indicates the percentage of the plan covered by natural daylight (twice the area of the voids / total building floor area).
- Heat gains from lights can be calculated by substitution in the equation:

$$Q_{light\ corr} = Q_{light}\ (1- F_{daylight} /2)$$ [2] {4-5}

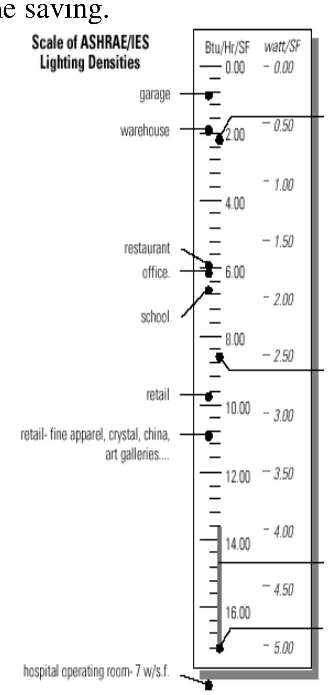


Fig.(4-1)
ASHRAE Scale for Lighting Densities
Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point" P. 15

(1),(2) Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point", 1997 P. 16

(4-2-1-3) Internal Heat Gains from Equipments

- Electrical appliances and equipments operating in a certain space contribute heat to that space due to their operation; the building type reflects the scale of equipments and thus, their heat production.

- Electric Energy that goes into equipment such as electric motors and computers, ends up as a waste heat in the space, accordingly, more efficient equipment is recommended for both saving and decreasing its heat emissions, and hence their cooling loads.

- As a quick way of calculation, approximate assumptions of equipments' heat production for different buildings' types is proposed in many fundamental books, despite of adding up all the detailed fractions given by each equipment. Ex: ASHRAE Handbook of Fundamentals.

- Table [4-3] illustrates heat gain from equipments for different building types / floor area. (1)

Building type	Heat gain (Btu/hr,ft^2)		Heat gain (W/m^2)	
	Low	High	Low	High
Sales	3	5	10	17
Office	3	5	10	17
Assembly	1	2	4	7
Warehouse	2	4	8	13
Restaurant	10	16	31	52
Education	4	7	14	23
Grocery	8	13	24	42
Lodging	3	5	10	17
Residential	1	2	3	6

(1) Brown, G.Z and Mark, Dekay "Sun, Wind and Light", 2000, P.44

(4-3) Skin Load and Internal Load Dominated Buildings

- This classification of buildings with respect to the manner of heat flow helps us to understand and capture the difference in energy flow patterns that balance point highlights between large commercial and office buildings versus small residential buildings.

(4-3-1) Skin Load Dominated Buildings

- Buildings having high rates of heat transfer through their enclosures, having their balance point temperature near the thermostat temperature (desired indoor temperature) are withdrawn under this classification, e.g. residential buildings. [1]

- External heat source (solar radiation) plays here a major role representing the most effective thermal factor acting on the building, where its envelope acts as a protective shell.
  i.e.: Increasing the insulation of the external envelope of a building lowers its balance point temperature and vice versa.

- <u>Example: Solar hemicycle-Frank Lloyd Wright, Wisconsin</u>

  Although the building was designed to match with the surrounding environment [2], the poor insulation of the building's envelope lead to severe internal conditions, where enormous amounts of fuel were being dissipated over the course of the winter to overcome them.(fig.(4-2))

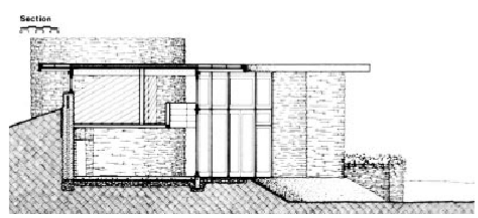


Fig. (4-2)
The Solar Hemicycle (section)
Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point" P. 3

(1) Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point", 1997 P. 5
(2) Refer to chapter I (A Historic Review towards Solar Architecture) (1-8-1-2)

(4-3-2) Internal Load Dominated Buildings

- They are buildings characterized by having generic thermal factors, i.e.: equipments, lighting and metabolism, where the balance point temperature is lowered, meaning that a low outdoor temperature is required for the heat losses and gains to balance at an acceptable indoor temperature, e.g.: office buildings. [1]

- The solar radiation here also represents an important source of energy, in addition to the huge internal heat gains, and thus, increasing the cooling load.

- This is why the architecture of skyscrapers as an image of the commercial community has always been considered a symbol of energy crisis. [2]

---

(1) Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point", 1997, P. 5
(2) Refer to chapter I (A Historic Review towards Solar Architecture) (1-8-2)

(4-4) Building Balance Point as a Design Tool

(4-4-1) Conceptual Structure

- It is a visual comparative graph on which the ambient air temperature is plotted together with the balance point temperature curve over the course of the day.
- For each case study, four graphs are provided representing an average day of each season hence, the thermal performance of the building can be traced over the course of the year.
- The ambient air temperature curve is provided by annual climatic data for the building's site, while the balance point curve is driven from the equation {4-1}, where the effect of the internal and external thermal forces acting on the building is noticed by lowering the balance point at the daytime intervals of their action – (fig.(4-3)).
- In case the magnitude of the balance point is greater than that of ambient air temperature, this means that the building looses heat and vice versa; heat loss from the building will be proportional to the difference between the ambient air temperature and the balance temperature.
- The Less the difference in magnitude between the two values, the more efficient the building is.
- This method is very helpful in comparative analysis, especially in the schematic phase of the design to pick up the most suitable group of skin variables matching site and program.

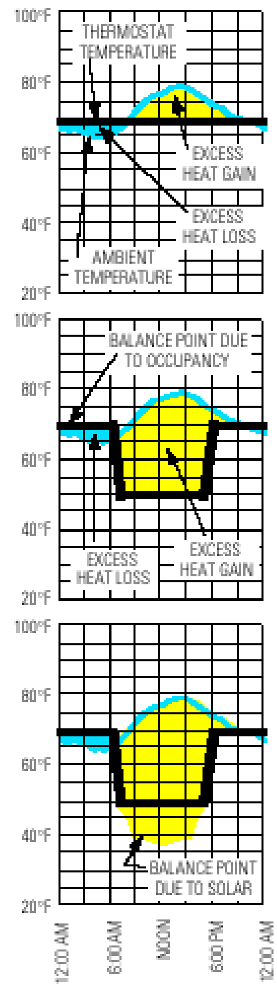


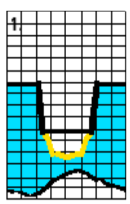
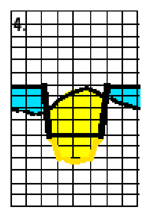
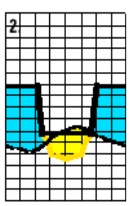
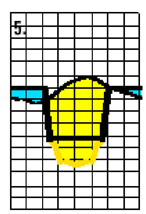
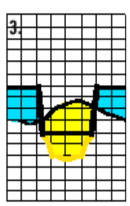
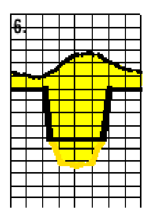
Fig.(4-3)
Balance Point Graph Structure
Utzinger, Michael and Wasley, James
"Vital Signs. Building Balance Point" P. 7

(4-4-2) Possible Outcomes of a Balance Point Analysis

During the schematic phase, the designer goal is to manipulate:

1- The sources of internal heat gains.
2- The enclosure heat transfer.
3- The incoming solar energy.

Table [4-4] reviews the possible outcomes from a balance point graph and the equivalent strategies.[1]

Output	Explanation and Treatment	Output	Explanation and Treatment
	**1-Always too cold**: -Increase captured heat gains to minimize heating load. -Decrease rate of heat transfer between the building and environment.		**4-Too hot with good potential of night cooling.** -Decrease captured solar heat gains to balance. (possible daytime ventilation) -Store excess daytime gains to offset night losses.
	**2-Too cold +some excess solar heat gains during day** -Increase captured heat gains to balance losses. -Store excess daytime gains to offset night losses.		**5-Too hot with some potential of night cooling.** -Decrease captured solar heat gains to balance.(too hot for daytime ventilation) -use night losses to offset daytime gains
	**3-Potential balance between daily gains and losses.** -Store excess daytime gains to offset night losses.		**6-Always too hot** -Decrease captured solar heat gains to minimize cooling load. -increase insulation to separate the mechanically cooled building from environment.

(1) Utzinger, Michael and Wasley, James"Vital Signs, Building Balance Point",1997 P. 29

(4-5) Case Studies Using Balance Point Application

This part will discuss the application of balance point method on different buildings classified roughly into two groups;

1- Internal Load dominated examples.
2- Skin Load dominated examples.

Two architectural examples will be studied for each case in a comparative analysis manner.

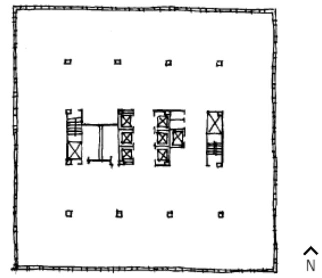


Fig.(4-4)
Portland Building (Plan)
Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point" P. 20

(4-5-1) Wainright-Portland Case Study [1]

This case study is a numerical comparative one between two famous office buildings, where they are both classified as internal load dominated buildings due to their program, however, their thermal performance will be judged through practical results.

(4-5-1-1) General Architectural Features

A. Portland Building

The Portland building, designed by Michael Graves associates, 1980 is characterized by having a deep plan (Fig (4-4)), thus, the need of illumination necessities the use of electric light rather than daylight, meaning that excessive heat results from illumination.

Fig.(4-5)
Portland Building
Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point" P. 19

(1) The case study was done by Utzinger, Michael and Wasley, James "Building Balance Point", 1997¸PP.19-27

Moreover, the massive plan decreases the surface to volume ratio, minimizing heat loss through skin.
The small ratio of glazing characterizing the facades increases the overall resistance to heat flow through the envelope (fig.(4-5)).

Fig.(4-6)
Wainright Building
Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point" P. 19

B. <u>Wainright Building</u>

- The Wainright building, Saint Lois, Missouri, designed by Alder and Sullivan, 1891, for the first sight appears to be similar to the Portland building, (fig.(4-6)), having an enormous scale façade with small ratio of glazing characterizing it, however, "behind the unifying façade lies a typical pre-modern plan, approximately 40 feet thick (≈12.20m.) wrapping 3 sides of a deep court". (1)

Fig.(4-7)
Wainright Building
(Court)
Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point" P. 19

- This court was necessary to bring light and natural ventilation in the days before florescent lighting and mechanical ventilation were widely used afterwards in such a type of buildings (fig.(4-7)).

- This plan leads to increasing the surface volume ratio, and accordingly heat exchange with the external environment. (fig.(4-8)).

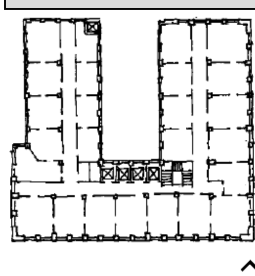


Fig.(4-8)
Wainright Building (Plan)
Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point" P. 20

(1) Utzinger, Michael and Wasley, James "Building Balance Point", 1997,P.20

(4-5-1-2) Basic Building Data and Areas

Table [4-4] gives information about the geometry of the two buildings.

		Wainright Building		Portland Building	
Building Thermostat Setting		70 ºF ≈ 21 ºC		70 ºF ≈ 21 ºC	
Building Occupancy Schedule		7 a.m. → 5 p.m.		7 a.m. → 5 p.m.	
Perimeter		560 ft	170.688 m	600 ft	182 m
Nº of Floors		11		15	
Area/Floor		10700 ft^2	994.03 m^2	23500 ft^2	2183.15 m^2
Total Floor Area (A_f)		117700 ft^2	10934.33 m^2	406000 ft^2	32747.25 m^2
Horizontal Planes	Roof Area (A_{Roof})	10700 ft^2	994.03 m^2	23500 ft^2	2183.158 m^2
	Horizontal Glazing Area (A_{GlzH})	—		—	
Glazing Areas	South Glazing Area ($A_{Glz'S}$)	3596 ft^2	334.06 m^2	3213 ft^2	298.48 m^2
	East Glazing Area ($A_{Glz'E}$)	5994 ft^2	556.84 m^2	3213 ft^2	298.48 m^2
	West Glazing Area ($A_{Glz'W}$)	5994 ft^2	556.84 m^2	3213 ft^2	298.48 m^2
	North Glazing Area ($A_{Glz'N}$)	3596 ft^2	334.06 m^2	3213 ft^2	298.48 m^2
	Total Glazing Area (A_{Glz})	18100 ft^2	1681.49 m^2	12852 ft^2	1193.95 m^2
Opaque Wall Areas	Overall Wall Areas	76720 ft^2	7127.288 m^2	128520 ft^2	11939.5 m^2
	Net Wall Area (A_{Wall})	57540 ft^2	5345.466 m^2	115668 ft^2	10745.5 m^2

All numerical data are transformed by the researcher into S.I. units as the original case study was done by Utzinger, Michael and Wasley, James "Building Balance Point", 1997, PP.19-27 using BTU.

(4-5-1-3) Characterizing Enclosure Heat Flows

Table [4-5] calculates the building enclosure values for each case.

		Wainright Building		Portland Building	
		BTU/hr ºF ft^2	W/m^2 ºC	BTU/hr ºF ft^2	W/m^2 ºC
Walls	U_{Wall}	0.18	1.021	0.18	1.021
	$\hat{U}_{Wall} = \frac{U_{Wall} \times A_w}{A_f}$	0.09	0.51	0.05	0.28365
Roof	Uroof	0.14	0.79	0.14	0.79
	$\hat{U}_{roof} = \frac{U_{roof} \times A_r}{A_f}$	0.01	0.0567	0.01	0.0567
Glazing	$U_{Glazing}$	1.10	6.24	1.10	6.24
	$\hat{U}_{Glazing} = \frac{U_{Glazing} \times A_{Glazing}}{A_f}$	0.18	1.02	0.03	0.17
Ground	U_{Ground}	1.75	9.92	1.75	9.92
	$\hat{U}_{Ground} = \frac{U_{Ground} \times \text{Perimeter}}{A_f}$	0.01	0.056	0.0025	0.014
Ventilation	$\hat{U}_{Vent}$ (1)	0.15	0.857	0.15	0.851
$\hat{U}_{bldg} = \hat{U}_{Wall} + \hat{U}_{roof} + \hat{U}_{Glazing} + \hat{U}_{Ground} + \hat{U}_{Vent}$		0.44	2.5	0.25	1.4

N.B.: Multiply BTU/hr ºF ft^2 by 5.673 to convert to W/m^2 ºC.(2)

(1) For different values of U_{vent} according to the building's type, refer to G.Z Brown and Decay, Mark "Sun, Wind and Light",2000, P.51

(2) www.diydata.com, also www.ibiblio.org , accessed 11/2003

(4-5-1-4) Characterizing Internal Heat Gains

Table [4-6] calculates the internal heat gains for both buildings.

		Wainright Building		Portland Building	
Heat Gains from People	Occupant Heat Gains(1)	400 BTU/Person/hr		400 BTU/Person/hr	
	Density	150 ft^2/Person	45.72 m^2/Person	150 ft^2/Person	45.72 m^2/Person
	Q_{People}	2.7 BTU/hr ft^2	8.51 W/m^2	2.7 BTU/hr ft^2	8.51 W/m^2
Heat Gains from Equipment	Q_{Equip}(2)	2.5 BTU/hr ft^2	7.88 W/m^2	2.5 BTU/hr ft^2	7.88 W/m^2
Heat Gains from Light	Q_{Light}	3.6 BTU/hr ft^2	11.35 W/m^2	5.4 BTU/hr ft^2	17.024 W/m^2
Total	$Q_{IHG} = Q_{People} + Q_{Equip} + Q_{Light}$	8.8 BTU/hr ft^2	27.74 W/m^2	10.6 BTU/hr ft^2	33.414 W/m^2

N.B.

Notice that Q_{People} and Q_{Equip} have same rates for both buildings as they are strictly engaged to the building's function, on the other hand, Q_{Light} differs in both cases as it depends on the building's mass and the percentage of the daylight contribution.

i.e.:

(a) For Wainright Building: From equation (4-4)

$Q_{LightCor} = Q_{Light} * (1- F_{Daylight} / 2) = 6* (1- 0.8 / 2) = 3.6$ BTU/hr ft^2

= (11.35 W/m^2)

($F_{Daylight} = 0.8$, assuming that light penetrates 80% of the floor area).

(b) For Portland Building: (similarly)

$Q_{LightCor} = Q_{Light} * (1- F_{Daylight} / 2) = 6* (1- 0.2 / 2) = 5.4$ BTU/hr ft^2

= (33.414 W/m^2)

($F_{Daylight} = 0.2$, assuming that light penetrates 20% of the floor area).

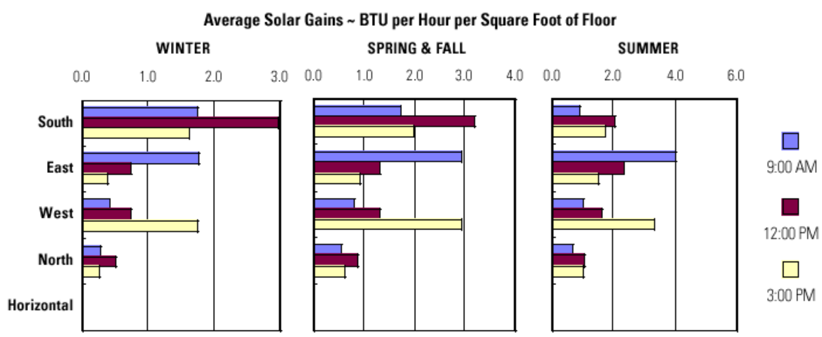
<u>(4-5-1-5) Characterizing Solar Heat Gains</u>

- This part is the most sophisticated among all previous stages, as it deals with a multi-case dynamic condition, in this case study, there was a strong support by special tables supplying solar data for the building's sites.

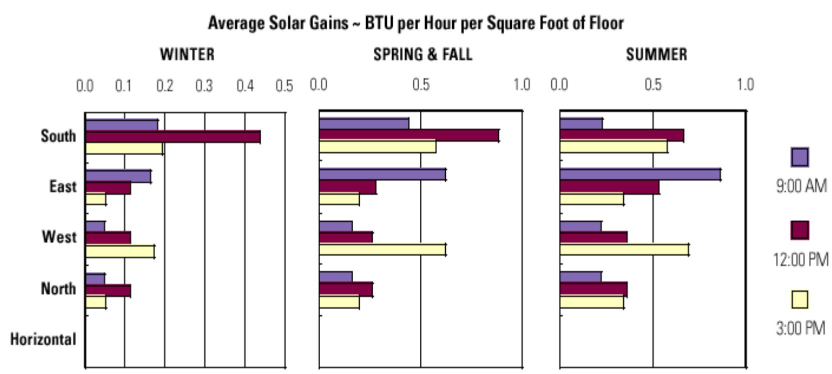
- Solar data is calculated three times a day, for an average day of three seasons; summer, winter and equinoxes, for the four orientations and the roof.

<u>The following charts show these values for the Wainright building and the Portland building respectively:</u>

Wainright building



Portland building



- By substitution in the equation: [1]

$$Q_{Sol} = \sum_{I=1}^{n} I_{Sol}\, Sc\, \frac{A_{gi}}{A_f} \qquad \text{---------- } \{4\text{-}6\}$$

- The solar heat gains of a building represents a very effective daytime contribution of heat gains, varying instantly due to the continuous change in the amount of solar radiation (I) reaching the earth as a result of the motion of the sun in the sky dome.

Where:

I_{Sol} = Average solar gain for a given orientation (i),time, season.
Sc = Glazing shading coefficient for a given orientation (i).
A_{gi} = Glazing area for a given orientation (i).
A_f = Building floor area.

N.B:

- In other case studies, solar data may not be available in the form of charts, the only data supplied concerning the building's site may be only its latitude and longitude, accordingly, a tool of calculation is needed; stereographic diagrams, cylindrical diagrams , and most recommended solar calculators[2] , where calculations are made much more simple.

(1) Utzinger, Michael and Wasley, James "Building Balance Point", 1997,P.17
(2) Refer to (4-5-2-5)

(4-5-1-6) Evaluating the Balance Point Graphs

All previous data will be used to plot the balance point graphically by substitution in equation {4-1}, where these graphs can be evaluated by monitoring the relation between the ambient air temperature and the balance point temperature.

A. The Wainright Building:

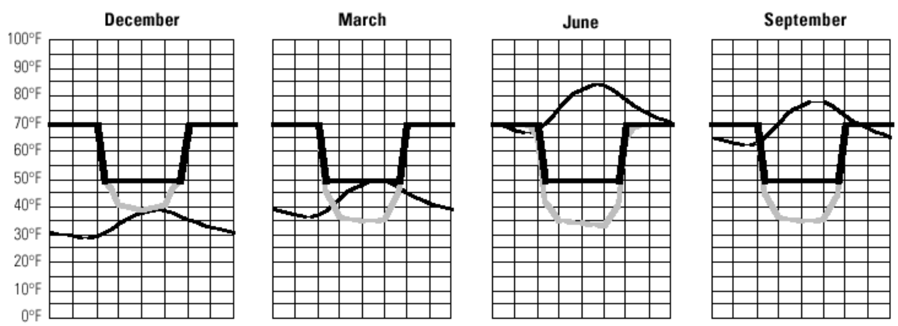


Fig.(4-9)
The Wainright Building's Annual Balance Point Graph
Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point" P. 23

- Climatic data shows a sharp fluctuation in temperature throughout the year course in Saint Lois.
- Balance point due to internal heat gains is decreased by 20ºF approximately (11ºC).
- The contribution of solar gains in decreasing the balance point is considerable, causing a further 15ºF → 10ºF drop (≈ 8.3 - 5.5 ºC) at its peak point.
  - **In winter,** the balance point is always greater than ambient temperature, indicating heat loss, however, the need for heating is very limited during the operation of the building.
  - **In spring,** the graph shows small cooling loads needed within a portion of the daytime, caused by solar heat gains.
  - **In fall and summer,** the increase of the outside ambient temperature indicates excessive need for cooling (notice the solar heat gains).

B. The Portland Building:

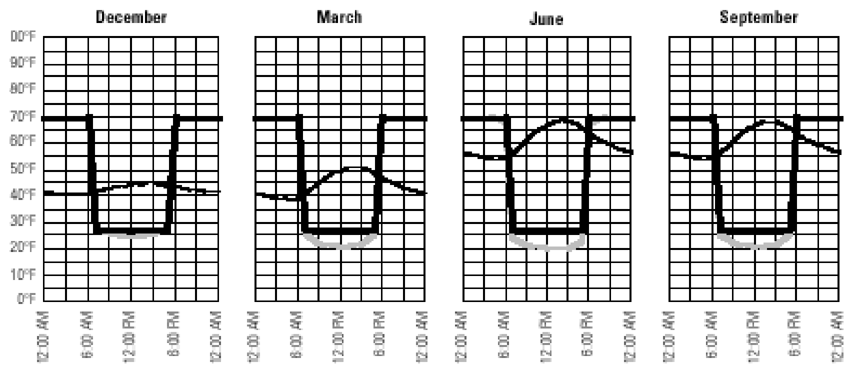


Fig.(4-10)
The Portland Building's Annual Balance Point Graph
Utzinger, Michael and Wasley, James "Vital Signs, Building Balance Point" P. 23

- Climatic data shows a sharp fluctuation in temperature throughout the course of the year.
- Balance point due to internal heat gains is decreased sharply by 42.8ºF (≈ 23.7 ºC), indicating enormous internal heat production.
- The contribution of solar gains is very small due to the compact building's mass.
    - **In winter and spring,** moderate cooling loads are needed to balance the extreme internal gains during the building's operation.
    - **In fall and summer,** the need for cooling loads are increased enormously, which is classified to be a non economical condition.

(4-5-2) Mit-Rehan – Cairo Villa Case Study [1]

- This case study represents a further category of buildings, classified as "Skin Load Dominated" ones, where the role of the building's envelope becomes very important to resist the external conditions similarly, this case study is a numerical comparative analysis as the previous one, following the same criteria and steps.

(4-5-2-1) General Architectural Features

A) Mit-Rehan Villa:

- Mit-Rehan is a neo-traditional house, by architect Hassan Fathy, it was completed in 1981. It is located on the Sakkara road outside Cairo-Egypt.
- The building is a single family residence consisting of two floors, and containing rich traditional architectural elements (notice the courtyard, mashrabias).
- The plan is characterized by its thick walls made of sandstone (50 cm thick) indicating a large thermal mass to provide sufficient protection against the hot dry weather. (fig.(4-12))
- Using the mashrabia increases the shading coefficient of the voids in the building's skin, thus limiting the direct solar effect on the building's interior. (fig.(4-13))

Fig.(4-11)
Mit-Rehan Villa (exterior)
http://arch.ced.berkeley.edu/vitalsigns/workup/two_houses

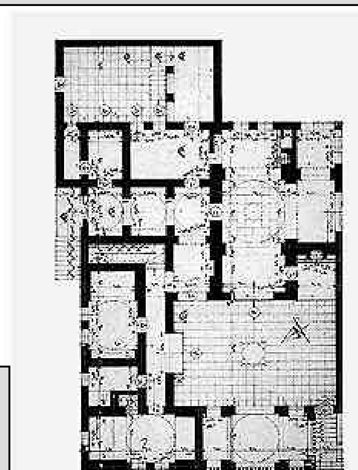


Fig (4-12)
Mit-Rehan Villa (plan)
http://arch.ced.berkeley.edu/vitalsigns/workup/two_houses

(1) This case study is a further extension done by the researcher to that of Ihab El-Ziady, university of Wisconsin, Milwaukee, 1996.

(b) Cairo Villa:

- This house was designed by architect Ali Nassar, in 1962, and took more than a year for the completion of the construction. It is located in the heart of the urban context of Cairo-Egypt. (fig.(4-14)).
- The building is composed of two separate floors designed as two apartment houses.
- The structure of the villa is a reinforced concrete skeleton, and common brick-in fill, (thermal mass is 1/3 of that of Mit-Rehan villa).
- To minimize the heat gains and losses from the roof, 80 mm foam core is used for heat insulation from direct solar gains.
- Clear glass panes were used in the external facades, increasing the amounts of direct solar gains (fig.(4-15)), however, it was treated by using trees as shading elements in the building's context.

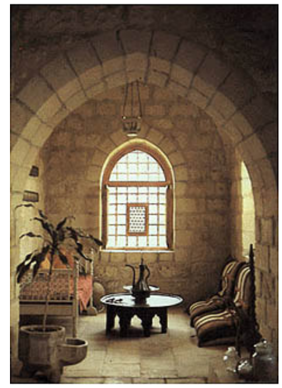


Fig (4-13)
Mit-Rihan (interior)
http://arch.ced.berkeley.edu/vitalsigns/workup/two_houses

Fig (4-14)
Cairo Villa (exterior)
http://arch.ced.berkeley.edu/vitalsigns/workup/two_houses

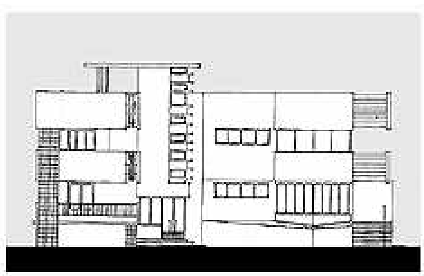


Fig (4-15)
Cairo Villa (elevation)
http://arch.ced.berkeley.edu/vitalsigns/workup/two_houses

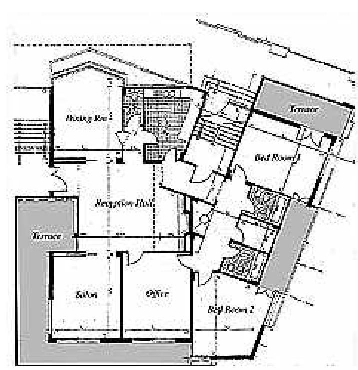


Fig (4-16)
Cairo Villa (plan)
http://arch.ced.berkeley.edu/vitalsigns/workup/two_houses

(4-5-2-2) Basic Building Data and Areas

Table [4-7] summarizes the geometry of the two buildings.

		Mit-Rehan villa	Cairo villa
Building Thermostat Setting		24 ºC	24 ºC
Building Occupancy Schedule(1)		10 a.m. → 10 p.m.	10 a.m. → 10 p.m.
Perimeter		63.5 m	56.5 m
Closed ground floor area		242 m^2	200 m^2
Closed first floor area		110 m^2	220 m^2
Total Floor Area (A_F)		352 m^2	420 m^2
Horizontal Planes	**Roof Area (A_{Roof})**	110+67=177 m^2	220 m^2
	Horizontal Glazing Area (A_{GlzH})	-	-
Glazing Areas	**South Glazing Area ($A_{Glz'S}$)**	23.3 m^2	28.125 m^2
	East Glazing Area ($A_{Glz'E}$)	11.66 m^2	16.875 m^2
	West Glazing Area ($A_{Glz'W}$)	11.66 m^2	28.125 m^2
	North Glazing Area ($A_{Glz'N}$)	23.3 m^2	16.875 m^2
	Total Glazing Area (A_{Glz})	70 m^2	90 m^2
Net Wall Area (A_{Wall})		550 m^2	420 m^2

(1) For residential buildings, it is more unpredictable to set an accurate fixed occupancy schedule due to the overlap of the occupants all over the day, hence, it is assumed to be roughly from 8am to 10pm.

(4-5-2-3) Characterizing Enclosure Heat Flows

Table [4-8] calculates the building enclosure for each case.

		Mit-Rehan villa W/m² ºC	Cairo villa W/m² ºC
Walls	U_{Wall}	1.15	1.73
	$\hat{U}_{Wall} = U_{Wall} \times \frac{A_w}{A_f}$	1.79	1.73
Roof	Uroof	1.91	0.48
	$\hat{U}_{roof} = U_{roof} \times \frac{A_r}{A_f}$	0.96	0.25
Glazing	$U_{Glazing}$	3.12	6.24
	$\hat{U}_{Glazing} = U_{Glazing} \times \frac{A_{Glazing}}{A_f}$	0.62	1.337
Ground	U_{Ground}	4.76	5.36
	$\hat{U}_{Ground} = \frac{U_{Ground} \times Perimeter}{A_f}$	0.86	0.7219
Ventilation	$\hat{U}_{Vent}$	0.28	0.28
$\hat{U}_{bldg} = \hat{U}_{Wall} + \hat{U}_{roof} + \hat{U}_{Glazing} + \hat{U}_{Ground} + \hat{U}_{Vent}$		4.51	4.319

(4-5-2-4) Characterizing Internal Heat Gains

Table [4-9] calculates the internal heat gain for each case.

		Mit-Rehan villa	Cairo villa
Heat Gains from People	**Occupant Heat Gains**	73 W	73 W
	Density	0.03 p/m^2	0.03 p/m^2
	Q_{People}	2.19 W/ m^2	2.19 W/ m^2
Heat Gains from Equipment	Q_{Equip}	3 W/ m^2	3 W/ m^2
Heat Gains from Light	Q_{Light}	6.24	6.13
Total	$Q_{IHG} = Q_{People} + Q_{Equip} + Q_{Light}$	11.43 W/ m^2	11.32 W/ m^2

N.B.

1- Area of windows at Mit-Rehan= 70 m^2
Light penetration = 70x2 = 140 m^2
$F_{daylight}$ = 140/352 = 0.397
Q_{Light} = 7.8 x (1-0.4/2) = 6.24 W/ m^2

2- Area of windows at Cairo villa= 90 m^2
Light penetration = 90x2 = 180 m^2
$F_{daylight}$ = 180/420 = 0.428
Q_{Light} = 7.8 x (1-0.428/2) = 6.13 W/ m^2

(4-5-2-5) Characterizing Solar Heat Gains [1]

A. Calculating Solar Angles and Incident Radiation (I_{DN})

a) Cairo Villa

Location: Cairo
Table [4-10] gives the values of the altitude, azimuth and incident solar irradiance I_{DN} three times a day for four days over the course of the year, where they represent the four seasons, the sunrise and sunset time is also shown.

	Sunrise	8.00 a.m.	Noon	4.00 p.m.	Sunset
21-Dec. Local time	**6.46**	**8**	**12**	**16**	**16.59**
A	0	12.9	36.41	9.98	0
Z	-	127.15	152.39	235.27	-
I_{DN}(W/m²)	0	885	1055	835	0
21-Mar. Local time	**5.58**	**8**	**12**	**16**	**18.06**
A	0	25.4	60	25.9	0
Z	-	105.9	179.4	253.8	-
I_{DN}(W/m²)	0	1010	1100	1010	0
21-Jun. Local time	**4.54**	**8**	**12**	**16**	**18.59**
A	0	37.6	83.2	35.6	0
Z	-	82.3	190	278.6	-
I_{DN}(W/m²)	0	1055	1100	1055	0
21-Sep. Local time	**5.42**	**8**	**12**	**16**	**17.53**
A	0	28.8	60.5	23.3	0
Z	-	107.4	186.6	256.4	-
I_{DN}(W/m²)	0	1010	1100	1010	0

(1) All calculations are done using the excel sheet developed by the researcher.

b) Mit-Rehan Villa

Location: Giza
Table [4-11] gives the values of the altitude, azimuth and incident solar irradiance I_{DN} three times a day for four days over the course of the year, where they represent the four seasons, the sunrise and sunset time is also shown.

	Sunrise	8.00 a.m.	Noon	4.00 p.m.	Sunset
21-Dec. Local time	**6.47**	**8**	**12**	**16**	**16.59**
A	0	12.7	36.5	10.3	0
Z	-	126.9	182	235.2	-
I_{DN}(W/m²)	0	885	1055	835	0
21-Mar. Local time	**5.59**	**8**	**12**	**16**	**18.07**
A	0	25.2	60.1	26.3	0
Z	-	105.6	178.7	253.7	-
I_{DN}(W/m²)	0	1010	1100	1010	0
21-Jun. Local time	**4.54**	**8**	**12**	**16**	**18.59**
A	0	37.3	83.3	36	0
Z	-	82.1	186.4	278.5	-
I_{DN}(W/m²)	0	1055	1100	1055	0
21-Sep. Local time	**5.43**	**8**	**12**	**16**	**17.54**
A	0	28.5	60.6	23.6	0
Z	-	107.1	185.9	256.3	-
I_{DN}(W/m²)	0	1010	1100	1010	0

B. Calculating Global Solar Irradiation (I_G) (1)

a) Cairo Villa

Table [4-12] gives the values of global solar radiation for the four orientations & the Roof, three times a day for four days representing the four seasons.

	Sunrise	8.00 a.m.	Noon	4.00 p.m.	Sunset
21-Dec. Local time	**6.46**	**8**	**12**	**16**	**16.59**
I_{GN} (W/m²)	0	68.28882	100.9403	62.34546	0
I_{GE} (W/m²)	0	835.8998	619.1037	62.34546	0
I_{GW} (W/m²)	0	589.2547	853.306	530.855	0
I_{GS} (W/m²)	0	68.28882	100.9403	738.2028	0
I_{GH} (W/m²)	0	303.7764	752.8051	244.9092	0
21-Mar. Local time	**5.58**	**8**	**12**	**16**	**18.06**
I_{GN} (W/m²)	0	88.32122	120.2314	88.71849	0
I_{GE} (W/m²)	0	995.8569	221.4046	88.71849	0
I_{GW} (W/m²)	0	338.273	670.2012	342.1968	0
I_{GS} (W/m²)	0	88.32122	120.2314	961.1965	0
I_{GH} (W/m²)	0	554.4245	1084.628	562.3698	0
21-Jun. Local time	**4.54**	**8**	**12**	**16**	**18.59**
I_{GN} (W/m²)	0	355.9459	127.2131	100.337	0
I_{GE} (W/m²)	0	898.1121	127.2131	100.337	0
I_{GW} (W/m²)	0	101.8152	255.4788	100.337	0
I_{GS} (W/m²)	0	101.8152	149.8298	948.5133	0
I_{GH} (W/m²)	0	770.3031	1224.262	740.7397	0
21-Sep. Local time	**5.42**	**8**	**12**	**16**	**17.53**
I_{GN} (W/m²)	0	90.98856	120.4696	86.63505	0
I_{GE} (W/m²)	0	968.6867	152.5938	86.63505	0
I_{GW} (W/m²)	0	355.6605	658.5457	304.7601	0
I_{GS} (W/m²)	0	90.98856	182.7271	988.2561	0
I_{GH} (W/m²)	0	607.7712	1089.391	520.701	0

(1) Refer to Chapter II, (2-2-3-6)

b) Mit-Rehan Villa

Table [4-13] gives the values of global solar radiation for the four orientations & the roof, three times a day for four days representing the four seasons.

	Sunrise	8.00 a.m.	Noon	4.00 p.m.	Sunset
21-Dec. Local time	**6.47**	**8**	**12**	**16**	**16.59**
I_{GN} (W/m^2)	0	68.13819	101.0069	62.57499	0
I_{GE} (W/m^2)	0	758.5444	101.0069	62.57499	0
I_{GW} (W/m^2)	0	586.5098	948.5593	531.4413	0
I_{GS} (W/m^2)	0	68.13819	130.6041	737.1852	0
I_{GH} (W/m^2)	0	300.7639	754.138	249.4998	0
21-Mar. Local time	**5.59**	**8**	**12**	**16**	**18.07**
I_{GN} (W/m^2)	0	88.16185	120.2793	89.0351	0
I_{GE} (W/m^2)	0	968.3724	132.7196	89.0351	0
I_{GW} (W/m^2)	0	333.921	668.4747	343.1651	0
I_{GS} (W/m^2)	0	88.16185	120.2793	958.092	0
I_{GH} (W/m^2)	0	551.2371	1085.586	568.7019	0
21-Jun. Local time	**4.54**	**8**	**12**	**16**	**18.59**
I_{GN} (W/m^2)	0	216.9427	127.2244	226.7929	0
I_{GE} (W/m^2)	0	932.8557	127.2244	100.6357	0
I_{GW} (W/m^2)	0	101.5959	254.7624	100.6357	0
I_{GS} (W/m^2)	0	101.5959	141.5301	944.7735	0
I_{GH} (W/m^2)	0	765.9178	1224.488	746.7134	0
21-Sep. Local time	**5.43**	**8**	**12**	**16**	**17.54**
I_{GN} (W/m^2)	0	90.75652	120.5168	86.87763	0
I_{GE} (W/m^2)	0	939.1234	120.5168	86.87763	0
I_{GW} (W/m^2)	0	351.7483	657.6504	306.0776	0
I_{GS} (W/m^2)	0	90.75652	176.0241	986.0719	0
I_{GH} (W/m^2)	0	603.1303	1090.335	525.5525	0

C. Calculating Solar Heat Gains (Q_{sol})

The solar heat gains is divided into two components:

1. Direct gain through glazing, depending upon the kind of glazing, and the shading strategies (either internal or external).
   This portion of solar heat gain can be calculated using the equation {4-6}.

2. Indirect gain through the building's opaque envelope, depending upon the U value of these parts (walls and roof).
   This portion of solar heat gain can be calculated using the following formula [(1)]:

$$Q_{sol}\text{ (Indirect)} = ((Ta + (a * I_{Gi} / 20) - LWR) - T_{thermostat}) * (U_{wall\ i} \times A_{wall\ i} / A_f)$$

-------- {4-7}

where:

Ta	= ambient air temperature.
a	= surface absorptivity.
I_{Gi}	= Global irradiance falling on the surface.
LWR	= temperature drop due to long wave radiation (2 °c for vertical surfaces and 5 °c for horizontal surfaces).
$T_{thermostat}$	= designed indoor temperature

3. The overall solar heat gain is calculated as the sum of the two previous components.

(1) Givoni, Baruch, "Climate Consideration in Buildings and Urban Design", p.132, 1998

a) Cairo Villa

Table [4-14] and [4-15] calculate Q_{sol} three times a day for four days representing the four seasons, sunrise and sunset time is shown.

	Sunrise	8.00 a.m.	Noon	4.00 p.m.	Sunset
21-Dec. Local time	**6.46**	**8**	**12**	**16**	**16.59**
Q_{sol} (W/m^2)	0	56.71691	78.07375	59.94923	0
21-Mar. Local time	**5.58**	**8**	**12**	**16**	**18.06**
Q_{sol} (W/m^2)	0	64.03514	68.54009	79.89552	0
21-Jun. Local time	**4.54**	**8**	**12**	**16**	**18.59**
Q_{sol} (W/m^2)	0	77.6453	54.34071	79.06293	0
21-Sep. Local time	**5.42**	**8**	**12**	**16**	**17.53**
Q_{sol} (W/m^2)	0	70.30989	71.81276	73.25481	0

b) Mit-Rehan Villa

	Sunrise	8.00 a.m.	Noon	4.00 p.m.	Sunset
21-Dec. Local time	**6.47**	**8**	**12**	**16**	**16.59**
Q_{sol} (W/m^2)	0	11.95719	33.50071	27.65002	0
21-Mar. Local time	**5.59**	**8**	**12**	**16**	**18.07**
Q_{sol} (W/m^2)	0	34.97307	55.42733	59.57596	0
21-Jun. Local time	**4.54**	**8**	**12**	**16**	**18.59**
Q_{sol} (W/m^2)	0	57.0377	67.64788	77.1138	0
21-Sep. Local time	**5.43**	**8**	**12**	**16**	**17.54**
Q_{sol} (W/m^2)	0	44.2262	62.18675	55.77484	0

(4-5-2-6) Evaluating the Balance Point Graphs

By substitution in the equation {4-1}, the balance point graphs can now be plotted together with the ambient air temperature graph (1) for judgment.

a) Cairo Villa

- In winter, the amount of gains is considerably less than the losses, having a peak value at noon, and indicating a need of increasing solar gains to overcome these losses.
- In spring, gains and losses balance, with a peak of gains near 4 o'clock in the afternoon.
- In summer, the gains from the roof are decreased considerably; this is noticed from the broken graph, which indicates a well insulated roof.
- In autumn, gains are slightly greater than losses indicating the need for limiting the undesirable solar heat gains during the daytime.
- A very significant property of such kinds of buildings is the very small contribution of the internal heat gains on the contrary to commercial and office buildings.

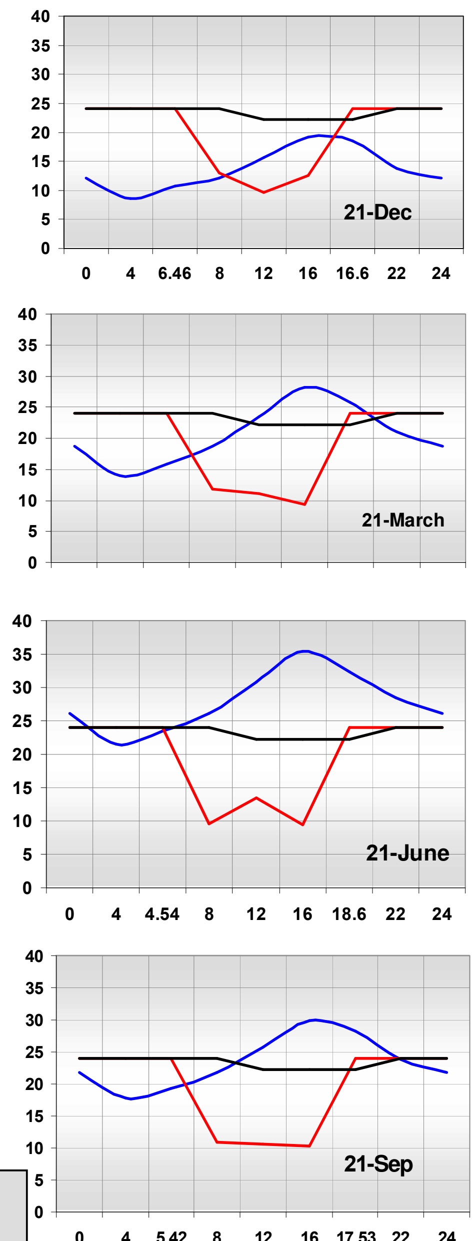


Fig.(4-17)
Balance Point Graphs – Cairo Villa
By the Researcher.

(1) Climatic data for different cities in Egypt is based on the charts taken from : Hosni, Samir, " Climate and Architecture, a National Evaluation", 1978.

b) Mit-Rehan Villa

- The solar heat gains either direct through the glazing or indirect through the opaque building material, are small as compared to the previous example, having an average balance point temperature at 15°, this is because of the large thermal mass of the building and the use of mashrabias on the openings; which limits the overall solar heat gains.

- Spring and autumn shows balance between the losses and the gains, indicating an ideal case.

- In winter, the limited solar heat gains cause continuous need of heating, increasing direct solar heat gains is a question.

- In summer, there is a need of cooling most of the time, with a potential of night cooling possibility that can be magnified by night ventilation.

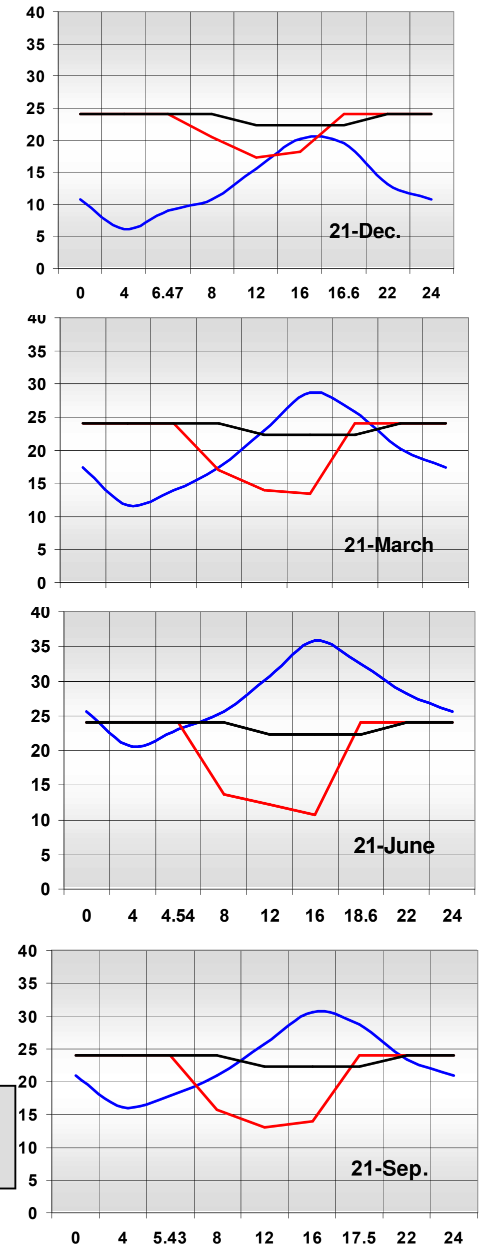


Fig.(4-18)
Balance Point Graphs – Mit Rehan Villa
By the Researcher.

(4-6) Conclusions

- The evaluation of the thermal performance of a building needs a quantitative dynamic method, whereas the thermal flow through the building takes place in a dynamic way, depending upon the activities, lighting, and equipment on one hand, and the solar impact on the other hand, having the building's envelope in between as a heat flow regulator.

- The balance point concept and understanding the modes of energy flow provides a way to reach an insightful design.

- The balance point temperature is the outdoor air temperature at which the heat generated inside the building balances the building's heat losses to maintain a desired indoor temperature.

- Balance point temperature represents the overall result describing the thermal condition of the building as a result of all heat forces acting on it, thus it is affected by these forces in addition to other factors describing the performance of the building in its location.

- The factors affecting the balance point temperature are:
  - Solar radiation.
  - Building envelope.
  - Internal heat gains.

- Buildings having high rates of heat transfer through their enclosures, having their balance point temperature near the thermostat temperature (desired indoor temperature) are classified as skin load dominated buildings, e.g. residential buildings. External heat source (solar radiation) plays here a major role representing the most effective thermal factor acting on the building, where its envelope acts as a protective shell.

- Buildings characterized by having generic thermal factors, i.e.: equipments, lighting and metabolism are classified to be internal load dominated buildings, where the balance point temperature is lowered, meaning that a low outdoor temperature is required for the heat losses and gains to balance at an acceptable indoor temperature, e.g.: office buildings. The solar radiation here also represents an important source of energy, in addition to the huge internal heat gains, and thus, increasing the cooling load.

- The balance point graph is a visual comparative one on which the ambient air temperature is plotted together with the balance point temperature curve over the course of the day, for each case study, four graphs are provided representing an average day of each season hence, the thermal performance of the building can be traced over the course of the year.

- In case the magnitude of the balance point is greater than that of ambient air temperature, this means that the building looses heat and vice versa; heat loss from the building will be proportional to the difference between the ambient air temperature and the balance temperature. The Less the difference in magnitude between the two values, the more efficient the building is.

- During the schematic phase, the designer's goal is to manipulate:
    1- The sources of internal heat gains.
    2- The enclosure heat transfer.
    3- The incoming solar energy.

CHAPTER V
Simulation of the Building's Thermal Performance

Introduction

- The needs of the architect to initiate a design taking in consideration the thermal forces acting on the building depend greatly upon the basic information, which may be supplied by traditional static methods or by dynamic simulation.

- This chapter will show the advantage of using more progressive simulation methods over traditional static ones, where saving time in the initial study phase is not the only goal, this is because precise conclusion helps to minimize the overall building cost either for the building materials, or for the installed A.C utilities which may be found worthless in case of using passive solar strategies as a substitute, then a detailed review of the research tool which is based on Excel application performed by the researcher is done showing the input and output screens of the program interface which in return is built on visual basic application that integrates with the former excel sheet for the sake of more facility in use.

- "At this point the site is still being analyzed and decisions regarding building geometry, materials and orientation are still being made. These three aspects of the design are arguably the most important determinants of overall building performance, making this the most crucial stage of most projects. However, even relatively imprecise analytical feedback at this stage can still be of great benefit to the designer, helping to guide the decision making process right from the start towards more effective and efficient design solutions - hopefully avoiding a lot of abortive work along the way."(1)

---

(1) March, Andrews and Raines, Caroline,http://www.squ1.com/ecotect/overview.html accessed 8 / 2003

- Although building dynamic simulation has been available to building design engineers for some time, steady state methods are still being used, despite of their insufficiency in providing the information required for making informed decisions on the best design options.

- "To determine the methods used for building design in Ireland a survey questionnaire was circulated to the "Royal Institute of Architects in Ireland" (RIAI) members and all "Chartered Institution of Building Services Engineers" (CIBSE) members in Ireland. The results of the survey showed that to assess the impact of changing a building's form, site, orientation, window design or insulation 63% of architects surveyed are using no method and 22% are using common sense or intuition." (1)

- Cost and doubts about usefulness were found to be the main inhibitions that make the architects and building services engineers in the UK not interested in such programs.

- "Bioclimatic design considers that architectural form and materials are to be treated as part of the environmental response of the building taking advantage of natural energy flows to create comfort conditions and to reduce the energy costs of the building. An important aspect of the interaction between buildings and the natural environment is the exposure to solar radiation. Although traditional methods are available for assessing solar access, developments in computer graphics have enabled computer modeling and rendering techniques to be used to model the effect of sun on the built environment." (2)

(1) Beattie, K.H, & Ward, I. C. "The Advantages of Building Simulation for Building Design Engineers", www.hvac.okstate.edu/pdfs/bs99/papers/PB/16.pdf , accessed 8 / 2003
(2) http://www.media.uwe.ac.uk/masoud/cal-97/papers/millar.htm, accessed 1 / 2004

(5-1) Simulation Design Tools

(5-1-1) Definition [1]

The term design tool is generally applied to a wide range of techniques, from the use of tabulated data sheets and manual calculation methods, through to sophisticated computer analysis software. In the context of this work, the term is used to describe computer software developed to replace laborious manual calculations used to inform the design decision making process. Using a computer to perform the mathematical component makes it possible to study effects not previously considered in many building designs.

(5-1-2) Evolution of Simulation Design Tools

“Since the early 1960’s, the use of computer modeling and simulation tools within the building industry has steadily increased. These tools have progressed from simple single-task applications with limited input and output requirements [Howard 1960, Belchambers, et al 1961], to quite sophisticated modeling systems that can simultaneously analyze a range of performance parameters.

However, after nearly 30 years of development, there is still some doubt as to the necessity and applicability of such tools to the design process. The basic question still remains: "Does the use of simulation and validation tools actually produce better buildings?". The real challenge is to make these tools applicable to the earlier stages of design, where a more informed analysis of possible alternatives can yield the most benefit and the greatest cost savings, both economic and environmental. Specialist skills may still be required, but just as important is the ability to translate the loosest architectural sketch into a valid input model and translate the result into fundamentally solid design feedback.”[2]

(1),(2) March, Andrew John, “Performance Analysis and Conceptual Design”, thesis presented for the degree of Doctor of Philosophy, The University of Western Australia School of Architecture and Fine Arts, 1997, www.squ1.com/research/papers/thesis/part_A.htm, - accessed 25/2/2004

(5-1-3) Advantages and Limitations of Using Computer Simulation over Traditional Methods

This part shows the advantages and limitations of using computer simulation programs over manual methods or charts.

(5-1-3-1) Advantages of Using Computer Simulation

(A) Precise Initial Information [1]

- Using the steady state methods does not provide the building designer with the information required for making informed decisions on the best design options.

- For informed decisions to be made, accurate information is required on the magnitude and duration of internal peak temperatures during the occupied period.

- This information is required for example by the building designer to decide if natural ventilation will work or if air conditioning is required. Accurate information is also required for the magnitude and time of occurrence of the peak heating and cooling loads and their variation over the heating and cooling season. The main influence on these loads (e. g. infiltration, or solar and casual gains from equipment lights and people) should also be determined accurately.

- If this information is not available to the building designer this means that opportunities are being missed to design buildings better in terms of environmental quality and energy consumption.

- Supplying the designer with a helping tool having a detailed data base saves a lot of effort, especially when the calculation process is done in the background without any interference, where his role is only to select variables and read the output.

---

(1) Beattie, K.H, & Ward, I. C. "The Advantages of Building Simulation for Building Design Engineers", www.hvac.okstate.edu/pdfs/bs99/papers/PB/16.pdf , accessed 8 / 2003

(B) Interactive Visual Dynamic Output

- One of the most important advantages of *some* simulation programs is its dynamic interaction with the non-specialized architect who is targeting a visual quick result that can be easily judged by the eye comparatively with other trials, and hence, the most suitable alternative can be chosen.

- The output can be in the form of dynamic charts or models, where thermal simulation, lighting, casting shadows, or even acoustics can be easily understood. (fig.(5-1),(5-2)).

- On the other hand, traditional and manual methods results were mostly numerical and complicated, consuming a lot of time and having a high possibility of error occurrence.

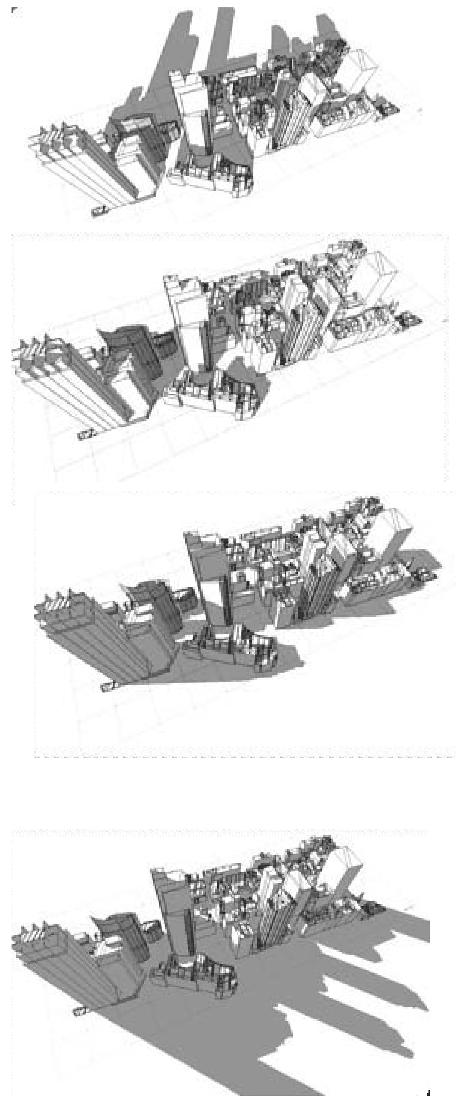


Fig.(5-1)
Sydney CBD Overshadowing Study
http://www.squ1.com/ecotect/gallery.html
accessed 8 / 2003

Fig.(5-2)
A Simple ECOTECT Model Using RADIANCE to Compare the Effect of Different Lighting Layouts
March, Andrews and Raines, Caroline,http://www.squ1.com/ecotect/overview.html accessed 8 / 2003

(C) Economy as a Result of Precision [(1)]

- "Computer simulation has become a very powerful and important technology for assisting engineers with their non trivial task of designing buildings and associated environmental systems such that the result is low fossil fuel consumption, good indoor conditions and minimal impact on the environment in general. Integrated modeling and simulation of buildings and systems allows engineers and other building design professionals to efficiently evaluate various energy saving strategies and environmental design options that cannot be judged adequately by more simple traditional design techniques."[(1)]

(1) Beattie, K.H, & Ward, I. C. "The Advantages of Building Simulation for Building Design Engineers", www.hvac.okstate.edu/pdfs/bs99/papers/PB/16.pdf, accessed 8 / 2003

- Building services engineers must ensure that the air conditioning systems that they specify for a building will adequately cater for the cooling load encountered and maintain design comfort conditions in the building. They usually add design margins to the load calculations to avoid the embarrassment and cost of having to replace the installed plant after the building has been handed over if the selected plant proves being inadequate, where they realize that the steady state method is a simplified method and that margins are necessary to compensate for this. Experience has shown that using this approach, the air conditioning plant will not be under- sized.

- Building services engineers do not normally check the plant sizes that they have designed unless occupants complain about the internal thermal conditions. This would apply if the heating or cooling plant was undersized and thus the possibility of identifying over sizing in most cases does not arise.

- Dynamic simulation programs are now available that allow building services engineers the possibility of checking their steady state air conditioning loads against dynamic simulation results, and showing a wide range of difference in sizing the A.C units with respect to traditional methods which means saving more expenses.

- However due to the conservative nature of the construction industry building services engineers continue to use the method that they are most familiar with.

- To encourage more use of dynamic simulation and thus achieve better designed buildings the buildings services engineers should be made aware of the potential for over sizing services using steady state methods.

(D) Indicating the Effect of Passive Strategies

- "Many of the new buildings being designed are non air- conditioned. In these buildings natural ventilation strategies often play an important role in achieving the desired conditions for occupants.
  To ensure that the proposed natural ventilation design strategy is effective for as much of the year as possible it is necessary to use dynamic airflow simulation in conjunction with dynamic thermal simulation. As steady state methods normally use fixed air change rates they are inadequate to design these new buildings."(1)

- "The information that is now required to design low environmental impact buildings includes duration of high temperatures, effect of window opening on internal environmental conditions, mixed mode operation, use of natural ventilation and daylight." (2)

(1),(2) Beattie, K.H, & Ward, I. C. "The Advantages of Building Simulation for Building Design Engineers", www.hvac.okstate.edu/pdfs/bs99/papers/PB/16.pdf , accessed 8 / 2003

(5-1-3-2) Limitations of Using Computer Simulation [1]

Using simulation models for building design has its limitations as existing models fail to tackle issue regarding data preparation in the initial design phases. Most programs available today are far from ideal. Major shortcomings of current simulation tools include:

- The program ***input*** is voluminous and scientifically detailed. Data, which is usually unavailable during early design stages, has to be assumed when doing the analysis.
- Program ***output*** consists of bulky computer printouts that confuse the user. Understanding and interpretation of the simulation results is difficult.
- Many detailed design tools are ***research orientated***. Learning to use them is difficult and a long time is required to become competent.
- The ***user interface*** of the tools is often neglected. Architects who are trained to express themselves graphically become frustrated by the strict data structure and requirements.
- The software does not allow users the ***flexibility*** to do any programming easily to meet particular needs.
- Result ***validation and accreditation*** are lacking. People are confused and uncertain about which programs will give better simulation results.

These shortcomings must be overcome (in the long run) by program improvement driven by the market and the users. To work effectively with the simulation tools, practitioners should learn to work within the limitations and understand the role of simulation in the building design process.

---

(1) Hui, S. C. M., "Simulation Based Design Tools for Energy Efficient Buildings in Hong Kong" , *Hong Kong Papers in Design and Development*, Vol. 1, 1998, pp. 40-46, Department of Architecture, University of Hong Kong , www.arch.hku.hk/~cmhui/hkpdd/hkpdd-v1.htm, accessed 25/2/2004

(5-1-4) Relation between Design Phases and Simulation.

Fig.(5-3) shows the possible applications of energy analysis at various stages of the building design process. “At the early design stages, only conceptual sketches and schematics, often rough and incomplete, are available. As the design proceeds, more information and detail will be developed. If energy analysis starts early in the generative design phase, then energy considerations can be integrated into the building form and design concept. It is believed that the best opportunities for improving the energy performance of a building occur early in the design process.”(1)

“Because of the possible time and effort required for a full thermal analysis, detailed simulation tools are not efficient for all design exercises. Provisions of other design tools for a quick assessment of design strategies would be very useful. For instance, the use of solar path and shading facility can allow the architect to repeatedly evaluate a design concept on solar shading with a minimum amount of effort. Design tools with different levels of sophistication should be used to meet the needs at various design stages.”(2)

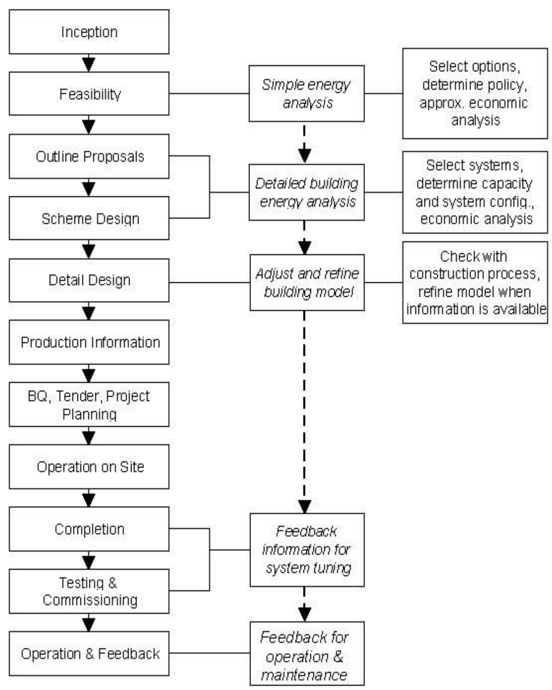


Fig.(5-3)
Relation Between Design Phases and Simulation
www.arch.hku.hk/~cmhui/hkpdd/hkpdd-v1.htm

(1),(2) Hui, S. C. M., “Simulation Based Design Tools for Energy Efficient Buildings in Hong Kong” , *Hong Kong Papers in Design and Development*, Vol. 1, 1998, pp. 40-46, Department of Architecture, University of Hong Kong , www.arch.hku.hk/~cmhui/hkpdd/hkpdd-v1.htm, accessed 25/2/2004

(5-1-5) The Need of a Conceptual Design Tool. [1]

The conceptual stage of design occurs very early in the design process. This is the time when a vast array of competing requirements are shaping the initial building form, when geometry, materials and orientation are still being formulated. As these are arguably the three most important determinants of building performance, this is the most crucial stage of a project.

Conceptual design is an initial process of generating ideas that then need to be evaluated and tested, for rejection or further refinement. Traditional methods of testing an idea involve quick perspective sketches, simple geometric analysis on a drawing board, or even small hand-calculations. The main criteria for these tests, is speed. Being able to quickly reject impractical ideas can save significant amounts of time. Each newly rejected idea providing one more clue to a more acceptable one.

In order to make environmental performance a practical consideration at this early stage, thereby informing the decision-making process as much as any other consideration, real and useful feedback has to be produced from what is often ill-defined and abstract information. The precise and detailed input requirements of most existing design tools preclude this. To use them, the designer must first enter the small amount of hard data they do have, and then arbitrarily quantify whatever else is needed before a result can be produced.

Overcoming this requires a completely different approach from the concise, solution-based nature of existing analysis tools.

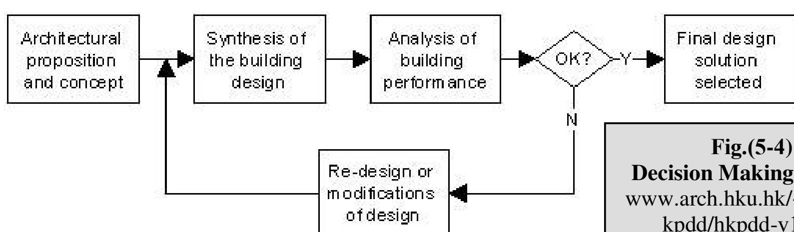


Fig.(5-4)
Decision Making Process
www.arch.hku.hk/~cmhui/hkpdd/hkpdd-v1.htm

(1) March, Andrew John, "Performance Analysis and Conceptual Design", thesis presented for the degree of Doctor of Philosophy, The University of Western Australia School of Architecture and Fine Arts, 1997, www.squ1.com/research/papers/thesis/part_A.htm, - accessed 25/2/2004

(5-1-6) An Intelligent Interface

The following requirements must be satisfied in the future interactive simulation programs:

- Reducing the perceived input requirements to define a model,
- Maximum utilization of whatever information is input.
- Allowance for constant development and refinement of the model.

Reducing input requirements and making the maximum use of whatever is input requires a step beyond traditional geometric interfaces that focus on geometric entities. Instead, focusing on architectural entities imbues the model with additional information which an intelligent interface can then use to automatically extract its own data or infer reasonable default values for items not directly input.

Additionally, basic relationships between architectural elements can be used to create geometric relationships between objects that can significantly reduce the time required when inputting and editing the model.

The following concepts are considered fundamentally important in the development of such an interface:

- Interactive modeling.
- Full graphical display of inputs and outputs.
- Multi-level inputs for all calculations.
- Simultaneous performance analysis.
- Use of components and library data.
- Interoperability with other tools.

(1) March, Andrew John, "Performance Analysis and Conceptual Design", thesis presented for the degree of Doctor of Philosophy, The University of Western Australia School of Architecture and Fine Arts, 1997, www.squ1.com/research/papers/thesis/part_A.htm, - accessed 25/2/2004

(5-2) Research Tool

Introduction

- This part of the chapter is meant to analyze the research tool which is developed by the researcher using Excel application to fulfill the main goal of the research.

- First, reasoning the need of such a tool is declared, followed by an explanation of the main function of the program, the database used as a source of information essential for calculations, and the flowchart of the program.

- Then, a detailed review of the program's user interface will be done, where it was developed using visual basic application that integrates with the former Excel application for the sake of a more easy use by non-specialists. The options and functions of each screen are shown in successive steps simulating the operation phases.

- Finally, the output screen of the program is reviewed to show its contents that are based on the same strategy of the balance point temperature method which was previously mentioned in the fourth chapter of the research.

- The user needs at this point to be aware how to read the graphical output so as to judge the thermal performance of the building in its site with its new group of skin parameters, where a quick visual analysis is enough for decision making.

(5-2-1) Program Rationale

- The need of a quick and easy method to plot the balance point graphs of a building dominates the potentials of needing such a tool, where the complicated long calculations of the solar radiation and the balance point temperature consume a lot of time and effort, it is also very possible to have errors while making hand calculations.

- An easy way of data input and output is needed by non specialists in order to have a dynamic opportunity of manipulating the available tools in the schematic phase of the design while the basic lines of the plan are still being drawn.

- Finally, the flexibility of using the program for most of the cities allover Egypt gives the designer the advantage of adapting the design to its site despite of the different climatic conditions.

(5-2-2) Program Function

- The function of the program is to study the effect of the building external envelope on its thermal heat gains for skin dominated (residential) buildings in their sites.

- The program is based on a two sided equation having the skin parameters on one side and the balance point graph on the other as an output of these items.

(5-2-3) Program Database

- The calculations are based on a series of tables representing different numerical properties of the skin parameters, these tables were previously mentioned in Chapter III, "Building Skin Parameters Affecting Thermal Heat Gains".

- For the terrain reflectivity, Table [2-4] is used as a reference.

- For other numerical properties characterizing the chosen location, table [5-1] shows the longitude, latitude together with the mean maximum and minimum temperatures in degrees Celsius for an average day of each season.

- Table [5-2] deals with the solar positioning with respect to the local time of the chosen site; sunrise and sunset timing together with the altitude and azimuth of the sun three times a day is tabulated for the 28 cities four times representing the same average day of each season referred to in table [5-1].

- The data shown in table [5-2] are based on calculation outputs using the "NOAA Solar Calculator", where it represents a very important piece of information to calculate direct and indirect solar heat gains.

Table [5-1] Latitude, Longitude and average (max.-min.) temperature [1]

	City	Lat.	Long.	21-Dec.		21- March		21-June		21-Sep.	
				max	min	max	min	max	min	max	min
1	**Cairo**	30.8	31.34	19.1	8.6	28.2	13.9	35.4	21.5	29.8	17.8
2	**Giza**	30.02	31.13	20.2	6.1	28.7	11.7	35.8	20.5	30.6	16.1
3	**Helwan**	29.52	31.2	18.8	8.6	28.3	14.2	35.3	21.5	30.1	18.6
4	**Alexandria**	31.12	29.57	18.3	9.3	23.6	13.5	29.6	22.7	27.7	17.8
5	**Ismaillia**	30.36	32.14	20.4	8.1	27.6	13.6	36.4	22.2	30.7	17.8
6	**Fayed**	30.2	32.17	19.9	7.9	28.3	12.9	35.9	20.9	30	16.8
7	**Port Said**	31.17	32.14	18	11.3	22.6	16.1	30.4	24.1	27.4	21.8
8	**Suez**	29.56	32.33	20.3	8.7	28.2	14.3	36.5	22.3	31.1	18.5
9	**Damietta**	31.25	31.49	18.4	8.2	23.2	13.7	31	21.2	27.6	18.7
10	**Mansoura**	31.03	31.23	19.6	7.3	27.3	12.3	34.9	20.7	30.3	17.6
11	**Damanhur**	31.02	30.28	19.6	7.7	26.4	12.3	32.5	20.2	29.5	17
12	**Tanta**	30.47	31	19.7	6	27.6	10.7	34.5	19.1	30.1	15.4
13	**El Arish**	31.07	33.45	19.3	8.3	23.6	13.2	30.6	21.1	28.6	17.9
14	**El Tor**	28.14	33.37	21.3	8	28	16.3	34.9	24.4	29.9	18.6
15	**Hughada**	27.17	33.46	20.6	9.6	26	16.1	32.6	24.8	28.5	19.7
16	**Qusier**	26.08	34.18	22.7	13.8	27.3	19.4	33.3	26.3	30.3	23
17	**Fayoum**	29.18	30.51	20.3	6.1	30.1	12.9	36.7	21.2	31.2	17.1
18	**Beni Suef**	29.04	31.06	20.8	5	30.1	12	36.8	20.1	31.8	15.8
19	**Minya**	28.05	30.44	20.6	4	30.6	11.8	36.9	20.2	31.2	15.6
20	**Asyout**	27.11	31.06	20.8	6.6	31.9	14.8	36.9	22.3	30.9	18
21	**Kena**	26.1	32.43	22.7	6.7	35.4	15.9	40.8	23.7	35.1	18.9
22	**Luxor**	25.4	32.42	23	5.4	34.8	15.7	40.7	23.6	35.1	17.8
23	**Aswan**	24.02	32.53	24.2	9.5	35.7	18.6	41.9	26.1	37.5	21.7
24	**Adindan**	22.3	32	26	9	33	21	40	26	36	22
25	**Siwa**	29.12	25.19	19.7	4.1	29.9	12.1	38	20.7	31.7	14.9
26	**Baharia**	28.2	28.54	19.9	4.7	30	12.7	36.8	20.6	31	15.9
27	**Dakhla**	25.29	29	21.4	4.4	32.7	14.3	38.6	23.1	33.2	17.4
28	**Kharga**	25.26	30.34	22.3	5.9	33.1	15.7	39.1	23.3	34	18.6

(1) Hosni, SamirBaiomy, “Climate and Architecture”, 1978, p.p.75-119

Table [5-2a] "Solar Position Table" (1)

		21-Dec					21-Mar					21-Jun					21-Sep				
		Sunrise	Altitude/Azimuth			Sunset	Sunrise	Altitude/Azimuth			Sunset	Sunrise	Altitude/Azimuth			Sunset	Sunrise	Altitude/Azimuth			Sunset
			8.00 am	12.00 pm	16.00 pm			8.00 am	12.00 pm	16.00 pm			8.00 am	12.00 pm	16.00 pm			8.00 am	12.00 pm	16.00 pm	
1	Cairo	6.46	12.9	36.4	9.98	16.59	5.58	25.4	60	25.9	18.06	4.54	37.6	83.2	35.6	18.59	5.42	28.8	60.5	23.3	17.53
			127	152	235			106	179	254			82.3	190	279			107	187	256	
2	Giza	6.47	12.7	36.5	10.3	16.59	5.59	25.2	60.1	26.3	18.07	4.54	37.3	83.3	36	18.59	5.43	28.5	60.6	23.6	17.54
			127	182	235			106	179	254			82.1	186	279			107	186	256	
3	Helwan	6.47	13	37	10	17	5.59	25	60	26	18.08	4.55	37	83	36	19	5.43	28	60	24	17.54
			127	182	235			105	178	253			82	185	278			107	185	256	
4	Alex.	6.54	11	35	10	17.02	6.04	24	59	27	18.12	4.56	36	82	37	19.07	5.47	27	59	24	17.59
			126	180	234			105	176	252			106	183	277			106	183	255	
5	Ismailia	6.44	13	35	9	16.54	5.54	26	59	25	18.03	4.49	38	83	35	18.57	5.38	29	60	22	17.5
			127	183	235			106	180	245			83	193	278			108	187	256	
6	Fayed	6.42	13	36	9.5	16.55	5.54	26	60	25	18.03	4.5	38	83	35	18.55	5.38	29	60	23	17.49
			127	183	236			106	180	254			82	194	278			108	188	257	
7	P.Said	6.46	12	35	8.8	16.52	5.54	25.7	58.8	25	18.03	4.47	38.3	82	35.2	18.58	5.38	29	59.2	22.5	17.5
			127	183	236			107	181	254			83.5	192	278			108	188	256	
8	Suez	6.41	13.7	36.5	9.4	16.54	5.53	26.3	60.2	25.2	18.01	4.49	38.4	83.2	34.7	18.54	5.37	29.6	60.6	22.5	17.48
			128	184	236			106	181	255			82.3	197	279			108	189	257	
9	Damietta	6.48	12.3	35	9	16.54	5.56	25.3	58.7	25.4	18.04	4.48	38	81.9	35.6	19	5.4	28.6	59.2	22.8	17.52
			128	182	235			107	180	253			83.4	189	278			108	186	256	
10	Mansou	6.48	12.2	35.5	9.5	16.56	5.58	25	59	25.8	18.06	4.51	37.5	82.3	35.9	19.01	5.42	28.3	59.6	23.2	17.53
			127	182	235			106	179	253			82.9	187	278			108	106	256	
11	Damanh	6.52	11.6	35.5	10.2	17	6.02	24.3	59	26	18.1	4.55	36.8	82.4	36.7	19.05	5.45	27.6	59	24	17.57
			126	181	235			106	177	253			82.5	180	278			107	184	255	
12	Tanta	6.49	12	35.7	10	16.58	5.59	24.8	59.3	26.2	18.08	4.53	37.2	82.6	36.2	19.02	5.43	28	60	23.6	17.55
			127	182	237			106	178	253			82.5	184	280			107	185	256	
13	El Arish	6.39	13.7	35.3	7.9	16.47	5.48	27	59	24	17.57	4.42	39.6	81.7	34	18.52	5.32	30.2	59.2	21.2	17.44
			129	185	237			108	184	255			84	202	279			109	191	257	
14	El Tor	6.33	15.9	38	9.56	16.54	5.49	27.7	61.8	24.7	17.57	4.49	39	84	33.5	18.45	5.33	31	62	22	17.44
			128	185	237			106	184	256			81.6	212	281			108	191	258	

(1) Solar position is calculated by the researcher using "NOAA Solar Calculator", given the city latitude and longitude from the previous data

Table [5-2b] Solar position table [1]

		21-Dec					21-Mar					21-Jun					21-Sep				
		Sunrise	Altitude/Azimuth 8.00 am	12.00 pm	16.00 pm	Sunset	Sunrise	Altitude/Azimuth 8.00 am	12.00 pm	16.00 pm	Sunset	Sunrise	Altitude/Azimuth 8.00 am	12.00 pm	16.00 pm	Sunset	Sunrise	Altitude/Azimuth 8.00 am	12.00 pm	16.00 pm	Sunset
15	Hurgada	6.3	16.1	39.1	9.96	16.55	5.48	28.1	62.8	24.8	17.56	4.51	39.1	85.1	32.2	18.43	5.33	31.5	63	22	17.43
			128	185	237			106	184	257			80.9	218	281			107	192	259	
16	Qusier	6.26	17.2	40.2	10.1	16.56	5.46	28.8	64	24.6	17.54	4.51	39.4	85.5	32.5	18.38	5.31	23.3	64	21.8	17.41
			128	186	237			106	186	257			80.1	233	282			107	194	260	
17	Fayoum	6.46	13	37.2	10.7	17.03	6	25.3	60.8	26.5	18.08	4.58	37.1	84.1	35.9	18.59	5.44	28.6	61.3	23.9	17.55
			127	182	235			105	179	254			81.5	186	279			107	186	257	
18	B.Suef	6.45	13.2	37.5	10.9	17.02	5.59	25.4	61	26.6	18.07	4.57	37	84.3	35.9	18.57	5.43	28.7	61.6	24	17.54
			127	182	235			105	179	254			81.3	186	279			107	186	257	
19	Minya	6.44	13.5	38.5	11.7	17.06	6.01	25.3	62	27.2	18.09	5.01	36.6	85.3	36	18.57	5.45	28.7	62.6	24.5	17.55
			126	182	235			105	178	254			80.5	184	280			106	185	257	
20	Asyout	6.41	14.3	39.4	12	17.06	6.59	25.8	62.9	27.1	18.07	5.02	36.7	86.2	35.5	18.53	5.43	29.3	63.4	24.4	17.54
			126	182	236			104	178	255			79.9	190	281			105	186	258	
21	Kena	6.32	16.1	40.4	11.4	17.02	5.53	27.5	64.1	26	18.01	4.58	38	86.6	33.9	18.44	5.37	30.9	64.4	23.2	17.47
			127	184	237			105	182	257			79.5	220	282			106	190	259	
22	Luxor	6.3	16.7	41.4	11.9	17.04	5.53	27.7	65	26.3	18.01	5	37.8	87.3	33.7	18.42	5.37	31.2	65.3	23.4	17.47
			127	184	237			104	182	257			78.8	232	283			105	191	259	
23	Aswan	6.27	17.5	42.4	12.4	17.06	5.52	28.2	66.1	26.3	18	5.01	37.8	87.6	33.4	18.39	5.37	31.6	66.3	23.4	17.47
			127	184	237			104	183	258			78.1	256	283			105	191	260	
24	Adindar	6.27	17.7	44	13.9	17.13	5.56	27.7	67.6	27.4	18.03	5.08	36.6	88.2	33.7	18.39	5.4	31.2	68	24.5	17.5
			126	183	237			102	180	258			76.7	-57	284			103	190	260	
25	Siwa	7.08	9	37.2	14.8	17.25	6.22	20.4	60.3	31.4	18.3	5.2	32.1	82.6	40.9	19.21	6.06	23.8	61.4	28.8	6.17
			123	175	232			102	167	250			79.2	140	277			103	174	253	
26	Bahria	6.51	12.2	38.5	13.8	17.13	6.08	23.7	62	28.8	18.16	5.08	35	85.2	37.6	19.04	5.52	27.1	62.7	26	6.03
			125	179	234			103	174	253			79.7	163	279			105	181	256	
27	Dakhla	6.43	13.8	41.1	14.5	17.18	6.08	24.4	64.5	29.4	18.15	5.14	34.6	87.5	37.1	18.58	5.52	27.8	65.3	26.6	6.02
			125	179	235			102	173	246			78.1	148	281			103	182	257	
28	Kharga	6.39	14.9	41.1	13.3	17.12	6.01	25.8	65	28	18.09	5.08	35.9	88	35.7	18.51	5.46	29.2	65.2	25.2	5.56
			126	181	236			103	177	255			78.5	184	282			104	185	258	

(1) Solar position is calculated by the researcher using "NOAA Solar Calculator", given the city latitude and longitude from the previous data

(5-2-4) Program Flowchart [1]

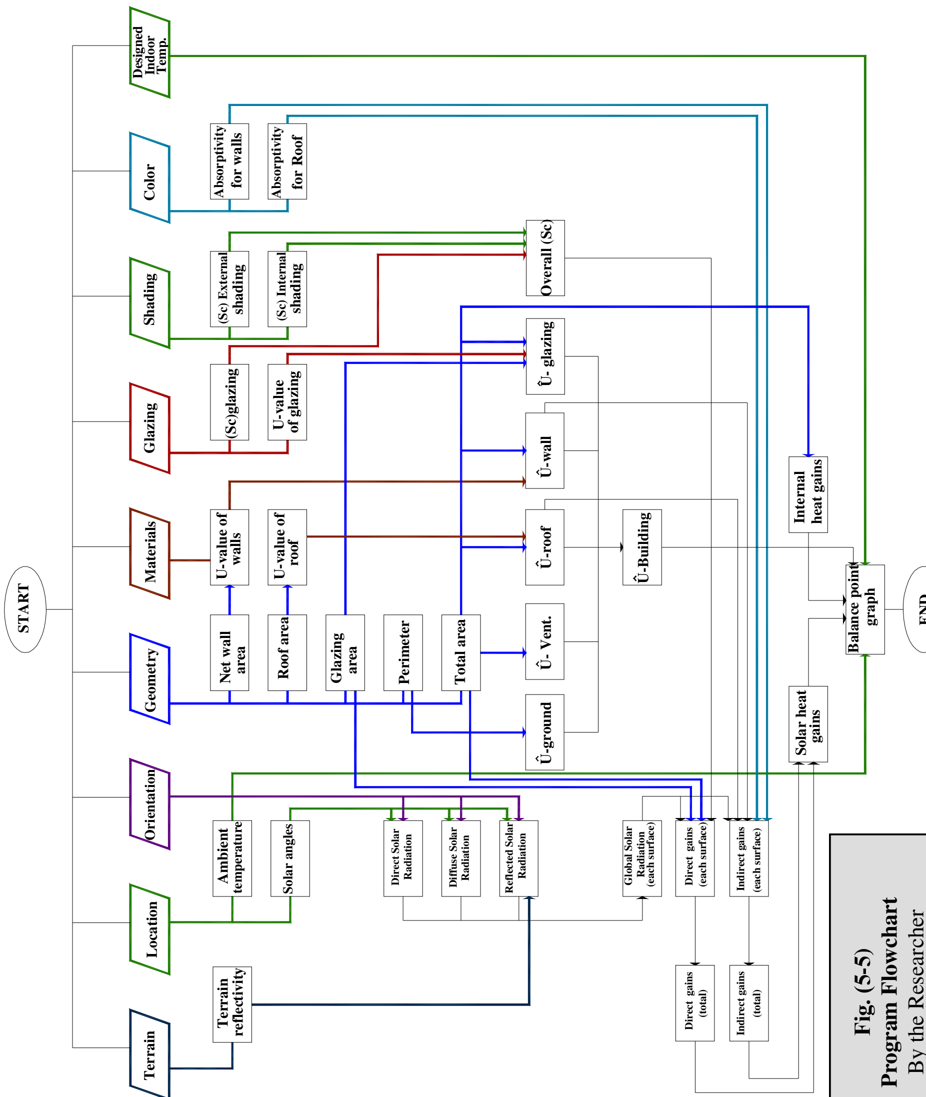


Fig. (5-5)
Program Flowchart
By the Researcher

---

(1) The program flowchart shows the overlap of the different elements in calculations on their way to reach the final goal represented by the balance point graph.

(5-2-5) Program Interface

The program interface consists mainly of a main window and eight dialog windows, where the strategy of operation depends on the values and selections made by the user in each dialog window.

(5-2-5-1) Main Window

The main window represents the node of the program from which the accessibility to the dialog windows is possible using the buttons on the right. The upper part of the main window shows the path of the Excel sheet linked to the interface, where this path can be altered to point to another path. The designed indoor temperature is set as a final step before calculation, having a range between (18 and 30℃). (Fig.(5-6))

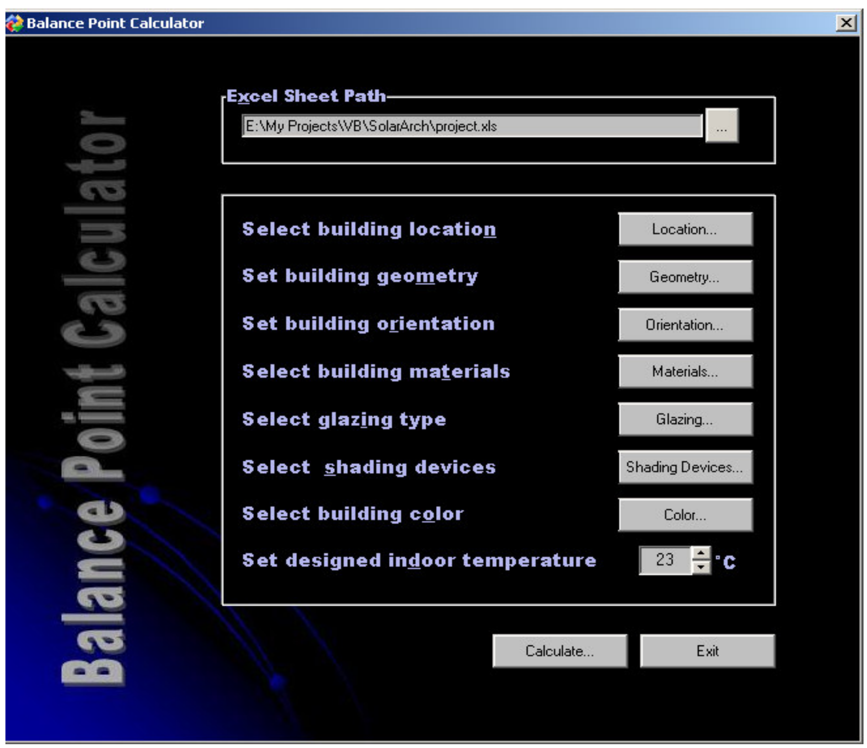


Fig. (5-6)
Research Tool, Main Window
By the Researcher

(5-2-5-2) Location Window

- This dialog window reads the city and terrain data from the Excel sheet allowing the user to make his selections, plotting the corresponding reflectivity (r) of the selected terrain (fig.(5-7)).

- On pressing (O.K), the program returns to the main window for the next step.

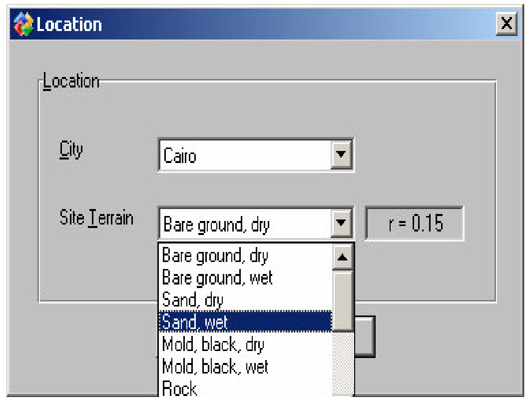


Fig. (5-7)
Research Tool, Location Window
By the Researcher

(5-2-5-3) Geometry Window

- This window allows the user to set the dimensions of the outer skin of the building numerically in meters (length, breadth, and height) , also the number of floors and the percentage of glazing for each elevation according to the design needs.

- On pressing (O.K), the program returns to the main window for the next step (Fig.(5-8)).

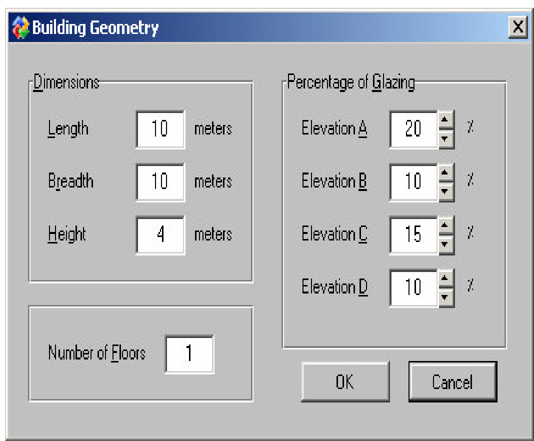


Fig. (5-8)
Research Tool, Geometry Window
By the Researcher

(5-2-5-4) Orientation Window

- This window allows the user to set the orientation of the building which is represented by the azimuth angle of elevation (A) relative to the north in a clockwise direction, and having a range between (0 and 360) degrees.
- On pressing (O.K), the program returns to the main window for the next step (Fig.(5-9)).

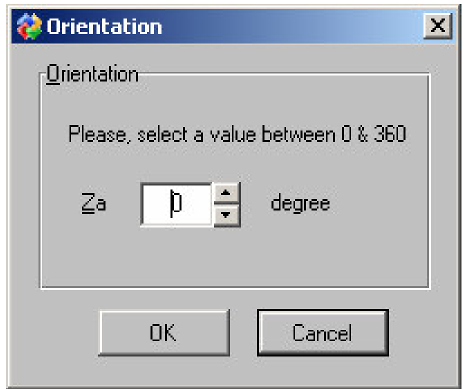


Fig. (5-9)
Research Tool, Orientation Window
By the Researcher

(5-2-5-5) Materials Window

- This window allows the user to choose the proper material for the opaque walls of the building, and the insulation degree of the roof, where the U-value is plotted beside each selection for indication.
- On pressing (O.K), the program returns to the main window for the next step (Fig.(5-10))

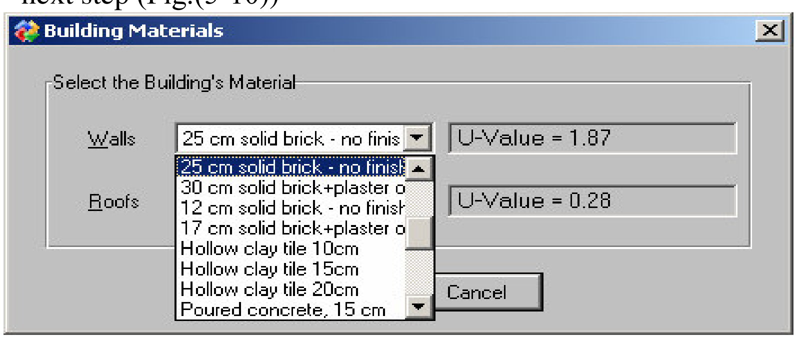


Fig. (5-10)
Research Tool, Materials Window
By the Researcher

(5-2-5-6) Glazing Window

- This window allows the user to choose the suitable glazing for each elevation individually; the shading coefficient (Sc) and the U-value are plotted beside each selection indicating the performance numerical evaluation of the selection.

- The glazing percentage for each elevation was previously set in the geometry window.

- On pressing (O.K), the program returns to the main window for the next step.

- Note that the selections for all the dialog windows are sent back to the excel sheet linked to the interface where all the calculations are done in the background (Fig.(5-11))

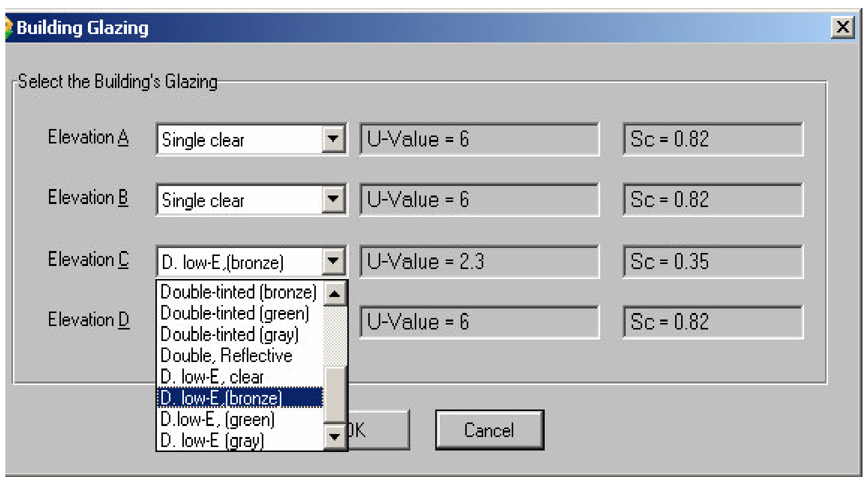


Fig. (5-11)
Research Tool, Glazing Window
By the Researcher

(5-2-5-7) Shading Window

- This window allows the user to choose the suitable external and internal shading strategy for each elevation individually, showing the corresponding shading coefficients (Sc) for the selections.
- Note that the overall (Sc) of the voids is the product of the shading coefficients of the glazing, external, and internal shading.
- On pressing (O.K), the program returns to the main window for the next step (Fig.(5-12)).

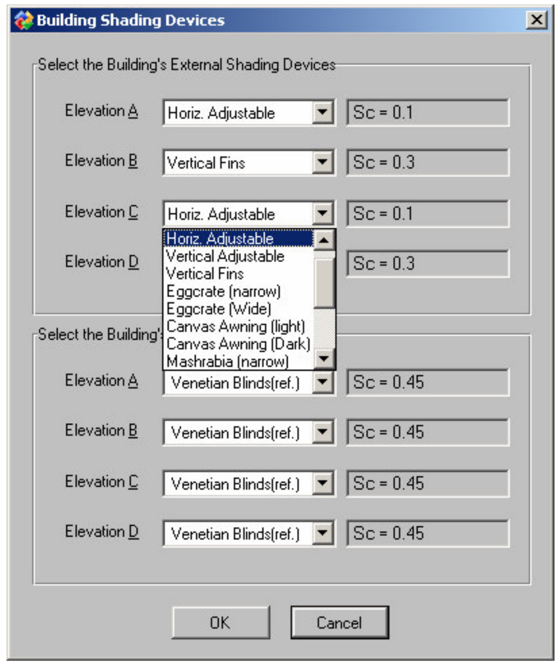


Fig. (5-12)
Research Tool, Shading Window
By the Researcher

(5-2-5-8) Color Window

- This window allows the user to choose the color of the walls and roof of the building declaring the absorptivity (a) for each selection.
- On pressing (O.K), the program returns to the main window for the next step (Fig.(5-13)).

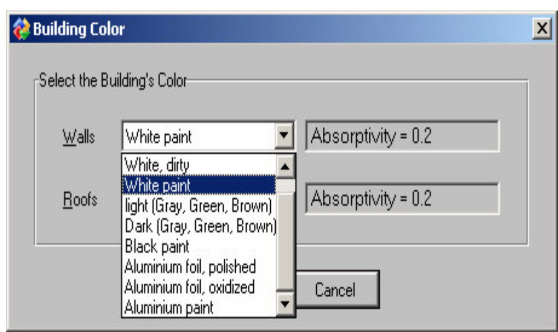


Fig. (5-13)
Research Tool, Color Window
By the Researcher

(5-2-5) Program Output

- The program output represents the final screen of the user interface, where the user at this point is supplied by the balance point graphs of the designed building in its site according to the group of choices that he has previously made.

- The screen consists mainly of two areas; the left one is a table of the chosen parameters of the building skin defining the studied case, while the right area consists of four balance point temperature graphs for an average day of the four seasons to cover the thermal adaptation of the building in its site over the course of the year, each graph has a source table identifying the ambient air temperature, the balance point due to internal heat gains, and balance point due to overall heat gains including solar gains.

- The user has the option of manipulating any of the available inputs, following a comparative analysis strategy, where a quick visual analysis is sufficient for judgment, this is made more easy as the program saves the last changes made by the user, accordingly any slight changes are easily made by activating the windows in question without repeating all the previous steps.

- The most suitable graphs are those having minimum requirements of cooling or heating, and balancing the night losses with the day gains.

- Fig.(5-14) shows the output window of the user interface.

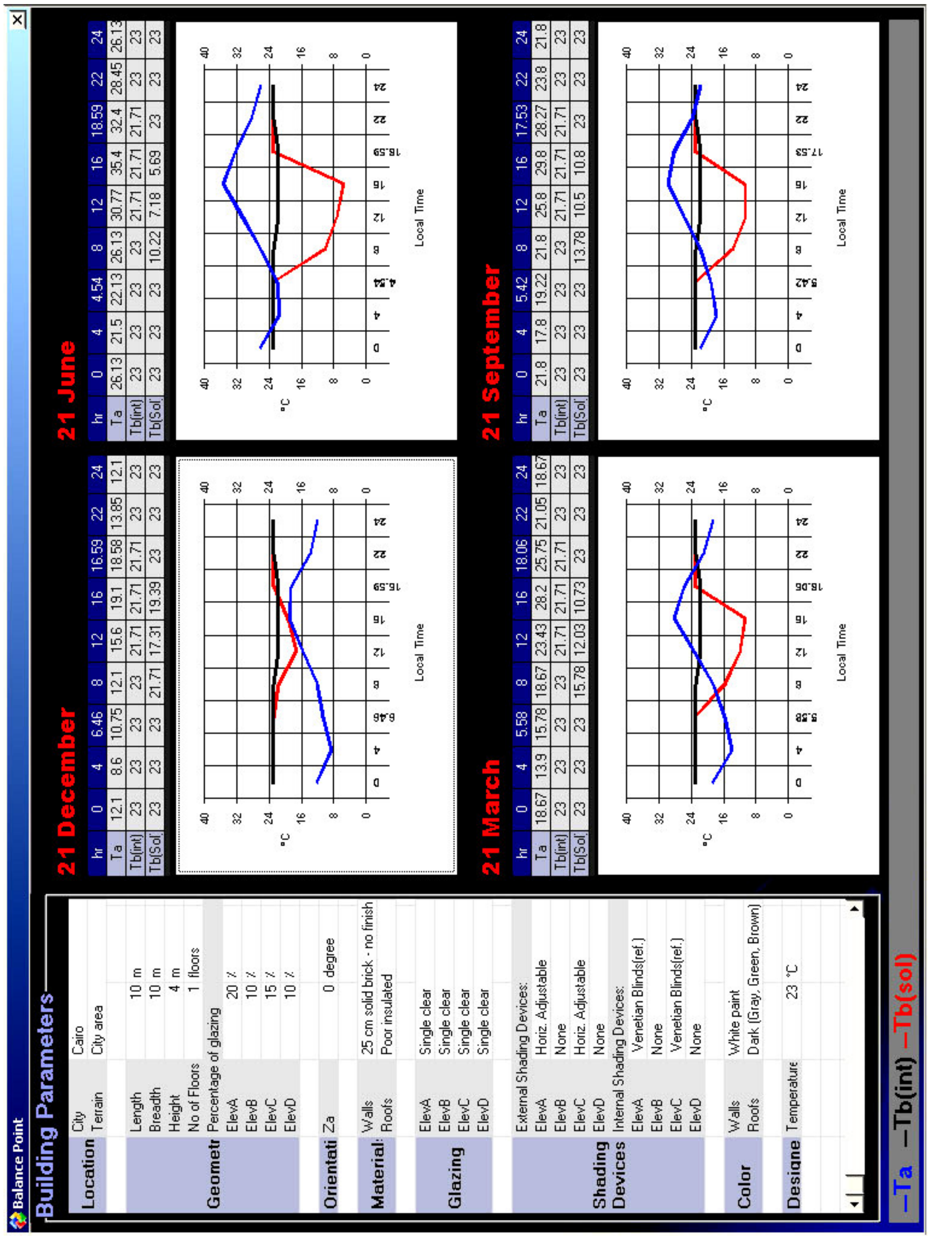


Fig. (5-14)
Research Tool, Output Window
By the Researcher

(5-3) Conclusions

- Building dynamic simulation has been available to building design engineers for some time. However steady state methods are still being used and these methods do not provide the information required for making informed decisions on the best design options.

- For informed decisions to be made, accurate information is required on the magnitude and duration of internal peak temperatures during the occupied period.

- One of the most important advantages of the simulation programs is its dynamic interaction with the non-specialized architect who is targeting a visual quick result that can be easily judged by the eye on the contrary to traditional and manual methods, where results are mostly numerical and complicated, consuming a lot of time and having a high possibility of error occurrence.

- Dynamic simulation programs that allow building services engineers the possibility of checking their steady state air conditioning loads against dynamic simulation results are now available, and showing a wide range of difference in sizing the A.C units with respect to traditional methods which means saving more expenses

- Simulation must be developed in sophistication with the development of the design process, accordingly, more than one level of simulation programs might be needed over the different courses of designing the building.

- The following requirements must be satisfied in the future interactive simulation programs:
  - Reducing the perceived input requirements to define a model,
  - Maximum utilization of whatever information is input.
  - Allowance for constant development and refinement of the model.

- The need of a quick method to plot the balance point graphs of a building, an easy way of data input and output in order to have a dynamic opportunity of manipulating the available tools, and the flexibility of using the program for most of the cities allover Egypt to give the designer the advantage of adapting the design to its site despite of the different climatic conditions are the main potentials of needing such a tool.

- The function of the program is to study the effect of the building external envelope on its thermal heat gains for skin load dominated (residential) buildings in their sites, where it is based on a two sided equation having the skin parameters on one side and the balance point graph on the other as an output of these items.

- The research tool is based on Excel application performed by the researcher while the program interface is built on visual basic application that integrates with the former Excel sheet for the sake of more facility in use.

- The program interface consists mainly of a main window and eight dialog windows, where the strategy of operation depends on the values and selections made by the user in each dialog window, the main window represents the node of the program from which the accessibility to the dialog windows is possible

- The program output is represented by the final screen of the user interface, where the user is supplied by the balance point graphs of the designed building in its site according to the group of choices that he has previously made.

- The user needs at this point to be aware how to read the graphical output so as to judge the thermal performance of the building in its site with its new group of skin parameters, where a quick visual analysis is enough for decision making.

CHAPTER VI
Case Study

Introduction

- This part of the research represents the practical application for all the previous chapters using the computer interface developed by the researcher.

- The chapter will first study the site chosen for application; a historical review for the vanished lands of Nubia is followed by a detailed study of the Nubian house clarifying the traditional treatments of the building skin parameters, followed by the effects of the foundation of the High Dam, the birth of Lake Nasser and the new features and potentials of the region in its new era.

- Then, a practical comparative analysis will be done using the computer interface in a matrix of trials and errors to criticize the performance of each element of the outer envelope individually.

- The most suitable balance point graph can be easily judged by visual analysis only, where both of the following features of the graph characterize the efficiency of the building's thermal performance:

  1- Smallest areas between the ambient temperature curve and the balance point curve indicate minimum needs for cooling or heating.
  2- Equal areas of cooling and heating needs; indicate the compensation of the gains to the losses and vice versa.

- Finally, a hypothetical example is proposed by the researcher as a result of the former analysis giving *one of the possible treatments* for the external envelope in the chosen site, where many other combinations may lead to similar thermal results by manipulating the skin parameters.

- Site limitations may force certain solutions regarding the building geometry, orientation or materials, thus, the idea of a prototype is not practical.

- This method represents a scientific way of decision making in the schematic phase of the design whilst the basic lines of the plan are still being drawn, helping the architect to make up his mind before making a detailed planning of the building, thus avoiding any missing points that may cause a non desirable solution.

- The balance point graphs of the different proposed groups of alternatives chosen by the user reveals some facts which may not be clear to a non specialist, where a comparative visual analysis is enough for evaluation.

(6-1) A Historical Approach to the Chosen Site

- The region of the chosen site is a very special one, where it witnesses nowadays a new birth of the Nubian civilization after several years of banishment, where the lands of Nubia were flooded after the construction of the High Dam in1964.

- The great economical potentials forced by the presence of Lake Nasser provide a fertile environment for investment, either in tourism, fishing, or even industrial activities depending upon the natural resources of the region.

- "Nubia contains dozens of sites of archaeological interest, including 24 temples, as well as fortresses and tombs. Many of these, including Dendour, Ellessiya, Amada and Wadi al-Sebowa were menaced by the waters of the High Dam." [(1)]

- Considering an environmental approach to design the buildings in the region is a real challenge for the architects, where binding the gained traditional experience together with the most recent scientific methods are the tools to reach an optimum solution.

- This part will draw light on the history of the region, the features of the Nubian house, and the changes after the construction of the High Dam.

(6-1-1) Old Nubia

- "Nubia was divided into three district groups, each with its own language; the Kanzi (Kanuz) area lay on the north, its people spoke Fadika, the Arab district lay in the middle, its people as the region's name would suggest, spoke Arabic, the Mahas district ran south joining the Nubi district to the Sudanese borders at Adindan"[(2)] (fig.(6-1)).

---

(1) "The Nubians and the Dam", http://carbon.cudenver.edu/stc-link/aswan2/culture.html - accessed 2/2004
(2) El Hakim, Omar, "Nubian Architecture", 1993, p.10

- Nubia was composed of 42 administrative areas called nahiat, each governed by an "Umda", they were in turn divided into small communities called "El-Naga'".

- By 1960, the total population of Nubia reached 48,028 person.

- The Nubians were very stick to their lands and depended mainly on agriculture and breeding animals where the export of dates was the main source of income in Nubia before the lands were flooded on three phases; at 1902 after the building of the Aswan Dam, the second time when the dam was elevated in1933, and finally at 1964 after the construction of the High Dam.

- Ironically, fishing never became an important factor that contributed in the economy or even food for the natives, where a very limited number of boats were possessed by the Nubians in Kanuz.

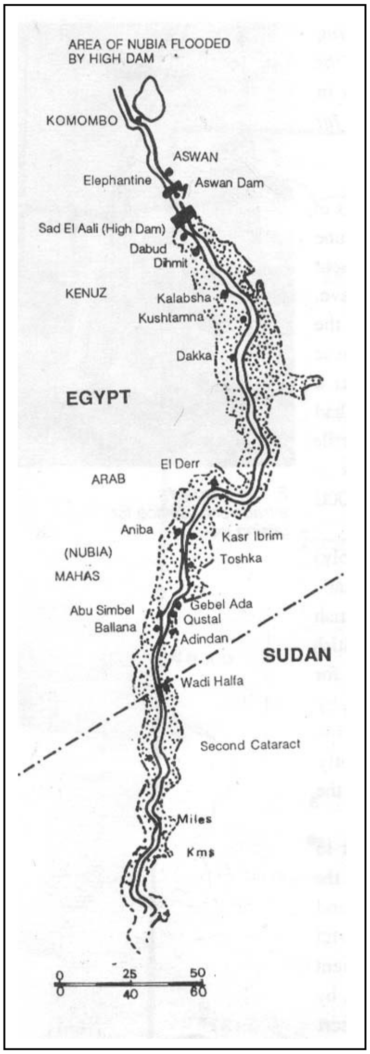


Fig. (6-1)
Old Nubia
El Hakim, Omar, "Nubian Architecture", 1993, p.10

(6-1-2) The Traditional Nubian House

- The Nubian house had a unique identity, having harmony with the surrounding nature and adapting with the available resources, either in materials or building technology.

- The building technology depended mainly on the human factor, where the members of the family shared in the construction of the houses; a Nubian proverb illustrating that tradition says that "One man cannot build a home, but ten men can easily build twenty homes"(1).

- "The houses in Nubia which made up the Naga' extended 320 km. along the Nile at irregular intervals at a staggered line more or less parallel to the river.
  At the north in the Kanuz district, where the bank was steep, dwellings extended following the natural contours of the ground forming clustered terraces. (fig.(6-2))
  Where the bank was relatively flat as in the Arab and Mahas districts, the dwellings stood out in bold outlines in rows where they were clustered towards the center which may contain the main mosque, a communal guesthouse, a post office and a few shops"(2)

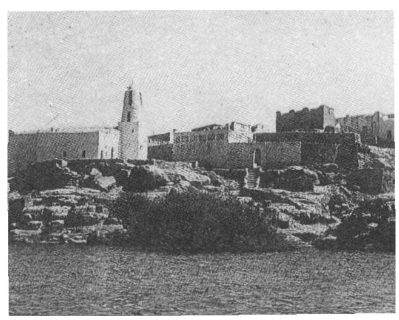


Fig. (6-2)
Terrace Houses in Kanuz
El Hakim, Omar, "Nubian Architecture", 1993, p.15

- The following points declares the main features of the skin parameters of the traditional Nubian house

(1) El Hakim, Omar, "Nubian Architecture", 1993, p.15
(2) El Hakim, Omar, "Nubian Architecture", 1993, p.15

(6-1-2-1) Building Materials [1]

- The materials and methods of construction of the walls and roof of the Nubian house were greatly affected by the surrounding environment, where all the solutions were homogenous and successful.

(A) Walls

- In the middle and the south, where the Nile bank was relatively wide at the Arab and Mahas districts, the mud was available and plentiful; a method known as "Tuf" or "Galos" technique of construction prevailed.

- The walls were made of mud or mud brick were half an arm's thick (40-45 cm.), thus minimizing the heat transfer by either convection or radiation from the surrounding media.

- In the Kanuz district at the north of old Nubia, where the Nile bank was very narrow with steep contours, stone walls were built. Earth mixed with husk or mud was used as mortar and the surfaces were finished with a layer of clay and sand. The random rubble stone was brought from the adjoining hills and transported to the site by donkeys.

(B) Roof

- In the middle and southern areas, of the Arabs and Mahas, the agriculture lands were spread with the presence of plenty of palms, the roofs of the houses were made of palm trunks and acacia wood beams, on the other hand, roofs were constructed as catenary vaults and domes in the northern lands at Kanuz where the agriculture lands were limited.

(1) El Hakim, Omar, "Nubian Architecture", 1993, p.17

(6-1-2-2) Openings

- Windows were mostly narrow slits located just below the roof, so as to provide privacy and to reduce the area exposed to the heat and glare of the sun.
- Glass was rarely used, where it was specially brought from Aswan, wooden shutters and doors were more common in case of bigger openings.

(6-1-2-3) Orientation

- "Throughout Nubia, principal entrances to the houses faced the river whether they were on the east, or west banks of the Nile, on approaching the front of a dwelling towards the main entrance, a person had his back to the river".[1]

(6-1-2-4) Color

- "The homes were generally white washed particularly in the Kanuz and Arab districts. The exteriors of the houses were plastered with a mixture of mud, clay and rock salt from the neighboring hills".[2]

- The white colors of the buildings show the inherited awareness of the color's role with respect to heat gain by radiation.

Fig. (6-3)
White Facades of the Nubian House
http://4egypt.info/nubian.htm

(1) El Hakim, Omar, "Nubian Architecture", 1993, p.15
(2) El Hakim, Omar, "Nubian Architecture", 1993, p.18

(6-1-2-5) Layout

- Mainly, the traditional plan of the Nubian house consisted of a main entrance that led to an open courtyard or "Haush", with rooms adjoining the exterior walls at one or more of its sides.

- "In the Kanuz district, houses were structured along the lines of the extended family, and were generally built in semi-detached terraces. There were also single dwellings, particularly in the Arab and Mahas districts, where the house was build with a perimeter wall surrounding a square or roughly rectangular courtyard. Any extra space in the Haush was used for developing the house."(1)

(6-1-2-6) Examples

(A) Row Housing in Northern Nubia

- Fig. (6-4) shows the morphology of the Nubian house at Kanuz; the row housing, the rooms clustered around the main court, thick stony walls, the presence of a terrace facing the Nile and having a "Mastaba" for seating the guests.
- The elevation and section show the narrow slits of the windows and using the catenary vault in construction
- White decorated elevation gives the house a unique identity.

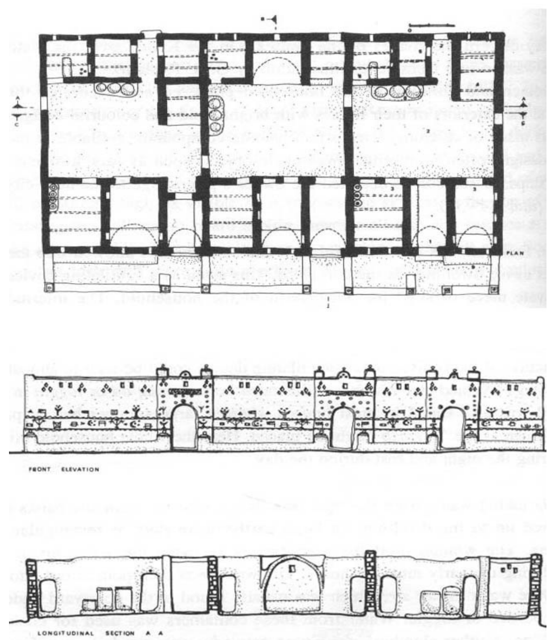


Fig. (6-4)
Row Houses in Kushtamna West, Kanuz District
El Hakim, Omar, "Nubian Architecture", 1993, p.20

(1) El Hakim, Omar, "Nubian Architecture", 1993, p.15

(B) Single Houses in Middle and Southern Nubia

- Although the same spirit of the houses in Kanuz is found in those at Arab and Mahas districts due to the same social and cultural factors, the topography and geography caused some differences.

- Fig.(6-5) shows the morphology of the Nubian house at middle and southern Nubia; packed mud (Tuf) was used as a building material for walls, whilst palm trunks were used for roofs as previously mentioned.

- Windows were organized similarly to those of northern Nubia.

- Shading was available for entrances, loggia, and courts using palm trunks

- Fig.(6-6) shows a plan of a single house in the southern Mahas district at Abusimbel west, where the outer loggia at the front of the house is shaded by palm trunks and serves as a guest area.

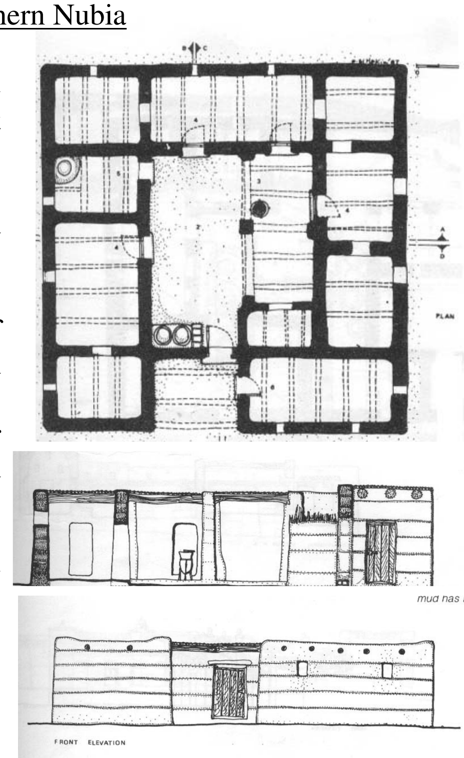


Fig. (6-5)
A House in Balana Village, Mahas District
El Hakim, Omar, "Nubian Architecture", 1993, p.22

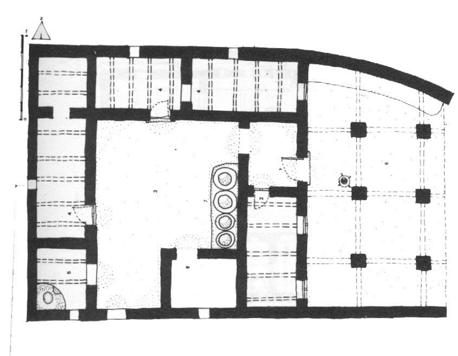


Fig. (6-6)
A House in Abusimbel West, Mahas District
El Hakim, Omar, "Nubian Architecture", 1993, p.25

(6-1-3) The Birth of Lake Nasser

- In June 1964, with the construction of the High Dam, the lands of old Nubia vanished forever as they were flooded by the water of the river.

- The Nubian population was made to leave; nearly 50,000 Egyptian Nubians were resettled at Komombo and Esna to the north of Aswan.

- The crown of the High Dam is 196m. above the sea level, extending 3.6 km. from shore to shore, causing the existence of an enormously giant lake to its south, having a length of 500 km. and a width ranging from 5 to 45 km. with an overall approximate surface area 5000 square kilometers, and having a water level at its peak 189 m. above the sea level.[1]

- The borders of the lake are difficult to be drawn accurately due to the continuous fluctuation of the water level with the annual floods, which must be taken in consideration in the future projects on its banks.

- Fig.(6-8) shows a map of the lake in its recent condition, noting its extension within the Sudanese lands, the map also indicates the temples on the banks of the lake, the positioning of the High Dam with respect to the old Aswan (British) Dam.

Fig. (6-7)
Lake Nasser as Seen from The Crown of The High Dam
http://www.ilec.or.jp/database/afr/afr-19.html

(1) El Hakim, Omar, "Nubian Architecture", 1993, p.12

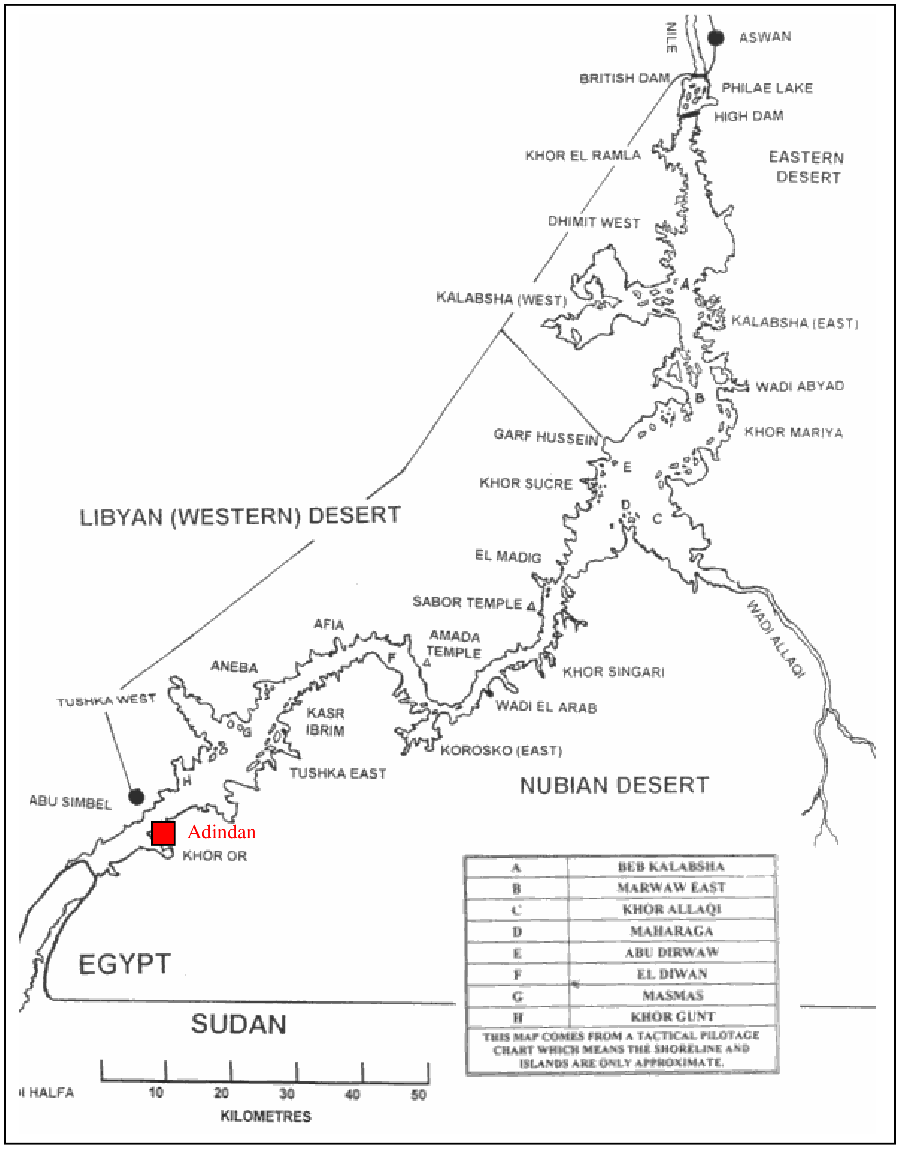


Fig. (6-8)
Lake Nasser -Map
http://www.african-angler.co.uk/lake.html

(6-2) Application

- The application is based on a hypothetical mother case of a 100 m2 house having dimensions (10m length X 10m width X 4m height), and a glazing percentage 15% for all elevations, 25 cm brick walls are used for opaque surfaces, having light (beige-green –gray) color, while the roof is moderately insulated and having a dark gray color. No shading strategies are used for the clear glazed openings, and the building is oriented towards the four marginal directions (Za = 0) [1].

- The building is located at Adindan on the east bank of Lake Nasser facing Abusimbel with a longitude 32° west and a latitude 22°30´ north, which means that the solar path in the sky dome will be inflected from south to north in summer, representing a unique case in Egypt, however, the research tool gives opportunity for application in 28 other cities allover Egypt.

- Sheet (6-1) represents the mother case of the application, where each of the previous variables (except location) will be manipulated separately to monitor its effect on the balance point graph, the internal designed temperature is assumed to be 24°c for all cases.

- The surface area is fixed for all cases (100m2) meaning that only proportions of the layout will be changed.

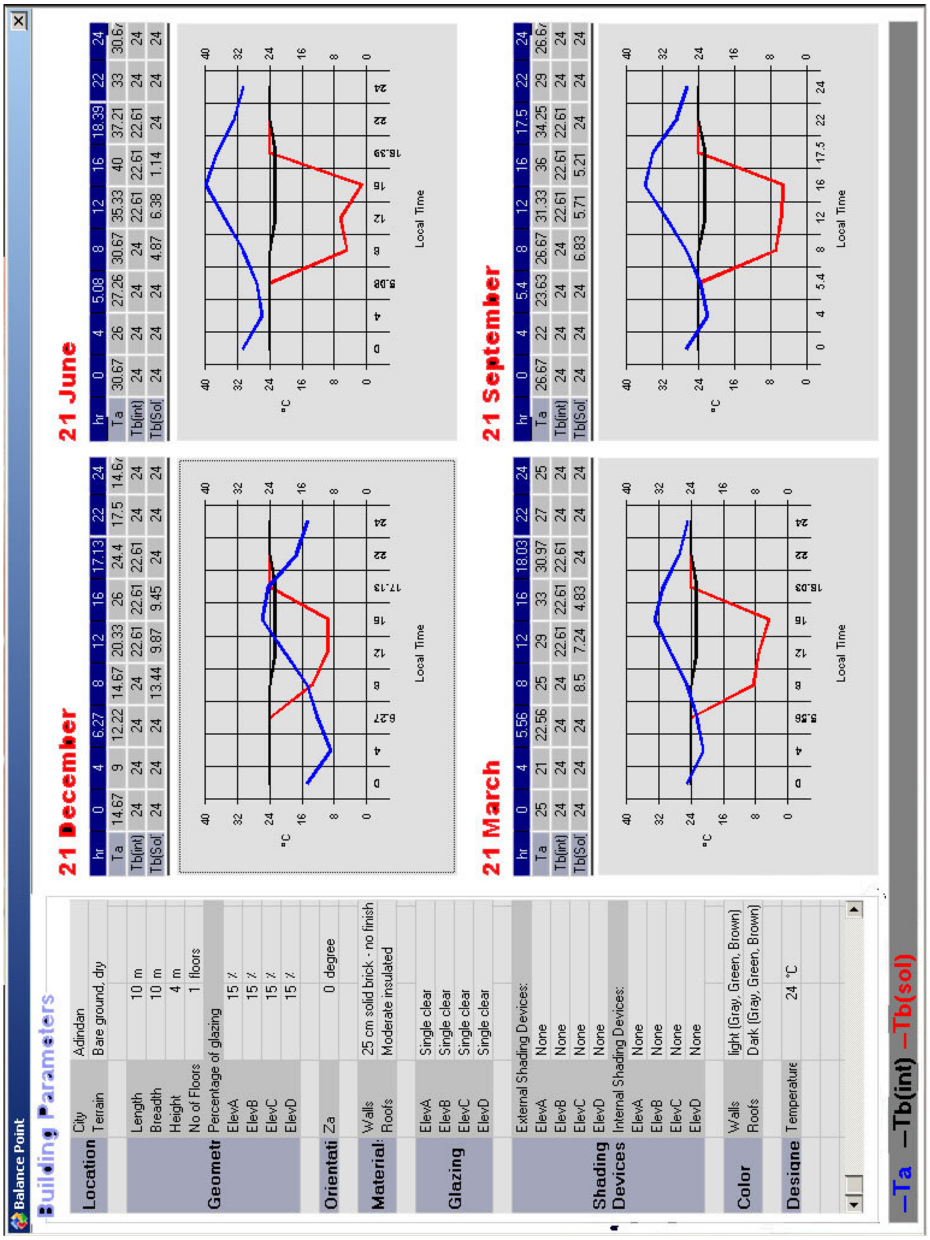
- Each sheet is characterized by having a list of skin variables and dimensions on its left side describing the studied case, while the output graphs are plotted on the right.

- A quick visual analysis of the graphs is enough to evaluate the thermal performance of the building with its new combination of skin variables.

- Finally, a hypothetical case will be proposed by the researcher having a group of recommended variables representing *a possible solution.*

---

(1) The orientation of the building is represented by the inclination of façade (A) with respect to the north in a clockwise direction, having a range between (0 – 360) degree, the length of the building refers to this façade, while its breadth refers to elevation (B).


Balance Point
Building Parameters
21 December
21 June
21 March
21 September
Local Time
–Ta –Tb(int) –Tb(sol)

Sheet (6-1)

(6-2-1) Examining the Effect of Building Geometry on Solar Heat Gains

- Sheets (6-2), (6-3), (6-4), (6-5) together with sheet (6-1) examine the effect of the building geometry on its thermal gains in the chosen site, noting the changing pattern of the sun path in the sky dome from south to north in summer, which represents a unique case in Egypt.

- Winter admittance for solar gains and summer protection both need support using the dimensions of the layout.

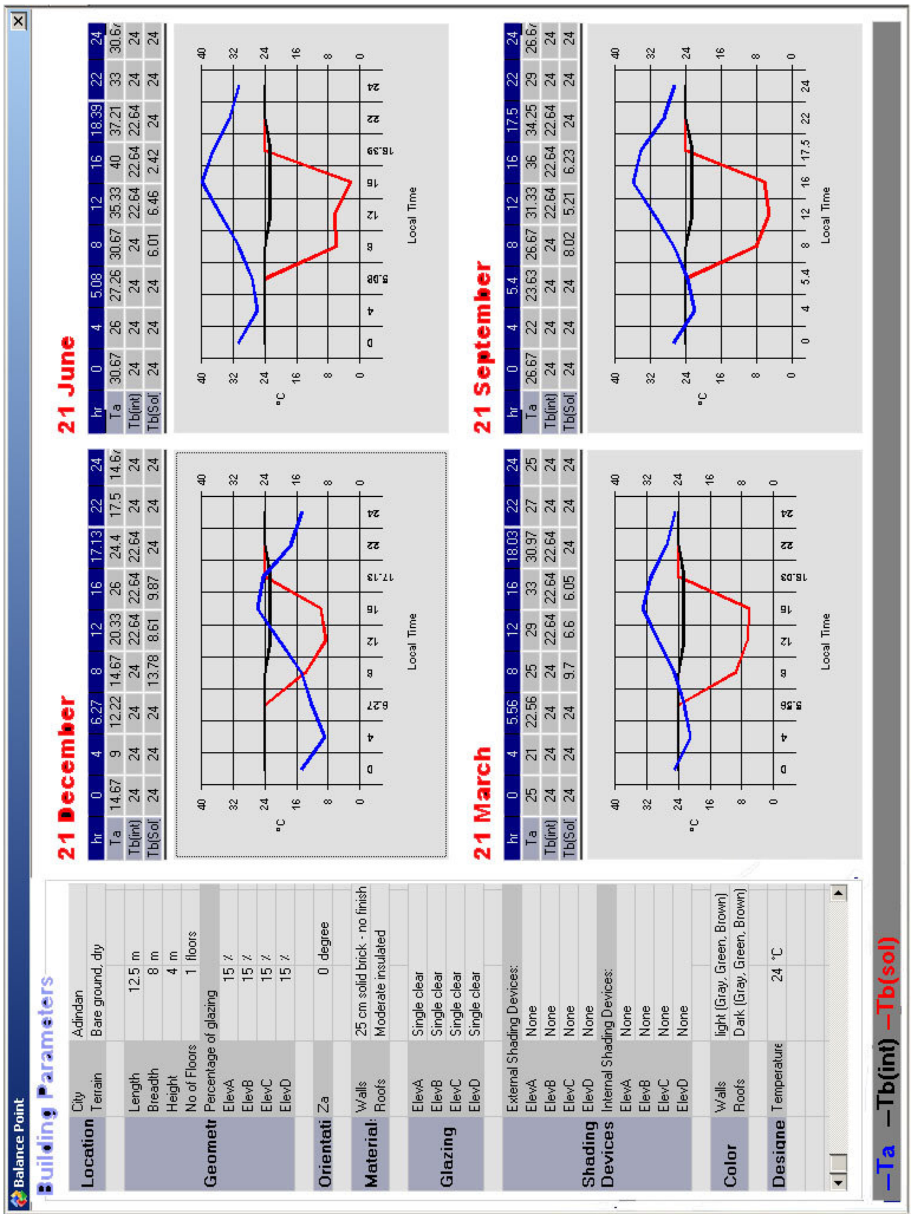
- Table (6-1) illustrates the differences in the building dimensions for each of the previous cases:

Sheet Nº	Length a (m)	Breadth b (m)	Height h (m)	Area A (m^2)
(6-1)	10	10	4	100
(6-2)	12.5	8	4	100
(6-3)	20	5	4	100
(6-4)	8	12.5	4	100
(6-5)	5	20	4	100

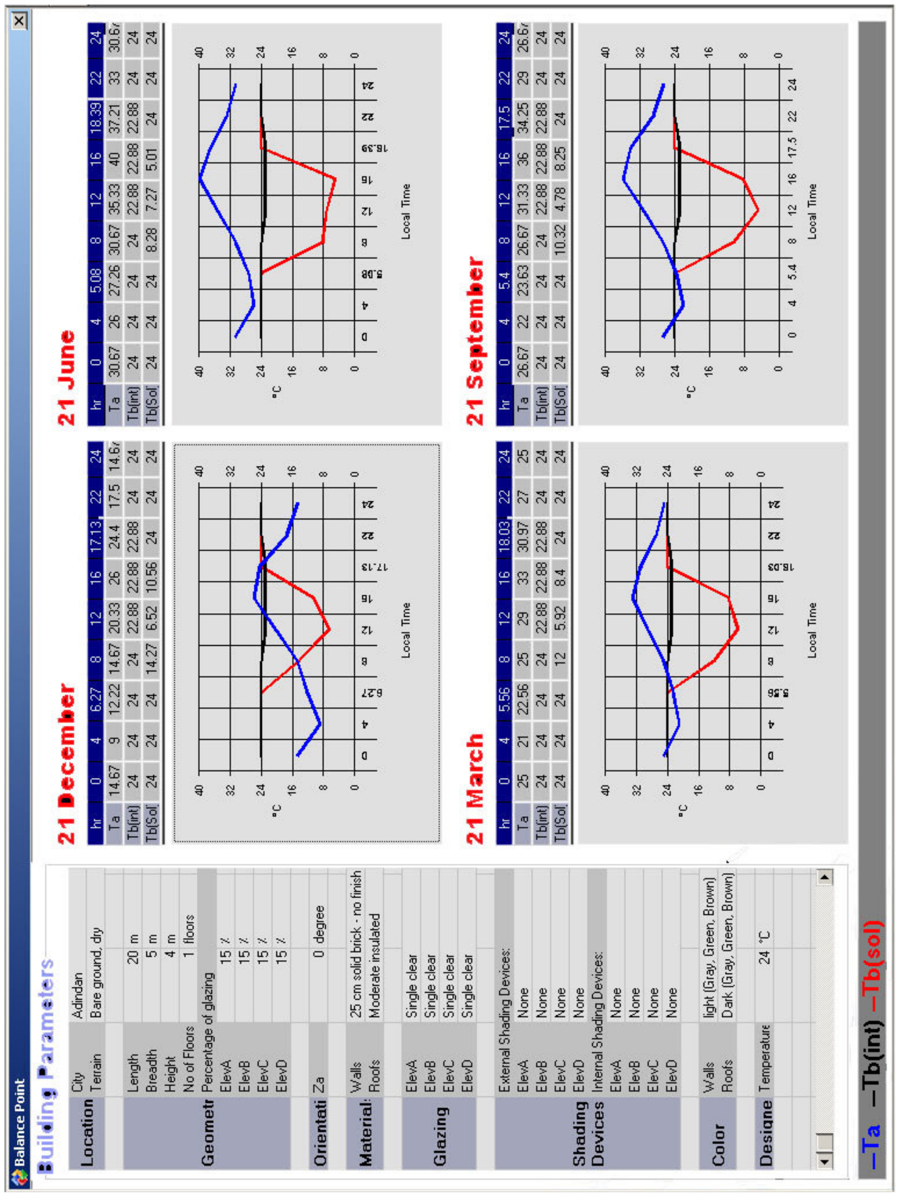
- All other skin parameters match those of the mother case.

- Sheet (6-3) having layout dimensions (20m X 5m) scores for most suitable performance than other cases, this is because the elongated east- west plan increases the solar heat gains needed in winter, while its undesirable effect in summer is limited, as the solar altitude facing the north is very high (88.5° at noon), finally, the short east and west facades decreases considerably the non desirable solar gains, when the solar altitude is still low in the sky dome.

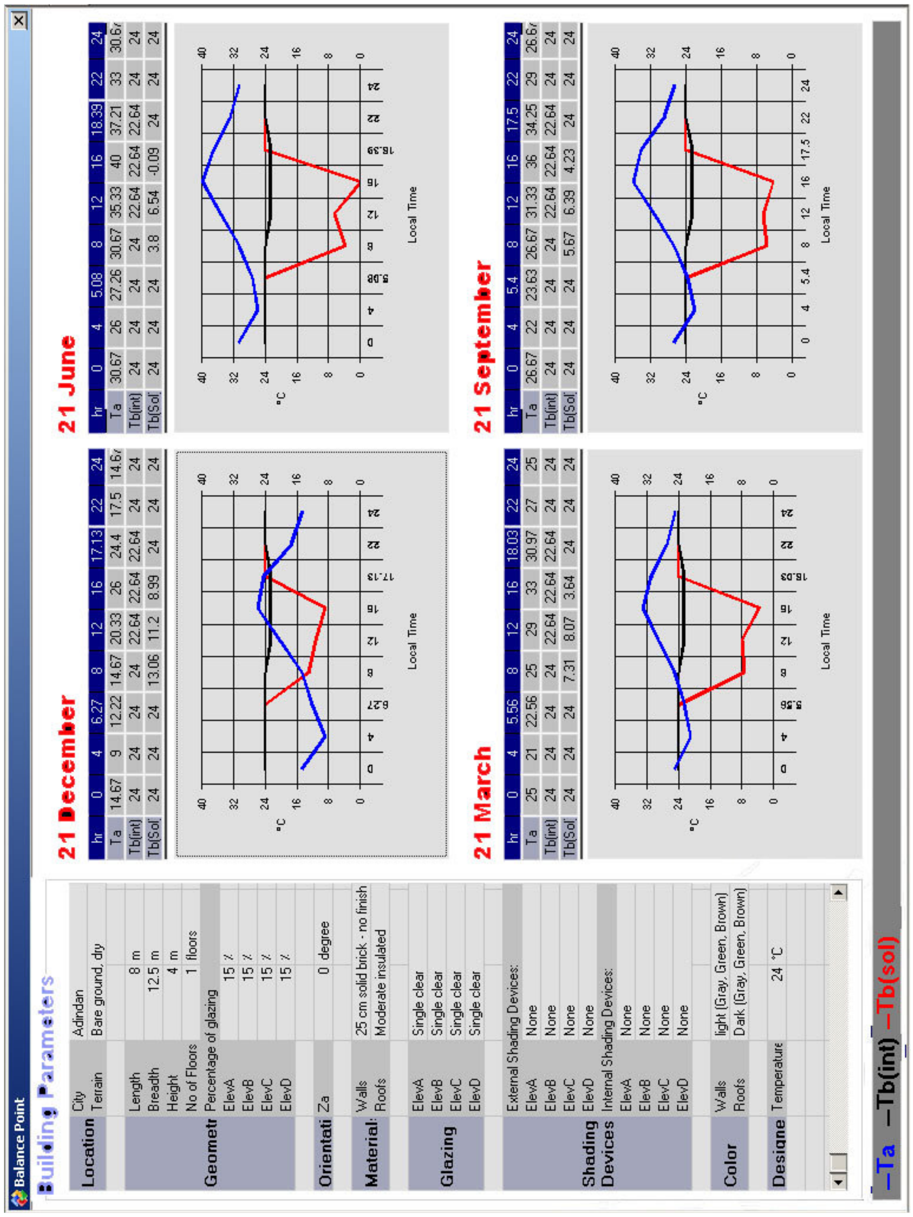
- The previous case goes exactly opposite to case (6-5), where desired solar heat gains are relatively low while undesirable solar heat gains in summer are extremely high.


Balance Point
Building Parameters
21 December
21 June
21 March
21 September
Local Time
–Ta –Tb(int) –Tb(sol)

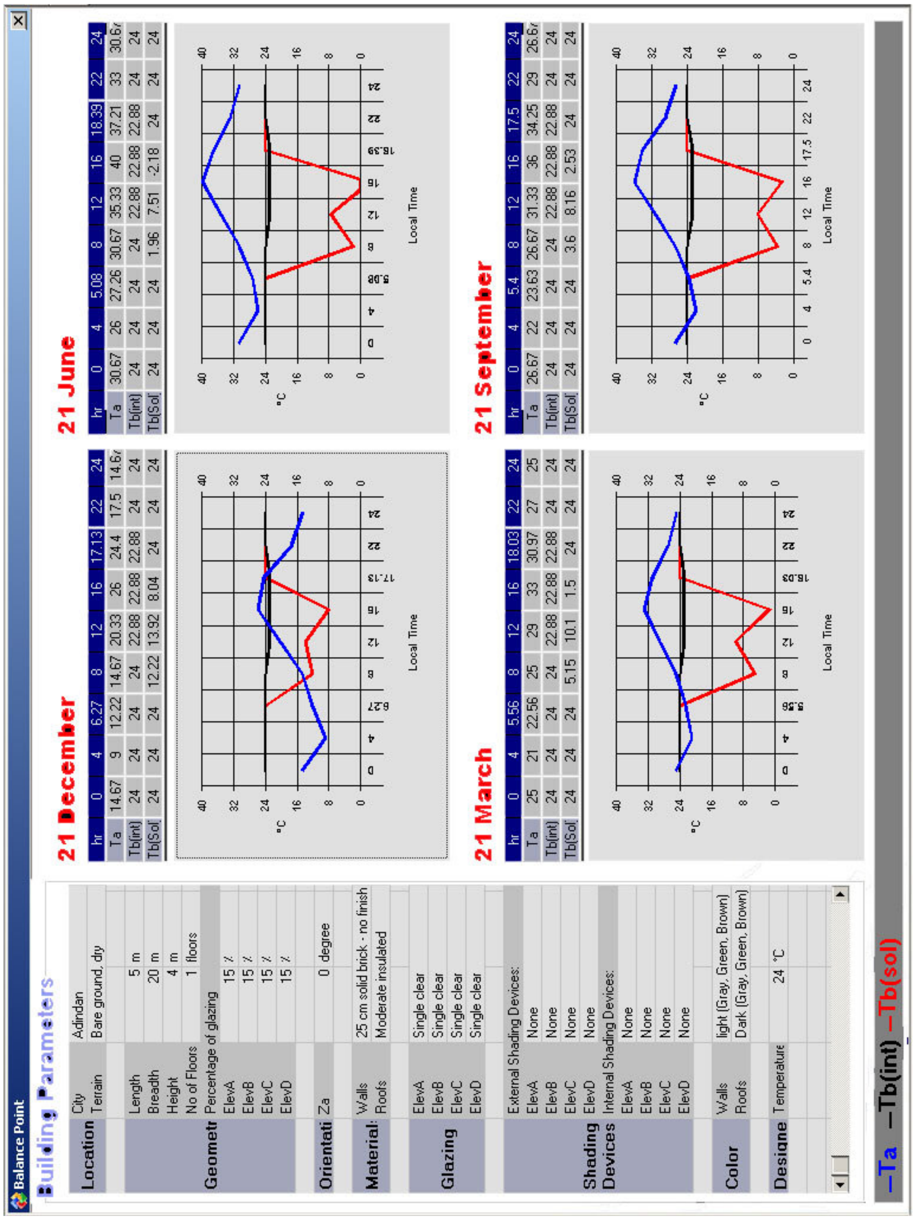
Sheet (6-2)


Balance Point
Building Parameters
21 December
21 June
21 March
21 September
Local Time
Ta
Tb(int)
Tb(sol)

Sheet (6-3)


Balance Point
Building Parameters
21 December
21 June
21 March
21 September
Local Time
–Ta –Tb(int) –Tb(sol)

Sheet (6-4)


Balance Point
Building Parameters
Location City Adindan
Terrain Bare ground, dry
Geometr Length 5 m
Breadth 20 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 15 %
ElevB 15 %
ElevC 15 %
ElevD 15 %
Orientati Za 0 degree
Material Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Designe Temperature 24 °C
21 December
hr 0 4 6.27 8 12 16 17.13 22 24
Ta 14.67 9 12.22 14.67 20.33 26 24.4 17.5 14.6
Tb(int) 24 24 24 24 22.88 22.88 22.88 24 24
Tb(Sol 24 24 24 12.22 13.92 8.04 24 24 24
21 June
hr 0 4 5.08 8 12 16 18.39 22 24
Ta 30.67 26 27.26 30.67 35.33 40 37.21 33 30.6
Tb(int) 24 24 24 24 22.88 22.88 22.88 24 24
Tb(Sol 24 24 24 1.96 7.51 -2.18 24 24 24
21 March
hr 0 4 5.56 8 12 16 18.03 22 24
Ta 25 21 22.56 25 29 33 30.97 27 25
Tb(int) 24 24 24 24 22.88 22.88 22.88 24 24
Tb(Sol 24 24 24 5.15 10.1 1.5 24 24 24
21 September
hr 0 4 5.4 8 12 16 17.5 22 24
Ta 26.67 22 23.63 26.67 31.33 36 34.25 29 26.6
Tb(int) 24 24 24 24 22.88 22.88 22.88 24 24
Tb(Sol 24 24 24 3.6 8.16 2.53 24 24 24
°C
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-5)

(6-2-2) Examining the Effect of Building Orientation on Solar Heat Gains

- Sheets (6-6), (6-7), (6-8), together with sheet (6-1) examine the effect of the building orientation on its thermal gains in the chosen site.

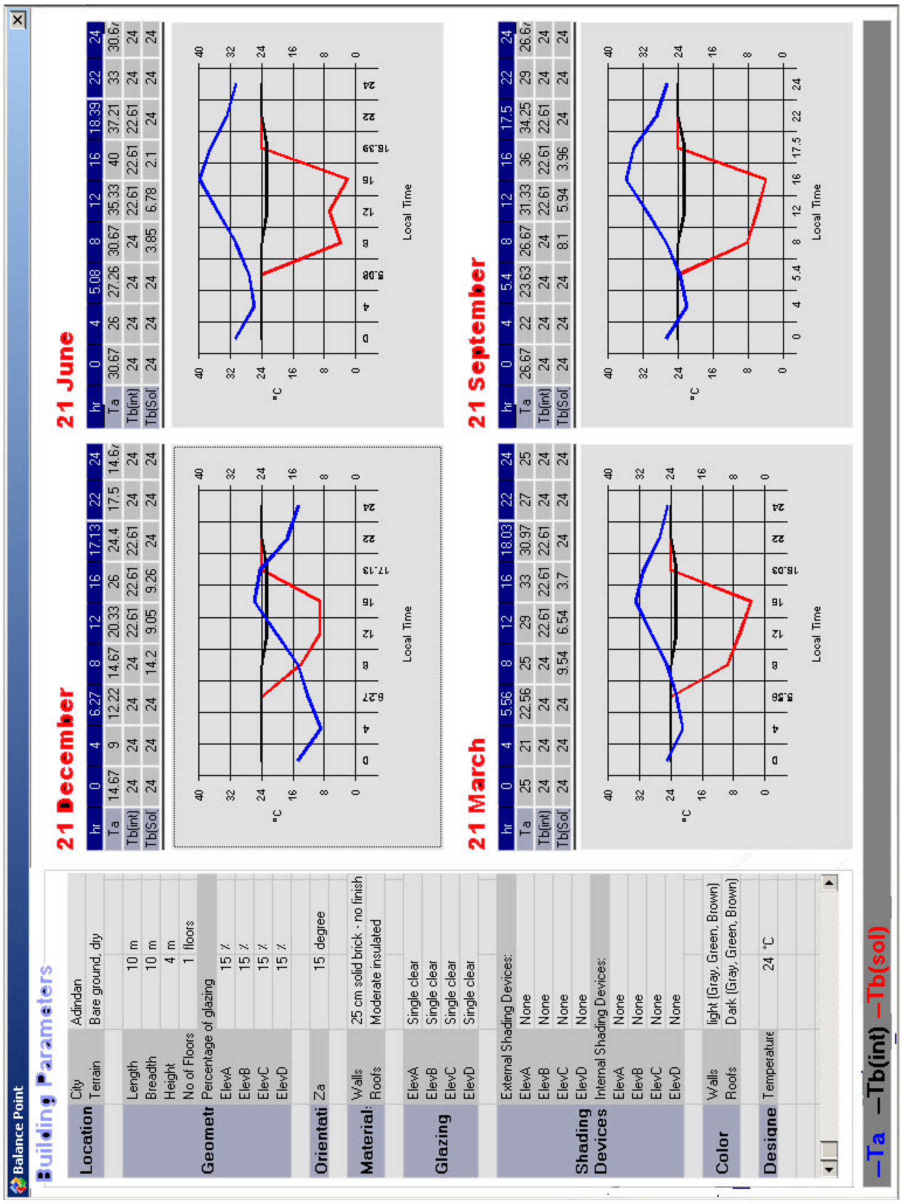
- A gradual inclination of the building with respect to the north is examined; 15, 30, and 45 degree respectively, where they are compared to sheet (6-1) which has zero orientation with respect to the north.

- Table (6-2) shows the orientation of elevation(A) (Z_a) with respect to the north in a clockwise direction for each of the studied cases:

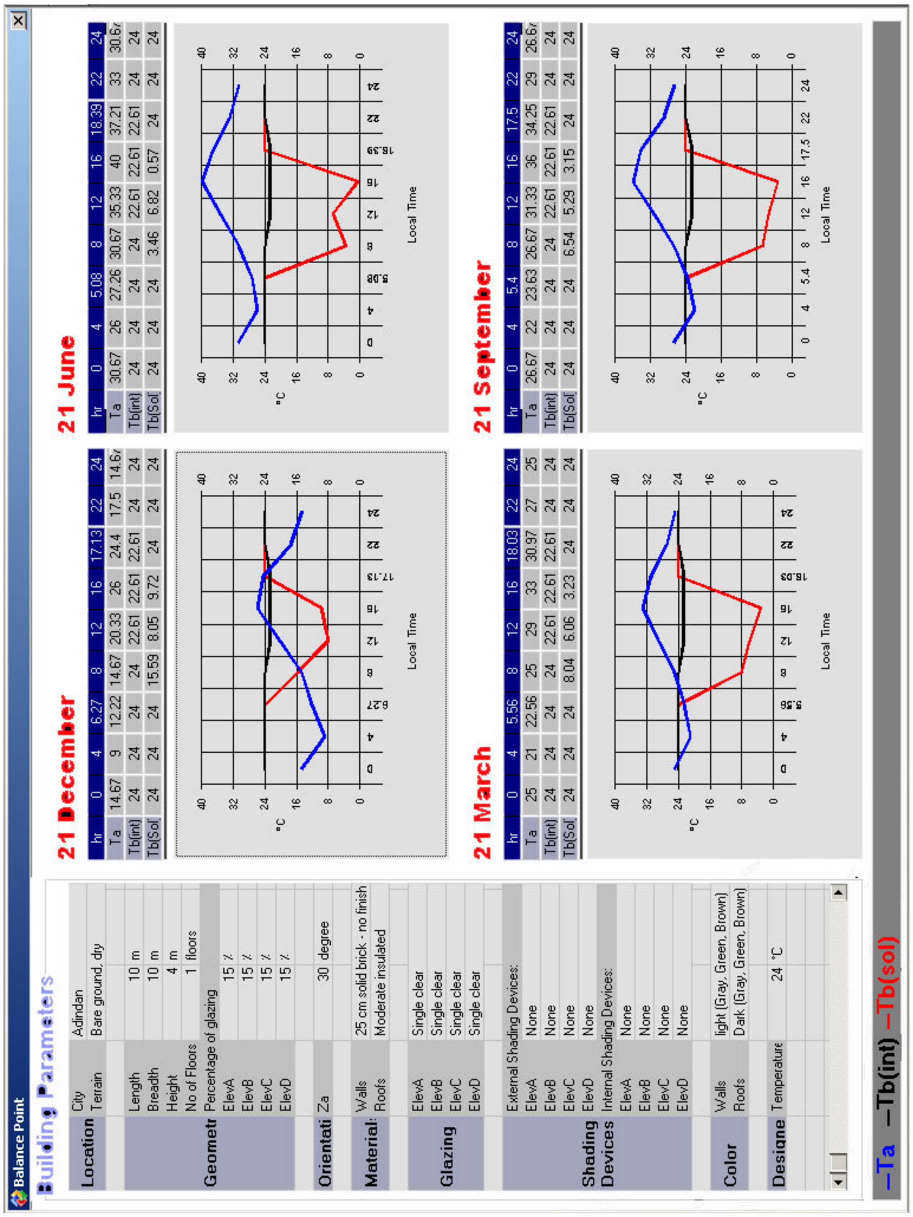
Sheet Nº	Orientation (Z_a) degree
(6-1)	0
(6-6)	15
(6-7)	30
(6-8)	45

- All other skin parameters match those of the mother case.

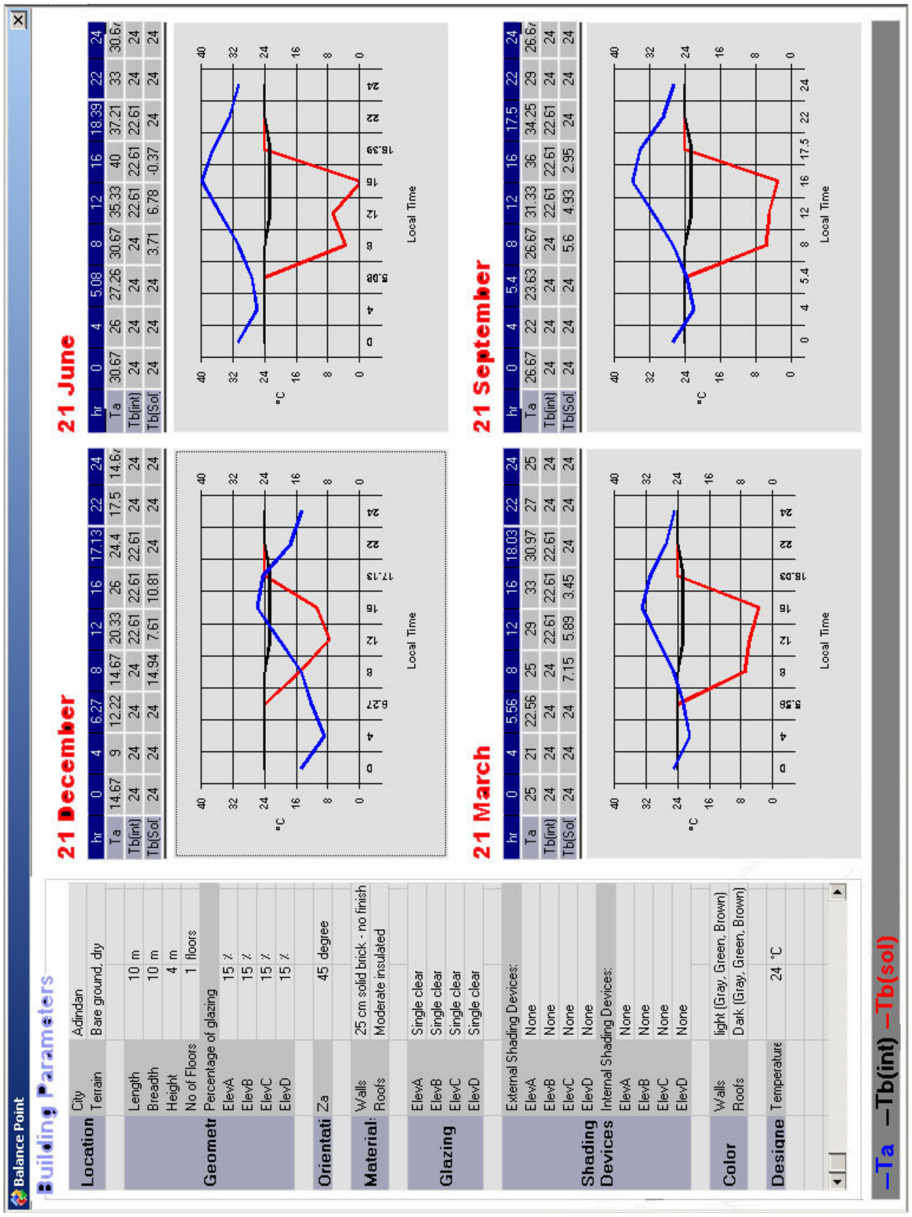
- The numerical results show a gradual undesirable increase in the solar heat gains by increasing the inclination of the building with respect to the north; meaning that case(6-1) has the lowest score with respect to solar heat gains.


Balance Point
Building Parameters
Location
City Adindan
Terrain Bare ground, dry
Geometr
Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
Orientati
Za 15 degree
Material
Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing
Single clear
Shading Devices
External Shading Devices:
Internal Shading Devices:
Color
Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Designe
Temperature 24 °C
21 December
21 June
21 March
21 September
Local Time
—Ta —Tb(int) —Tb(sol)

She6et (6-6)


Balance Point
Building Parameters
Location
City Adindan
Terrain Bare ground, dry
Geometry
Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 15 %
ElevB 15 %
ElevC 15 %
ElevD 15 %
Orientation
Za 30 degree
Materials
Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing
ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices
External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color
Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Design
Temperature 24 °C
21 December
21 June
21 March
21 September
°C
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-7)


Balance Point
Building Parameters
Location
City Adindan
Terrain Bare ground, dry
Geometry
Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 15 %
ElevB 15 %
ElevC 15 %
ElevD 15 %
Orientation
Za 45 degree
Material
Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing
ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices
External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color
Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Design
Temperature 24 °C
21 December
21 June
21 March
21 September
Local Time
°C
—Ta —Tb(int) —Tb(sol)

Sheet (6-8)

(6-2-3) Examining the Effect of Building Material on Solar Heat Gains

- Sheets (6-9), (6-10), (6-11), together with sheet (6-1) show different cases for well insulated, poor insulated, uninsulated, and moderately insulated roof respectively.

- Table (6-3) gives the roof U-value for each of the previous cases:

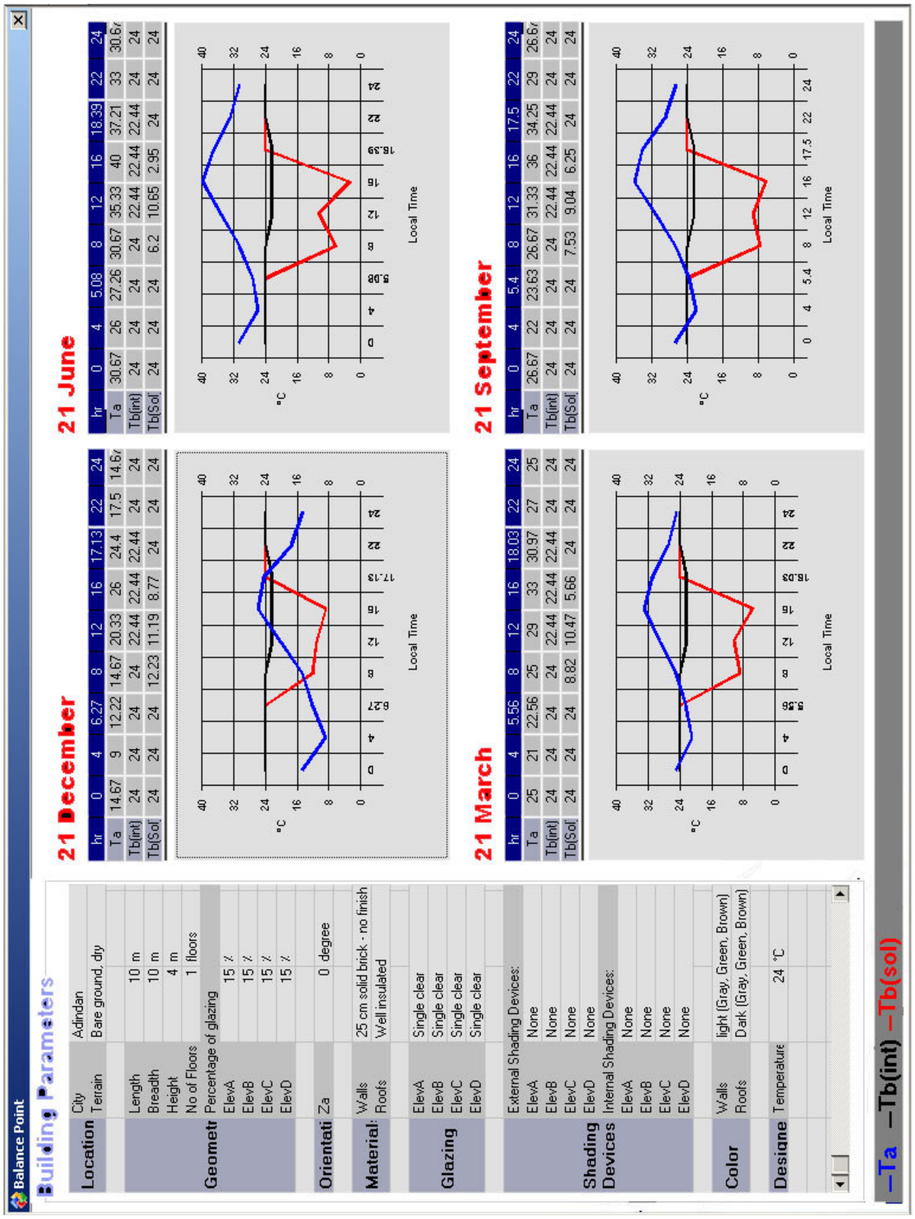
Sheet Nº	**Roof insulation**	**U-value W/m^2 °c**
(6-1)	**Moderately insulated roof**	1.15
(6-9)	**Well insulated roof**	0.28
(6-10)	**Poor insulated roof**	2
(6-11)	**Uninsulated roof**	2.8

- All other skin parameters match those of the mother case.

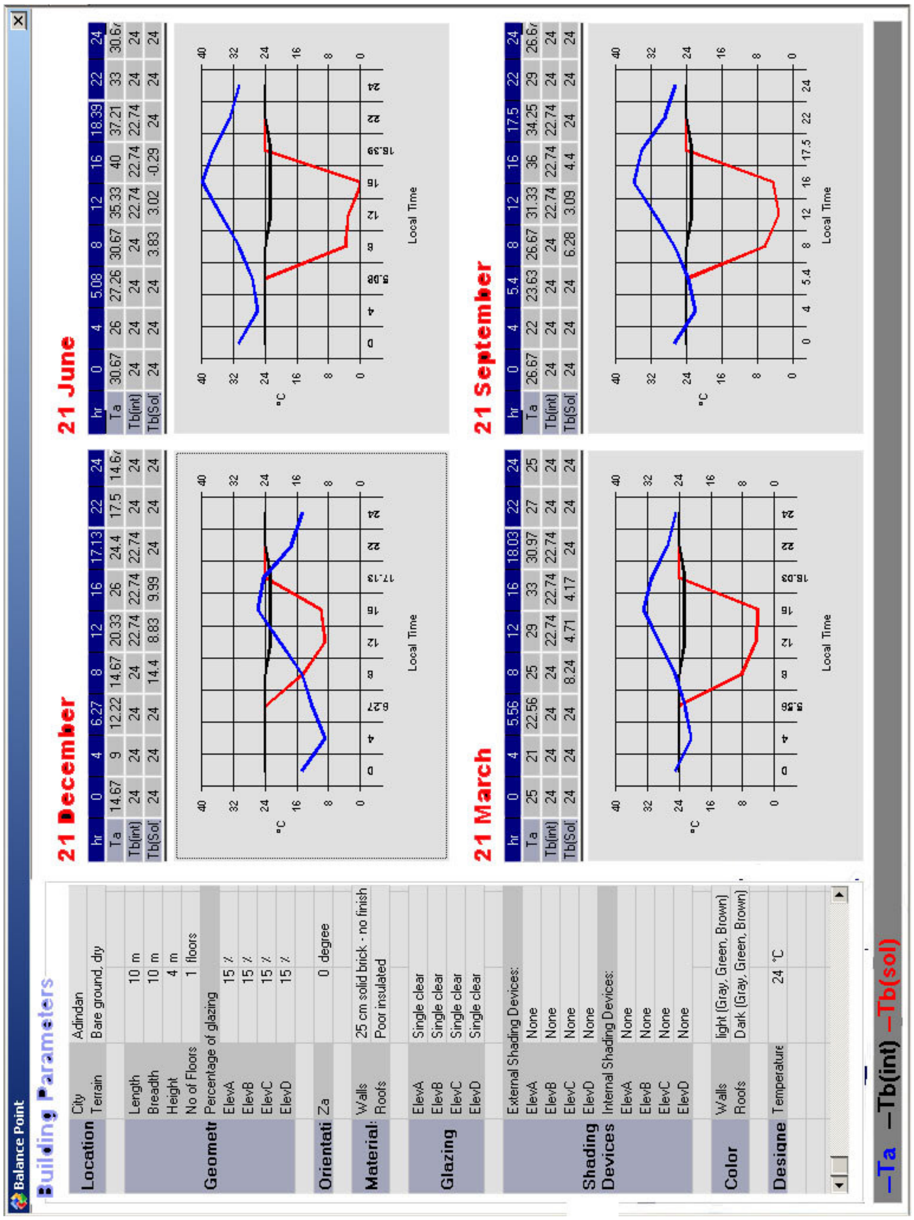
- The well insulated roof with lower U-value in sheet (6-9) scores for the lowest solar heat gains.

- The increase of the solar heat gains with the increase of the U-value is very clear, this is because of the high altitude of the sun in the sky dome over the course of the year, and hence, a high contribution of solar heat gains from the roof.

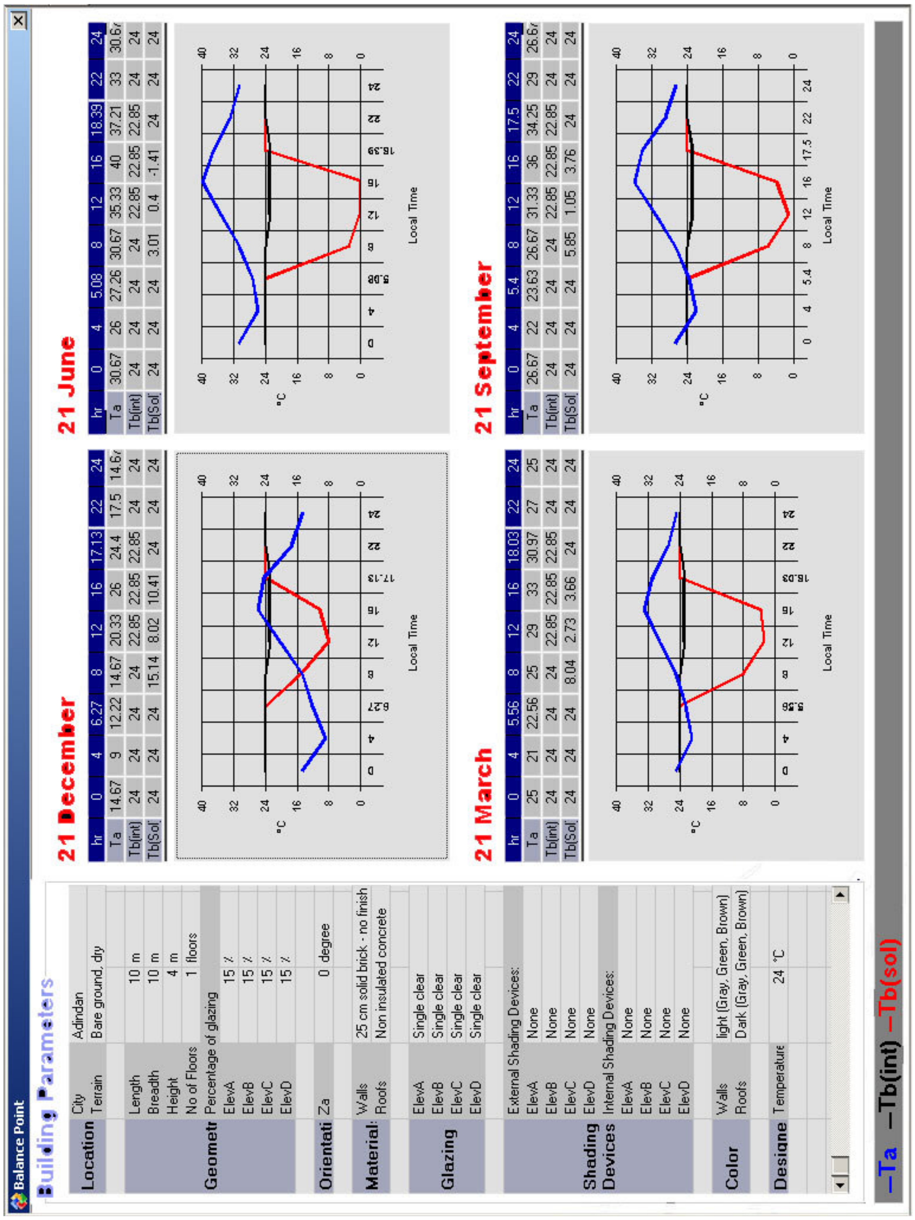
- A lower U-value of the building skin means less solar heat gains from opaque surfaces and vice versa, this concept reveals why the houses in old Nubia were characterized by thick walls.


Balance Point
Building Parameters
Location City Adindan
Terrain Bare ground, dry
Geometr Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 15 %
ElevB 15 %
ElevC 15 %
ElevD 15 %
Orientati Za 0 degree
Material: Walls 25 cm solid brick - no finish
Roofs Well insulated
Glazing ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Designe Temperature 24 °C
21 December
hr 0 4 6.27 8 12 16 17.13 22 24
Ta 14.67 9 12.22 14.67 20.33 26 24.4 17.5 14.6⁄
Tb(int) 24 24 24 24 22.44 22.44 22.44 24 24
Tb(Sol 24 24 24 12.23 11.19 8.77 24 24 24
21 June
hr 0 4 5.08 8 12 16 18.39 22 24
Ta 30.67 26 27.26 30.67 35.33 40 37.21 33 30.6⁄
Tb(int) 24 24 24 24 22.44 22.44 22.44 24 24
Tb(Sol 24 24 24 6.2 10.65 2.95 24 24 24
21 March
hr 0 4 5.56 8 12 16 18.03 22 24
Ta 25 21 22.56 25 29 33 30.97 27 25
Tb(int) 24 24 24 24 22.44 22.44 22.44 24 24
Tb(Sol 24 24 24 8.82 10.47 5.66 24 24 24
21 September
hr 0 4 5.4 8 12 16 17.5 22 24
Ta 26.67 22 23.63 26.67 31.33 36 34.25 29 26.6⁄
Tb(int) 24 24 24 24 22.44 22.44 22.44 24 24
Tb(Sol 24 24 24 7.53 9.04 6.25 24 24 24
°C
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-9)


Balance Point
Building Parameters
21 December
21 June
21 March
21 September
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-10)


Balance Point
Building Parameters
Location City Adindan
Terrain Bare ground, dry
Geometry Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 15 %
ElevB 15 %
ElevC 15 %
ElevD 15 %
Orientation Za 0 degree
Materials Walls 25 cm solid brick - no finish
Roofs Non insulated concrete
Glazing ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Designe Temperature 24 °C
21 December
hr 0 4 6.27 8 12 16 17.13 22 24
Ta 14.67 9 12.22 14.67 20.33 26 24.4 17.5 14.6
Tb(int) 24 24 24 24 22.85 22.85 22.85 24 24
Tb(Sol) 24 24 24 15.14 8.02 10.41 24 24 24
21 June
hr 0 4 5.08 8 12 16 18.39 22 24
Ta 30.67 26 27.26 30.67 35.33 40 37.21 33 30.6
Tb(int) 24 24 24 24 22.85 22.85 22.85 24 24
Tb(Sol) 24 24 24 3.01 0.4 -1.41 24 24 24
21 March
hr 0 4 5.56 8 12 16 18.03 22 24
Ta 25 21 22.56 25 29 33 30.97 27 25
Tb(int) 24 24 24 24 22.85 22.85 22.85 24 24
Tb(Sol) 24 24 24 8.04 2.73 3.66 24 24 24
21 September
hr 0 4 5.4 8 12 16 17.5 22 24
Ta 26.67 22 23.63 26.67 31.33 36 34.25 29 26.6
Tb(int) 24 24 24 24 22.85 22.85 22.85 24 24
Tb(Sol) 24 24 24 5.85 1.05 3.76 24 24 24
°C
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-11)

(6-2-4) Examining the Effect of Glazing Percentage and Type

(6-2-4-1) Glazing Percentage

- Sheets (6-12), (6-13), (6-14), and (6-15) show the effect of increasing the percentage of glazing for each façade individually.

- A percentage of glazing 10% for all facades except for the façade in question, which is increased to 30%.

- Table (6-4) illustrates the differences between the studied cases:

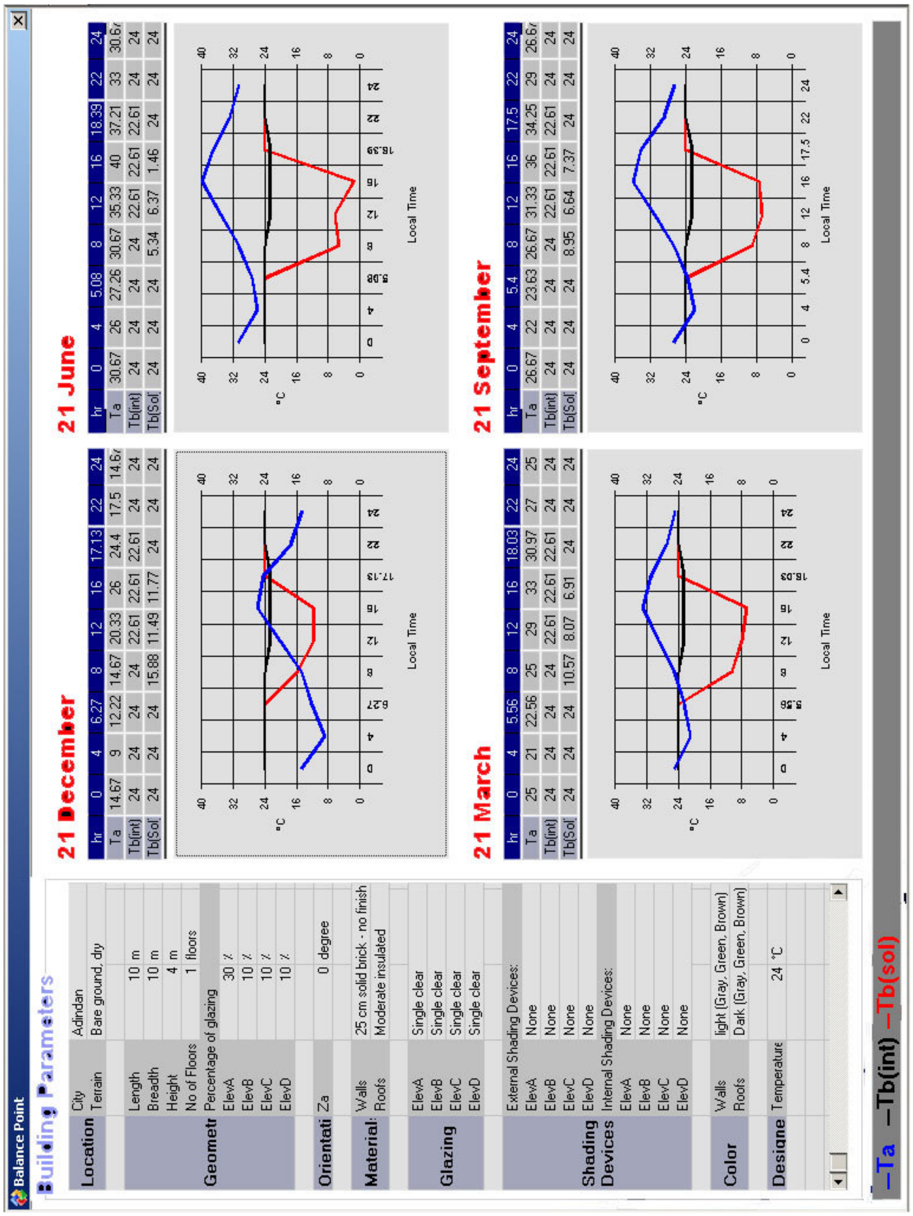
Sheet Nº	Glazing %			
	Elev.(A)	Elev.(B)	Elev.(C)	Elev.(D)
(6-12)	30 %	10 %	10 %	10 %
(6-13)	10 %	30 %	10 %	10 %
(6-14)	10 %	10 %	30 %	10 %
(6-15)	10 %	10 %	10 %	30 %

- All other skin parameters match those of the mother case.

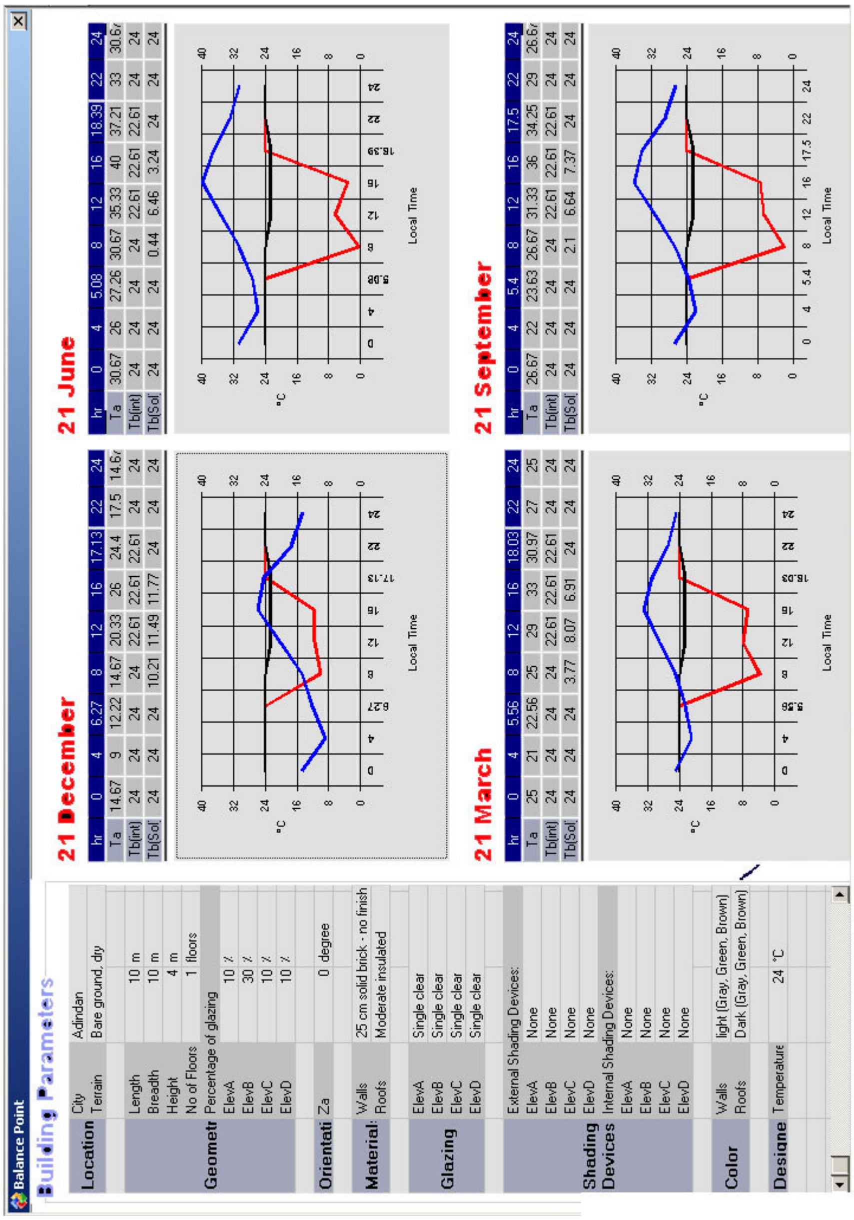
- Sheet (6-12) shows the lowest solar heat gains with respect to the other three cases, this is because the exposure of the north façade to solar radiation is limited as compared to the other three facades.

- Sheet (6-13) shows a slight increase in the solar heat gains for the periods before noon, when the incident radiation value is still comparatively low, on the contrary to sheet (6-15) which indicates a dramatic undesirable increase for the periods after noon over the course of the year, this is because the value of the incident radiation is relatively high.

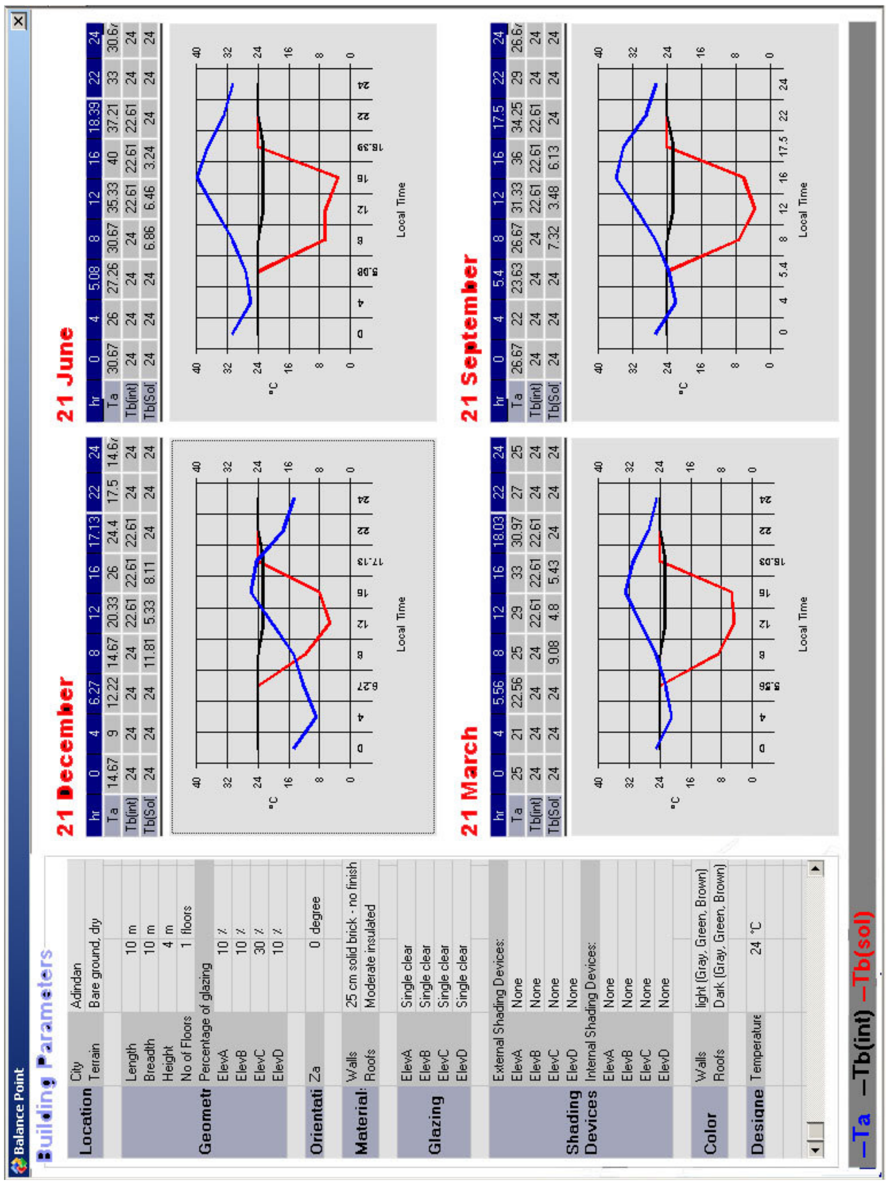
- Sheet (6-14) shows a special case swinging between a considerable increase in solar gains at winter, spring and autumn, while a slight decrease in summer is noticed as compared to sheet (6-12).


Balance Point
Building Parameters
Location City Adindan
Terrain Bare ground, dry
Geometr Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 30 %
ElevB 10 %
ElevC 10 %
ElevD 10 %
Orientati Za 0 degree
Material Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Designe Temperature 24 °C
21 December
hr 0 4 6.27 8 12 16 17.13 22 24
Ta 14.67 9 12.22 14.67 20.33 26 24.4 17.5 14.6
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 15.88 11.49 11.77 24 24 24
21 June
hr 0 4 5.08 8 12 16 18.39 22 24
Ta 30.67 26 27.26 30.67 35.33 40 37.21 33 30.6
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 5.34 6.37 1.46 24 24 24
21 March
hr 0 4 5.56 8 12 16 18.03 22 24
Ta 25 21 22.56 25 29 33 30.97 27 25
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 10.57 8.07 6.91 24 24 24
21 September
hr 0 4 5.4 8 12 16 17.5 22 24
Ta 26.67 22 23.63 26.67 31.33 36 34.25 29 26.6
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 8.95 6.64 7.37 24 24 24
°C
Local Time
—Ta —Tb(int) —Tb(sol)

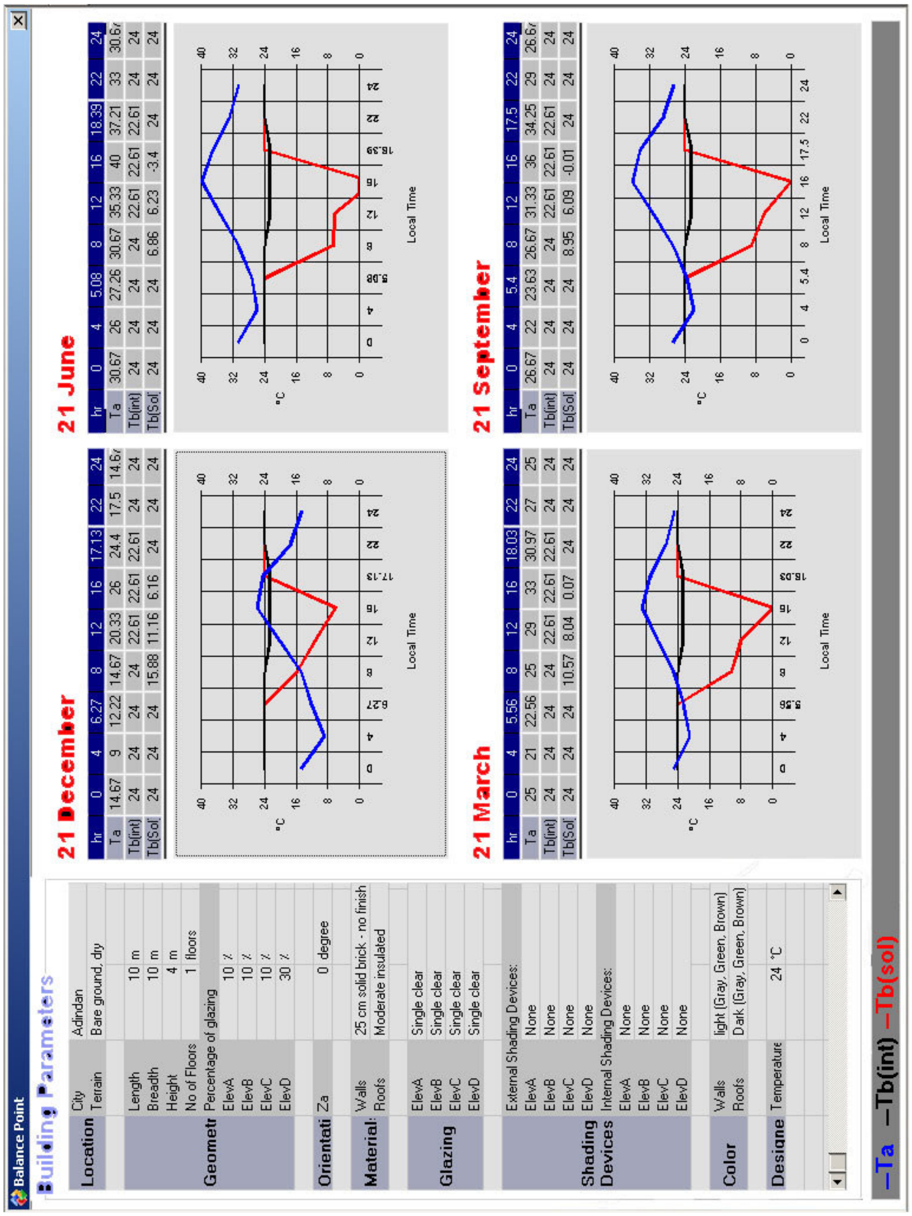
Sheet (6-12)


Balance Point
Building Parameters
Location
City Adindan
Terrain Bare ground, dry
Geometr
Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 10 %
ElevB 30 %
ElevC 10 %
ElevD 10 %
Orientati
Za 0 degree
Material:
Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing
ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices
External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color
Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Designe
Temperature 24 °C
21 December
21 June
21 March
21 September
Local Time

__Sheet (6-13)__


Balance Point
Building Parameters
Location City Adindan
Terrain Bare ground, dry
Geometry Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 10 %
ElevB 10 %
ElevC 30 %
ElevD 10 %
Orientati Za 0 degree
Material Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Designe Temperature 24 °C
21 December
hr 0 4 6.27 8 12 16 17.13 22 24
Ta 14.67 9 12.22 14.67 20.33 26 24.4 17.5 14.6
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol 24 24 24 11.81 5.33 8.11 24 24 24
21 June
hr 0 4 5.08 8 12 16 18.39 22 24
Ta 30.67 26 27.26 30.67 35.33 40 37.21 33 30.6
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol 24 24 24 6.86 6.46 3.24 24 24 24
21 March
hr 0 4 5.56 8 12 16 18.03 22 24
Ta 25 21 22.56 25 29 33 30.97 27 25
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol 24 24 24 9.08 4.8 5.43 24 24 24
21 September
hr 0 4 5.4 8 12 16 17.5 22 24
Ta 26.67 22 23.63 26.67 31.33 36 34.25 29 26.6
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol 24 24 24 7.32 3.48 6.13 24 24 24
°C
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-14)


Balance Point
Building Parameters
21 December
21 June
21 March
21 September
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-15)

(6-2-4-2) Glazing Type

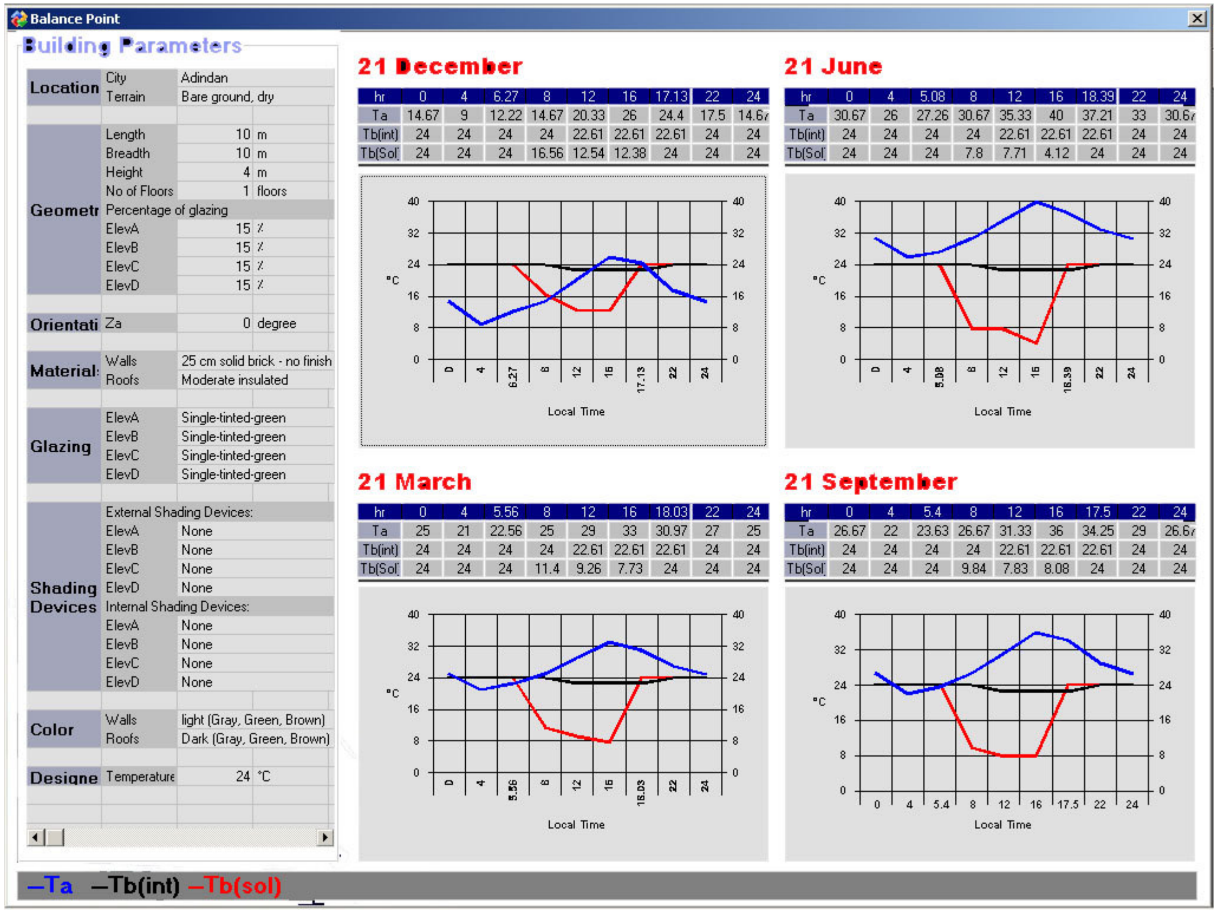
- Sheets (6-1), (6-16) and (6-17), shows a gradual decrease in the shading coefficient of the glazing.

- Table (6-5) shows different glazing types having different shading coefficients (Sc) for each of the studied cases

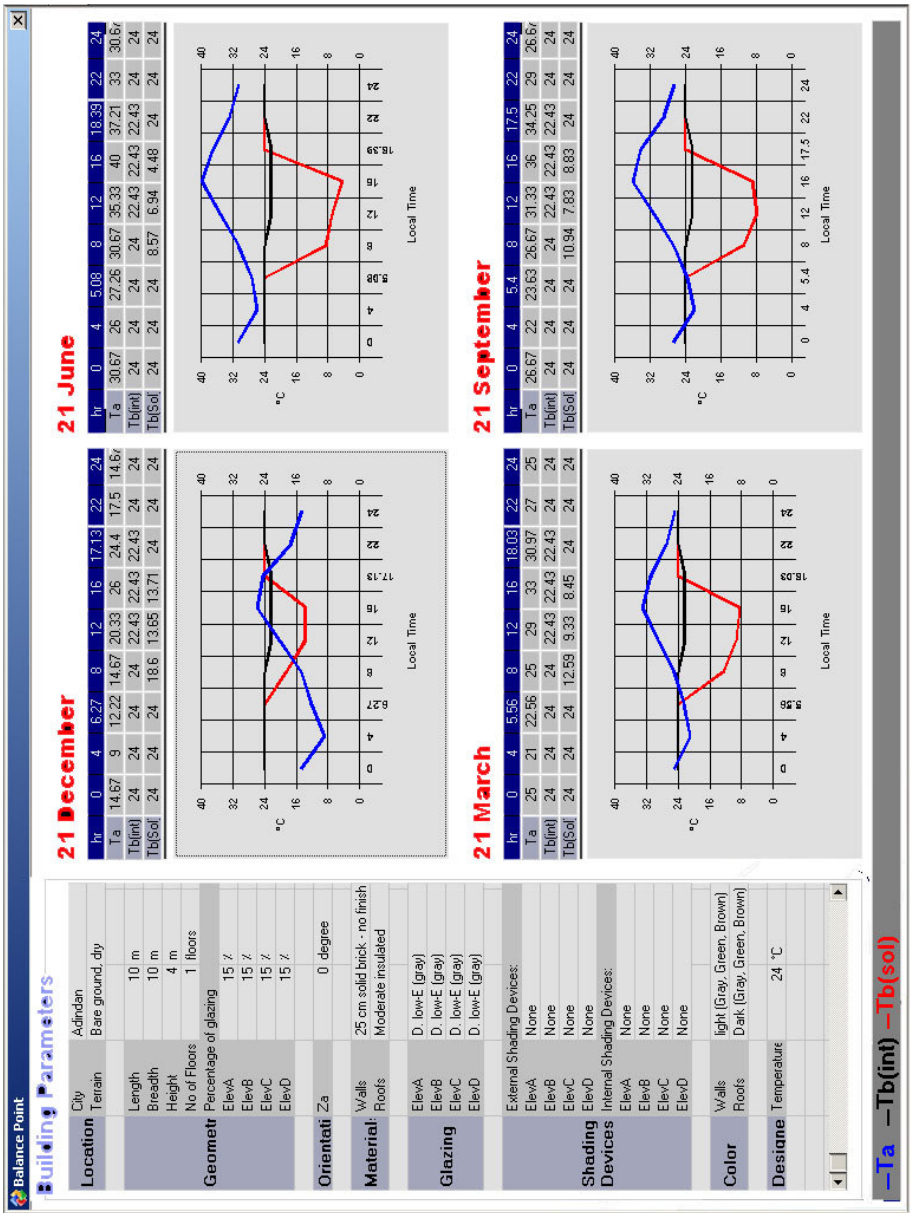
Sheet Nº	Glazing Type	Shading coefficient (Sc)
(6-1)	Single- clear	0.82
(6-16)	Single- tinted (green)	0.56
(6-17)	Double-low-E (gray)	0.34

- All other skin parameters match those of the mother case.

- This application is a practical verification of the equation (4-6), where the balance point graphs shows that the solar heat gains are decreased by decreasing the shading coefficient of the glazing and vice versa.


Balance Point
Building Parameters
Location City Adindan
Terrain Bare ground, dry
Geometr Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 15 %
ElevB 15 %
ElevC 15 %
ElevD 15 %
Orientati Za 0 degree
Material: Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing ElevA Single-tinted-green
ElevB Single-tinted-green
ElevC Single-tinted-green
ElevD Single-tinted-green
Shading Devices External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Designe Temperature 24 °C
21 December
hr 0 4 6.27 8 12 16 17.13 22 24
Ta 14.67 9 12.22 14.67 20.33 26 24.4 17.5 14.67
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 16.56 12.54 12.38 24 24 24
21 June
hr 0 4 5.08 8 12 16 18.39 22 24
Ta 30.67 26 27.26 30.67 35.33 40 37.21 33 30.67
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 7.8 7.71 4.12 24 24 24
21 March
hr 0 4 5.56 8 12 16 18.03 22 24
Ta 25 21 22.56 25 29 33 30.97 27 25
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 11.4 9.26 7.73 24 24 24
21 September
hr 0 4 5.4 8 12 16 17.5 22 24
Ta 26.67 22 23.63 26.67 31.33 36 34.25 29 26.67
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 9.84 7.83 8.08 24 24 24
°C
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-16)


Balance Point
Building Parameters
21 December
21 June
21 March
21 September
Local Time
Ta
Tb(int)
Tb(sol)

Sheet (6-17)

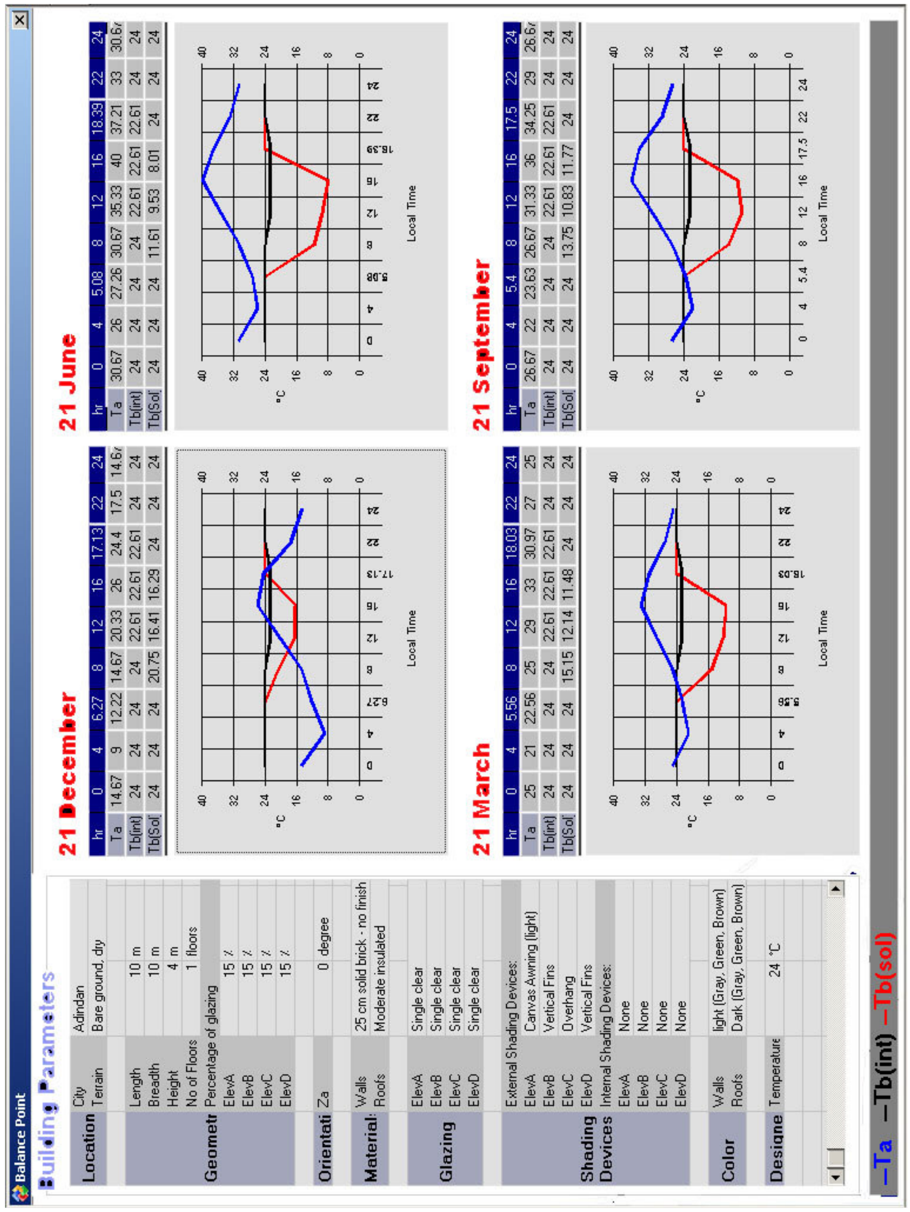
(6-2-5) Examining the Effect of External and Internal Shading on Solar Heat Gains.

- Sheet (6-18) shows the thermal performance of the architectural proposal in sheet (6-1) after using external shading strategies, where vertical fins are used for east and west elevations, overhang shading for south elevation and operable awnings for north elevation (for seasonal solar inflection).

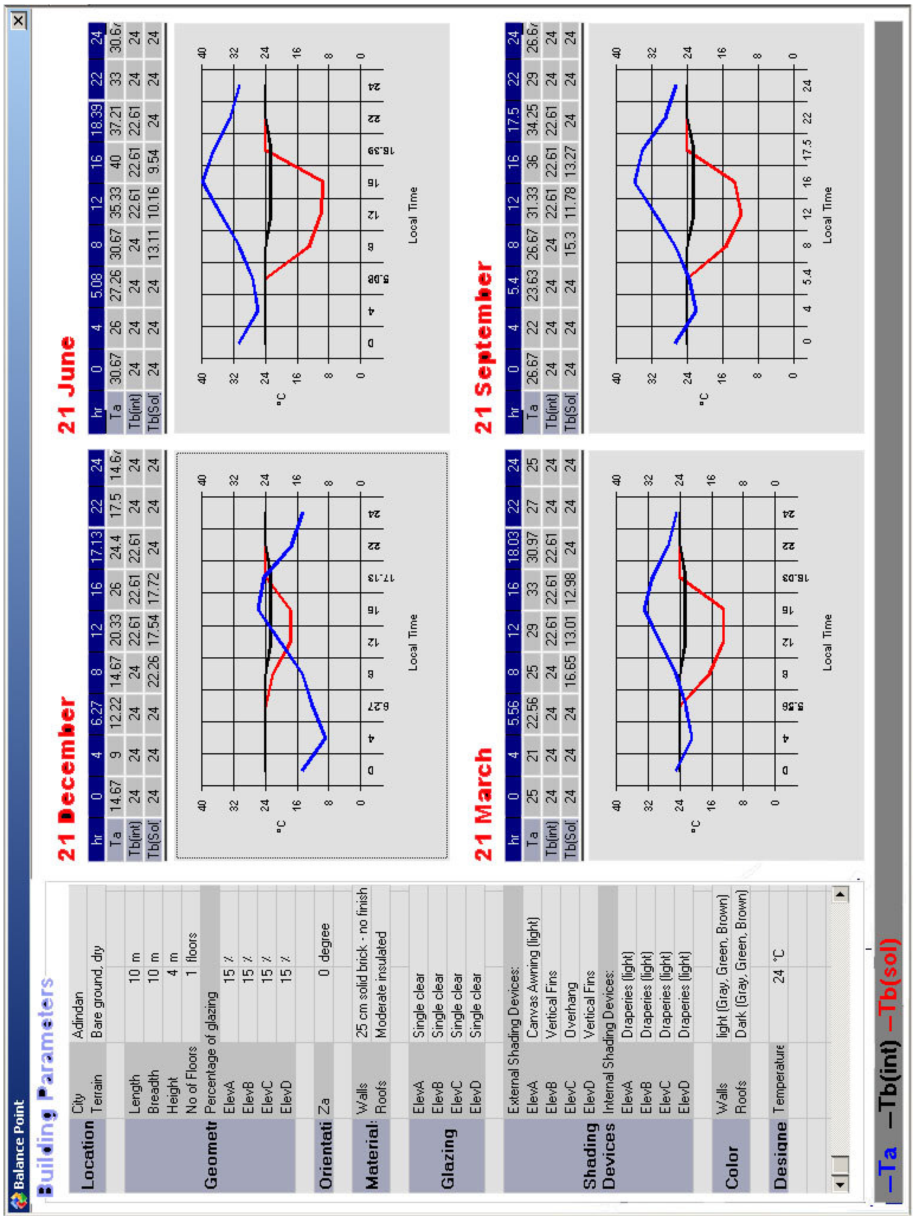
- It is very clear that solar heat gains are decreased notably, which is very desirable, however, this decrease is not recommended in winter so as to balance the night losses driven by the low ambient temperatures, accordingly, an operable shading tool is also recommended for the south elevations to admit sun in winter and block it in autumn and spring.

- Sheet (6-19) shows the performance of the example proposed in sheet (6-18), after using internal draperies for all elevations, decreasing the overall shading coefficient and thus causing a further control (decrease) in solar gains over the course of the year.

- The flexibility of the operable shading devices, (either internal or external) , gives an advantage to block the solar radiation or admit it according to the current needs , which means a more flexible (dynamic) environmental treatment for the building.


Balance Point
Building Parameters
Location City Adindan
Terrain Bare ground, dry
Geometry Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 15 %
ElevB 15 %
ElevC 15 %
ElevD 15 %
Orientati Za 0 degree
Material: Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices External Shading Devices:
ElevA Canvas Awning (light)
ElevB Vertical Fins
ElevC Overhang
ElevD Vertical Fins
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color Walls light (Gray, Green, Brown)
Roofs Dark (Gray, Green, Brown)
Designe Temperature 24 °C
21 December
hr 0 4 6.27 8 12 16 17.13 22 24
Ta 14.67 9 12.22 14.67 20.33 26 24.4 17.5 14.67
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 20.75 16.41 16.29 24 24 24
21 June
hr 0 4 5.08 8 12 16 18.39 22 24
Ta 30.67 26 27.26 30.67 35.33 40 37.21 33 30.67
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 11.61 9.53 8.01 24 24 24
21 March
hr 0 4 5.56 8 12 16 18.03 22 24
Ta 25 21 22.56 25 29 33 30.97 27 25
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 15.15 12.14 11.48 24 24 24
21 September
hr 0 4 5.4 8 12 16 17.5 22 24
Ta 26.67 22 23.63 26.67 31.33 36 34.25 29 26.67
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 13.75 10.83 11.77 24 24 24
°C
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-18)


Balance Point
Building Parameters
21 December
21 June
21 March
21 September
Local Time
Ta
Tb(int)
Tb(sol)

Sheet (6-19)

(6-2-6) Examining the Effect of Building Color on Solar Heat Gains.

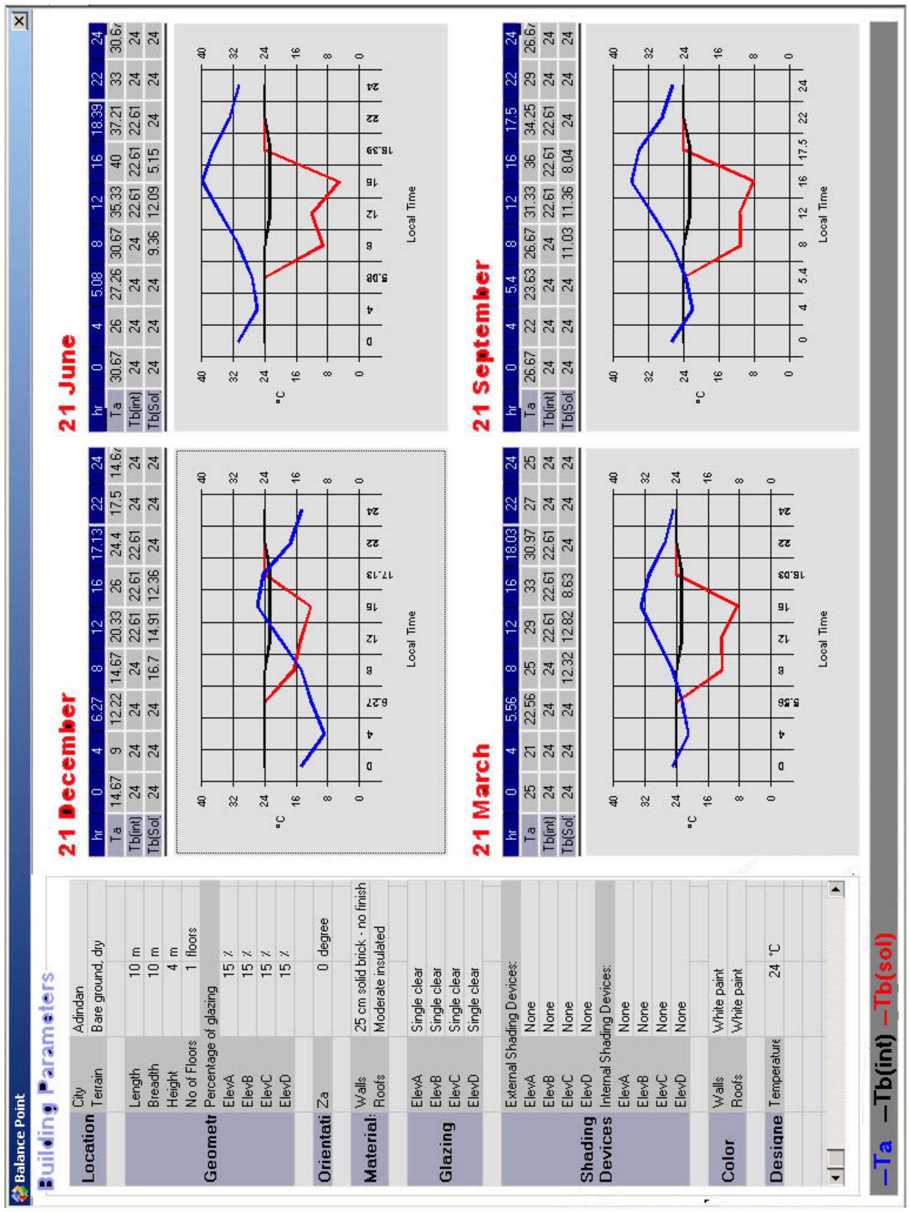
- Sheet (6-20), (6-1) and (6-21) show three different cases for the same architectural proposal examining the effect of color on solar heat gains, white, light (beige, green, gray), and dark (beige, green, gray) are used in the walls and the roof of the building respectively.

- Table (6-6) shows the color selections for the opaque parts of the envelope showing their absorptivity (a) in each case:

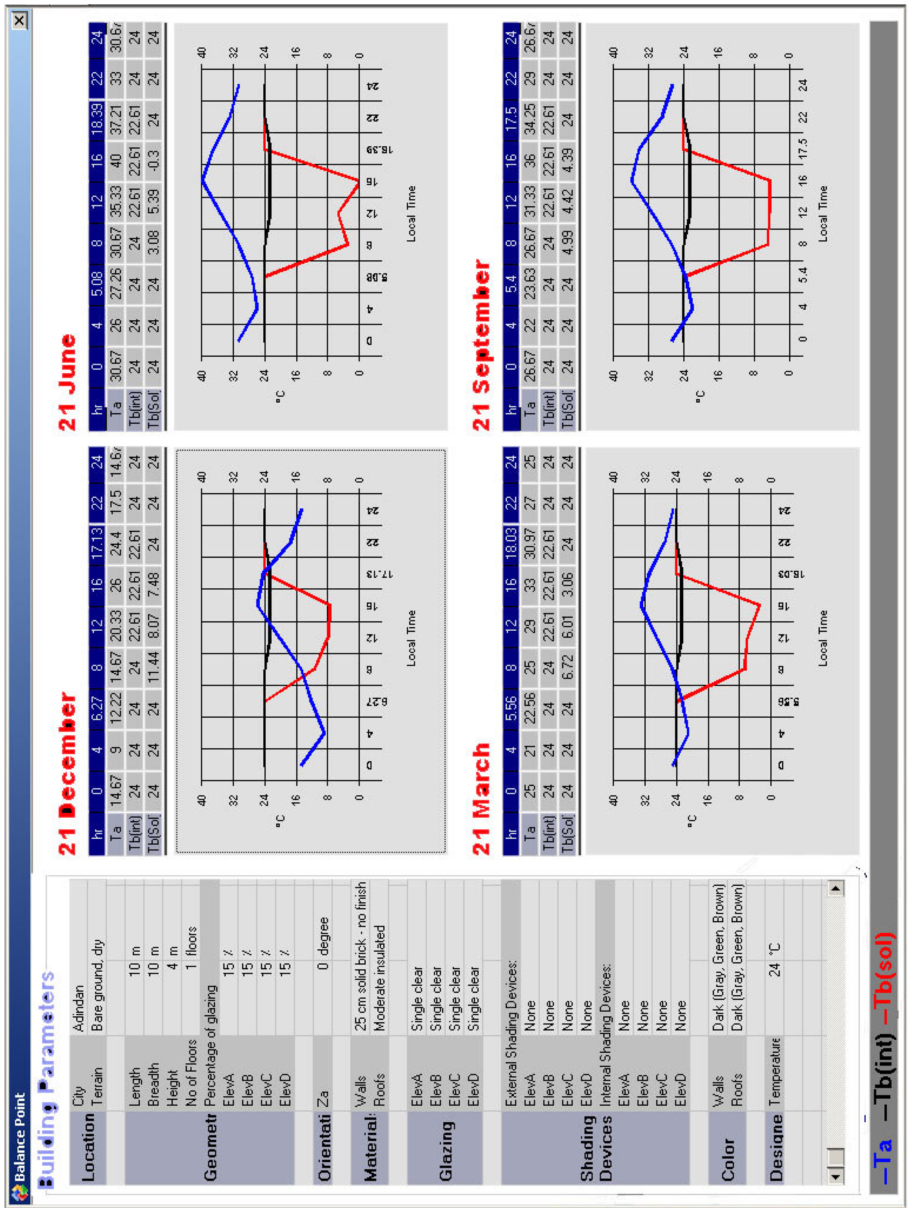
Sheet Nº	Wall / Roof color	absorptivity (a)
(6-1)	Light (beige, green, gray)	0.45
(6-20)	White	0.2
(6-21)	Dark (beige, green, gray)	0.75

- A quick visual analysis for the balance point diagrams reveals a rational gradual increase in solar heat gains accompanies the increase in the surface absorptivity.

- White colors shows better performance (smaller heat gains), specially for roofs which is the major source of solar heat gains over the course of the year.


Balance Point
Building Parameters
Location City Adindan
Terrain Bare ground, dry
Geometr Length 10 m
Breadth 10 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 15 %
ElevB 15 %
ElevC 15 %
ElevD 15 %
Orientati Za 0 degree
Material: Walls 25 cm solid brick - no finish
Roofs Moderate insulated
Glazing ElevA Single clear
ElevB Single clear
ElevC Single clear
ElevD Single clear
Shading Devices External Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Internal Shading Devices:
ElevA None
ElevB None
ElevC None
ElevD None
Color Walls White paint
Roofs White paint
Designe Temperature 24 °C
21 December
hr 0 4 6.27 8 12 16 17.13 22 24
Ta 14.67 9 12.22 14.67 20.33 26 24.4 17.5 14.6
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 16.7 14.91 12.36 24 24 24
21 June
hr 0 4 5.08 8 12 16 18.39 22 24
Ta 30.67 26 27.26 30.67 35.33 40 37.21 33 30.6
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 9.36 12.09 5.15 24 24 24
21 March
hr 0 4 5.56 8 12 16 18.03 22 24
Ta 25 21 22.56 25 29 33 30.97 27 25
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 12.32 12.82 8.63 24 24 24
21 September
hr 0 4 5.4 8 12 16 17.5 22 24
Ta 26.67 22 23.63 26.67 31.33 36 34.25 29 26.6
Tb(int) 24 24 24 24 22.61 22.61 22.61 24 24
Tb(Sol) 24 24 24 11.03 11.36 8.04 24 24 24
°C
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-20)


Balance Point
Building Parameters
21 December
21 June
21 March
21 September
Local Time
—Ta —Tb(int) —Tb(sol)

Sheet (6-21)

(6-2-7) Examining the Effect of a Selected Group of Recommended Skin Parameters.

- Sheet (6-22) proposes a hypothetical case, making use of all the possible variables of the building skin for the sake of a better thermal performance in the studied location, however, many other combinations might have similar results with respect to thermal efficiency, and accordingly, the example in sheet (6-22) is an attempt to reach a human comfort state inside the building using a group of tools that might be manipulated differently from one architect to another according to other design concepts, functions, and site restrictions.

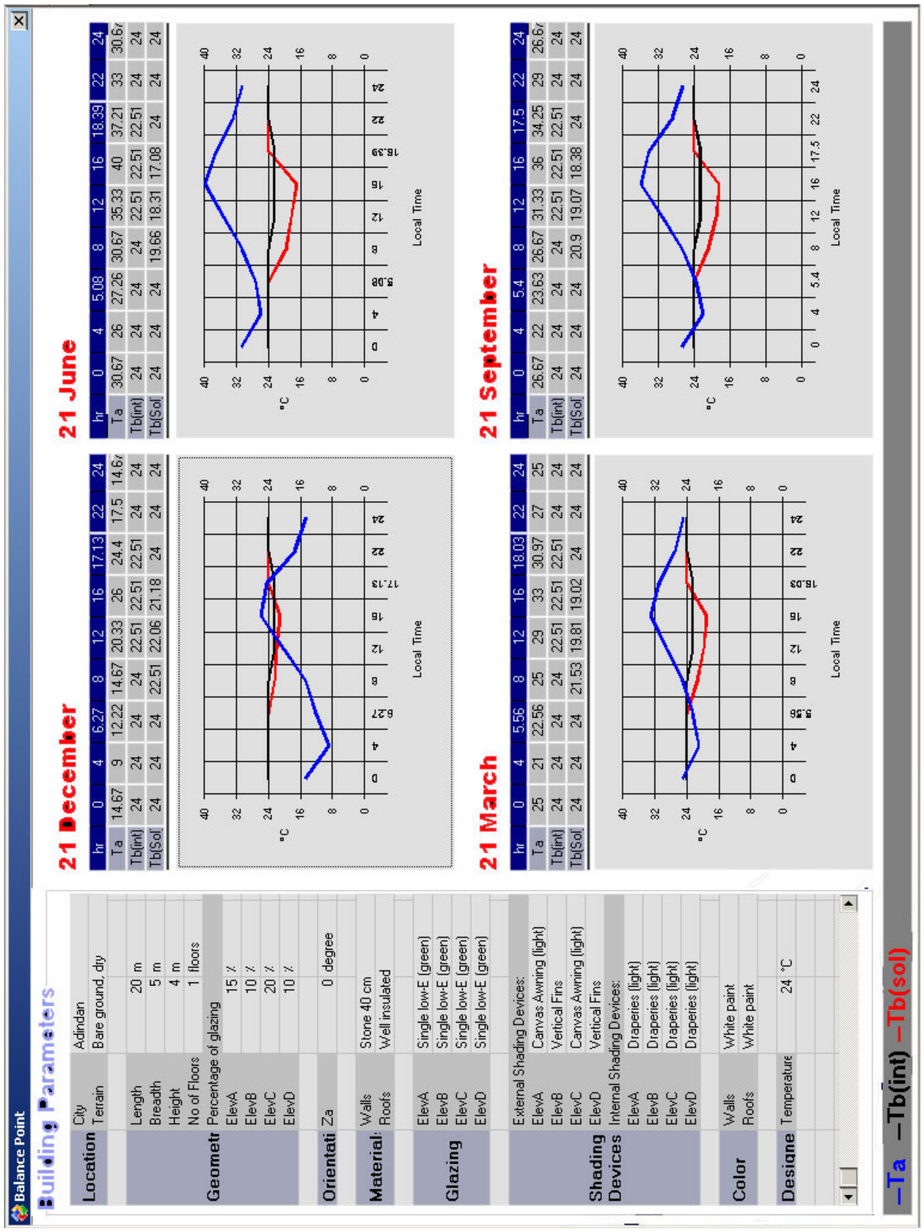
- The most feature characterizing this solution is the dynamic use of shading strategies, where external operable canvas awnings are used for north and south elevations, so as to admit desirable solar gains (direct from south and indirect from north in winter and spring), and block them in summer and autumn.

- Similarly, internal draperies are blocked in summer and autumn, and withdrawn in winter and spring for the sake of further gains.

- The balance point graphs show reasonable balance between heat gains and losses in winter and spring, while solar heat gains are decreased to a minimum possible limit in summer and autumn, when ambient air temperatures are always higher than the designed indoor temperature.

Table (6-7) shows the different parameters of the building skin in the proposed hypothetical example giving reason

					Reason
Geometry	Length	a	20	m	Refer to (6-2-1)
	Breadth	b	5	m	
	Height	c	4	m	
	No of floors	n	1	floor	
2- Orientation		Za	0	deg.	Refer to (6-2-2)
3- Materials					Refer to (6-2-3)
a-	Walls	Stone, 40 cm			
b-	Roof	Well insulated			
4- Glazing	Elev. A	15%	Single low-E(green)		Solar admittance in winter from south, limited effect from east and west, better illumination from north, low (Sc)
	Elev. B	10%	Single low-E(green)		
	Elev. C	20%	Single low-E(green)		
	Elev. D	10%	Single low-E(green)		
5- Shading		**Type**		**Sc**	
External	Elev. A	Canvas Awning (light)		0.2	Operable according to needs
	Elev. B	Vertical fins		0.3	Blocking undesirable east radiation
	Elev. C	Canvas Awning (light)		0.2	Operable according to needs
	Elev. D	Vertical fins		0.3	Blocking undesirable west radiation
Internal	Elev. A	Draperies (light)		0.4	Operable according to needs
	Elev. B			0.4	
	Elev. C			0.4	
	Elev. D			0.4	
6- color		Item	Color	a	Less gains from opaque surfaces dew to less absorptivity
		Walls	White	0.2	
		Roof	White	0.2	


Balance Point
Building Parameters
Location
City Adindan
Terrain Bare ground, dry
Geometry
Length 20 m
Breadth 5 m
Height 4 m
No of Floors 1 floors
Percentage of glazing
ElevA 15 %
ElevB 10 %
ElevC 20 %
ElevD 10 %
Orientation
Za 0 degree
Materials
Walls Stone 40 cm
Roofs Well insulated
Glazing
ElevA Single low-E (green)
ElevB Single low-E (green)
ElevC Single low-E (green)
ElevD Single low-E (green)
Shading Devices
External Shading Devices:
ElevA Canvas Awning (light)
ElevB Vertical Fins
ElevC Canvas Awning (light)
ElevD Vertical Fins
Internal Shading Devices:
ElevA Draperies (light)
ElevB Draperies (light)
ElevC Draperies (light)
ElevD Draperies (light)
Color
Walls White paint
Roofs White paint
Design
Temperature 24 °C
21 December
21 June
21 March
21 September
Local Time
°C
–Ta –Tb(int) –Tb(sol)

Sheet (6-22)

- In the previous solution, it is noticed that the solar heat gains are very limited in winter and are needed to be magnified by a dynamic use of the shading parameters, where the canvas awnings and the draperies are withdrawn for the sake of further gains that balances the night thermal losses (fig.(6-9)).

- The proposed solution represents one of the possible design alternatives for the architect, where further restrictions due to site, program, function, or expenses might force a different architectural solution, another group of skin parameters might have same or better numerical results, however, the previous methodology of decision making stays the same.

21 December

hr	0	4	6.27	8	12	16	17.13	22	24
Ta	14.67	9	12.22	14.67	20.33	26	24.4	17.5	14.67
Tb(int)	24	24	24	24	22.51	22.51	22.51	24	24
Tb(Sol	24	24	24	19.22	14.14	16.49	24	24	24

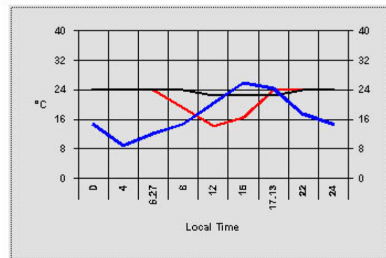


Fig. (6-9)
Balance Point Graphs for the Proposed Solution in Winter after Shading Modification
By the Researcher

(6-3) Conclusions

- The Nubian architecture was a real ideal example of the vernacular Egyptian architecture that made use of the available resources and technology to produce an environmental unique style.

- The building skin parameters of the traditional Nubian house fulfilled the thermal needs of the building.

- The Nubian house was characterized by a compact plan clustered around a central court , with a main entrance facing the bank of the Nile , walls were made of thick mud in the Arab and Mahas districts at middle and southern Nubia, while they were made of stone in the northern districts at Kanuz, the roofs of the houses were made of palm trunks and acacia wood beams in the middle and south, while constructed as catenary vaults and domes in the north, openings were narrow and white color dominated the buildings.

- The new features of the region after the birth of the lake that extended about 500 km. with a varying width from 5 to 45 km. provide strong economical potentials for investments.

- Blending the inherited traditional strategies together with the new scientific analysis methods could result in a new efficient hybrid.

- <u>The best balance point graph is characterized by:</u>

  a) Smallest areas between the ambient temperature curve and the balance point curve indicate minimum needs for cooling or heating either by using passive or active solar architecture strategies (where artificial methods that consume fuel resources are not recommended).

  b) Equal areas for needs of cooling and heating indicate the compensation of the gains to the losses and vice versa.

- The hypothetical example proposed by the researcher for the case study as a result of the former analysis gives *one of the possible treatments* for the external envelope in the chosen site, where many other solutions that can lead to similar thermal results are possible by manipulating the available tools, these tools can be used differently from one architect to another according to other design concepts, functions, and site restrictions.

- This method represents a scientific way of decision making in the schematic phase of the building design whilst the basic lines of the plan are still being drawn, helping the architect to make up his mind before making a detailed planning of the building, thus avoiding any missing points that may cause a non desirable solution.

- The balance point graphs of the different proposed group of alternatives chosen by the architect reveals some facts which may not be clear to a non specialist, where a comparative visual analysis is enough for evaluation.

Chapter VII
Conclusions and Recommendations

(7-1) Conclusions

- The building skin is the external barrier which protects the occupants from the undesirable climatic conditions; the need of suitable shelter was a motive that made man search for suitable strategies concerning the design of that barrier.

- The building skin parameters affecting solar heat gains are:

    - Building materials.
    - Building glazing.
    - Shading strategies.
    - Building Compactness.
    - Building color.
    - Building orientation.

- Proper glazing selection can reduce a building's energy use throughout the year; electric lighting requirements can be reduced by designing windows to take advantage of natural daylight. For buildings with significant cooling loads, special kinds of glazing can reject excessive summer solar heat.

- The shading strategies are one of the most important methods to overcome the undesired direct solar radiation, which increases the building internal temperature, especially in hot arid regions, the use of appropriate shading method is very important, especially within air conditioned buildings, where proper shading greatly reduces what is essentially a needless waste of energy, trying to cool a space with large areas of unprotected glazing.

- The main impact of building compactness from the indoor climate point of view is its effect on the envelope's surface area, relative to the floor's area, or the space volume, and hence, the rate of heat exchange of the building with the outdoors, also, the building's potential for natural ventilation and natural illumination.

- The color of the building represents a very effective factor in the process of heat gain from solar radiation, using light colors in hot climates and dark colors in cold climates is a well known inherited strategy.

- The evaluation of the thermal performance of a building needs a quantitative dynamic method, whereas the thermal flow through the building takes place in a dynamic way, depending upon the activities, lighting, and equipment on one hand, and the solar impact on the other hand, having the building's envelope in between as a heat flow regulator.

- The balance point concept and understanding the moods of energy flow provides a way to reach an insightful design.

- The factors affecting the balance point temperature are:

    - Solar radiation.
    - Building envelope.
    - Internal heat gains.

- During the schematic phase, the designer goal is to manipulate:
    1- The sources of internal heat gains.
    2- The enclosure heat transfer.
    3- The incoming solar energy.

- One of the most important advantages of ***some*** of the simulation programs is its dynamic interaction with the non-specialized architect who is targeting a quick visual result that can be easily judged by the eye on the contrary to traditional and manual methods, where results are mostly numerical and complicated, consuming a lot of time and having a high possibility of error occurrence.

- However, using simulation models for building design has its limitations as existing models fail to tackle issues regarding data preparation in the initial design phases.

- Voluminous data entry, bulky outputs, neglecting the user interface, lack of flexibility, lack of output validation and orientation towards research instead of commercial use are the main defects of most contemporary computer simulation programs.

- The need of a quick method to plot the balance point graphs of a building, an easy way of data input and output in order to have a dynamic opportunity of manipulating the available tools in the schematic design phase, and the flexibility of using the program for most of the cities allover Egypt to give the designer the advantage of adapting the design to its site despite of the different climatic conditions are the main potentials of the research tool.

- Blending the inherited traditional strategies together with the new scientific analysis methods could result in a new efficient hybrid.

- The hypothetical example proposed by the researcher for the case study as a result of the former analysis gives *one of the possible treatments* for the external envelope in the chosen site, where many other solutions that can lead to similar thermal results are possible by manipulating the available tools, these tools can be used differently from one architect to another according to different design concepts, functions, and site restrictions.

- This method represents a scientific way of decision making in the schematic phase of the building design whilst the basic lines of the plan are still being drawn, helping the architect to make up his mind before making a detailed planning.

(7-2) Recommendations and Future Research Work

- The external envelope of the building secures a very effective strategy for better internal thermal condition.

- The bioclimatic considerations must begin in the very early stages of the design for the sake of more economy and better outputs.

- The new concepts of environmental design must be accompanied by an efficient design simulation tool to cover all the intersecting issues regarding bioclimatic design.

- The new tools must have gradual sophistication with respect to the successive design phases varying from conceptual sketches until reaching a detailed design.

- The efforts of the specialized architects must integrate with those of the building design mechanical engineers and software developers for the sake of the birth of a new generation of simulation programs, where an individual solution always suffers from deficiency.

- Future research work is needed to overcome semantic gaps in the proposed research tool for the sake of further development, geometries other than rectangular layouts, inclined walls, openings positioning, must be included, monitoring time lag due to thermal mass effect, and accurate definition of building occupancy schedule, together with internal heat gain rates for different building types other than residential buildings is a question.

- The following requirements are needed in the future intelligent design tools:
    - Reducing the perceived input requirements to define a model.
    - Maximum utilization of whatever information is input.
    - Constant development and refinement of the model.
    - Validation of the output data.

Bibliography

Books:

1. **A Sunset Book,** "Energy Saving Projects", Lane Publishing Co., May- 1981.

2. **Behling, Sophia & Stephen,** "Sol - Power, The Evolution of Solar Architecture", Forward by Sir Norman Foster, Prestel - Welcy, 1996.

3. **Brown,G.Z & Dekay, Mark,** "Sun, Wind and Light – Architectural Design Strategies", Wiley, second edition, 2000.

4. **Cerver, Francisco Asensio,** "Architecture of Minimalism", Ancor for the Hearst Books International, 1997

5. **Edwards, Brian,** "Towards Sustainable Architecture – European Directions and Building Design", Buterworth - Hinemann Ltd., Oxford, 1996.

6. **El Hakim, Omar,** "Nubian Architecture, the Egyptian Vernacular Experience", The Palm Press, 1993.

7. **Gieck, Kurt,** "Engineering Formulas", McGraw-Hill Inc., third edition, 1997.

8. **Givoni, Baruch,** "Climate Considerations in Buildings and Urban Design", Van Nostrand Reinhold, 1998.

9. **Gropp, Louis,** "Solar Houses – 48 Energy Saving Designs", The Conde Nast Publications Inc., 1978

10. **Hawkes, Dean and Foster, Wayne,** " Architecture, Engineering and environment", Laurence King Publishing Ltd, 2002.

11. **Holm, Dieter,** "Energy Conservation in Hot Climates", The Architectural Press Limited, 1983

12. **Hosni, Samir,** "Climate and Architecture, a National Evaluation", Dar El-Maareff, 1978.

13. **Jones, David Lloyd,** " Architecture and the environment ", Laurence King Publishing Ltd , 1998.

14. **Lechner, Norbert,** "Heating, Cooling, Lighting – Design Methods for Architects", John Wiley & sons, 1990

15. **Markus,T.A., and Morris, E.N.** "Building, Climate and Energy", Pitman Publishing Ltd., 1980.

16. **McMullan, Randall,** "Environmental Science in Building", palgrave, fifth edition, 2002

17. **Olgyay, Victor,** "Design with climate – Bioclimatic Approach to Architectural Regionalism", Princeton University Press, 1963.

18. **Pfeiffer, Bruce Brooks,** "Frank Lloyd Wright", Benedict Taschen, 1996.

19. **Riba, A.J. Elder,** "A.J Handbook of Building Enclosure", The Architectural Press, London, 1974.

20. **Steele, James** "Architecture for Islamic Societies Today", St. Martin Press, 1994.

21. **Utzinger, Michael and Wasley, James,** "Vital Signs, Building Balance Point", school of architecture and Urban Planning – University of Wisconsin – Milwaukee, 1997.

22. **Wright, David,** "Natural Solar Architecture – A Passive Primer", Litton Educational Publishing Inc., revised edition, 1978.

23- ا.د / توفيق أحمد عبدالجواد ، "تاريخ العمارة، العصور المتوسطة الاوروبية و الاسلامية" ، 1969

Web Sites:

1. **ALPEN Glass Heat Mirror,** "Key Terms", http://alpeninc.com/features/key_terms, accessed 1/2003.

2. **ASHRAE 90.1 Standard** "Newly Revised ASHRAE 90.1 Standard Addresses the Thermal Performance of Metal Building Envelopes", www.insulatemetalbuildings.com, accessed 14/12/2003.

3. **Beattie, K.H, & Ward, I. C.** "The Advantages of Building Simulation for Building Design Engineers", www.hvac.okstate.edu/pdfs/bs99/papers/PB/16.pdf , accessed 8 / 2003.

4. **Bereau of Meteorology, Australia,** "Solar Radiation Definitions", http/www.bom.gov.au , p.p.1,2, accessed 10/2002.

5. **BuildingGreen.com, Environmental Building News,** "Thermal Mass and R-value: Making sense of confusing issue", From EBN Volume 7, N04- April 1998. www.buildinggreen.com /features/tm/thermal.html – accessed 20/2/2003.

6. **California Glass Bending,** "SECP Tables", www.calglassbending.com/secptabl.htm, accessed 14/12/2003.

7. **Cheung, K P,** "The Sun and Building Design Process I , II ", The University of Hong Kong, http://arch.hku.hk/~kpcheung/teaching/lecture/65156-8.htm, accessed 20/2/2003.

8. **China New Energy,** "Glossary of Energy Terms", www.newenergy.org.cn/english/glossary/searchletter.asp, accessed 25/6/2003.

9. **Crall, Chris P.,** "Newly Revised ASHRAE 90.1 Standard Addresses the Thermal Performance of Metal Building Envelopes", www.insulatemetalbuildings.com/metalbuilding/pages/resources/articles/ashrae.html, accessed 14/12/2003.

10. **D. G. Stephenson,** Canadian building digest, CBD-39. "Solar Heat Gain Through Glass Walls",2002, p.2, http://irc.nrc-cnrc.gc.ca/cbd/cbd039e.html - accessed 20/2/2003.

11. **D. K. Alexander, K. A. Ku Hassan, P. J. Jones,** "Simulation Of Solar Gains Through External Shading Devices" http-www.hvac.okstate.edu-pdfs-bs97-papers-P002.PDF., accessed 8/1/2002.

12. **Effendi Setiadarma,** "Shading Mask" A Computer-Based Teaching Tool for Sun Shading Devices, www.usc.edu/dept/architecture/mbs/papers/ecs/96_asemask/ases96mask.html, accessed 2/2003.

13. **EREC Brief,** "Solar Radiation for Energy: A Primer and Sources of Data", Energy Efficiency & Renewable Energy Clearinghouse, http://www.eren.doe.gov/consumerinfo/refbriefs/v138.html, accessed 1/2003.

14. **EREC Brief,** "Computer Software for Solar Energy Analysis and System Design", Energy Efficiency and Renewable Energy Clearinghouse, www.eren.doe.gov/consumerinfo/refbriefs/v101.html, accessed 20/2/2003.

15. **EREC Factsheets,** "Advances in Glazing Materials for Windows", Energy Efficiency and Renewable Energy Clearinghouse, www.eren.doe.gov/erec/factsheets/windows.html, accessed 19/2/2003.

16. **Green Building Design & Construction Guidelines,** "Envelope & Space Planning", http/www.santa-monica.org/GreenDesign/pdf/eni.pdf, accessed 2/2003.

17. **H.E. Coffey, E.H. Erwin and C.D. Hanchett,** "Solar Databases For Global Change Models", http://www.ngdc.noaa.gov/stp/SOLAR/solarda3.html, accessed 2/2003.

18. **Hastings, Robert,** "The evolution of solar architecture", for the Swiss Federal Office of Energy, 2002 http/www.ebd.lth.se/avd%20ebd/main/Summerschool/Lectures/lec.pdf accessed 16/10/2002

19. **Hedge, John F.,** "Library Case Study: Benefits of Passive SolarVersus Traditional Design, http/greenenergyohio.org/default.pdf accessed 11/1/2002.

20. **Hui, S. C. M.,** "Simulation Based Design Tools for Energy Efficient Buildings in Hong Kong" , *Hong Kong Papers in Design and Development*, Vol. 1, 1998, pp. 40-46, Department of Architecture, University of Hong Kong , www.arch.hku.hk/~cmhui/hkpdd/hkpdd-v1.htm, accessed 25/2/2004

21. **Hunkler Tim G.,** "Symbolism and Coincidences of the Great Pyramid" http://www.aloha.net/~johnboy/Pyramids/pyramic symbolism.htm, accessed 16/12/2002

22.	**Kyker, Lyndsay**	" Sir J. Norman Lockyer", Sweet Briar College http://witcombe.sbc.edu/earthmysteries/EMLockyer.html, accessed 21/10/2002
23.	**Kyker, Lyndsay**	, "Archaeoastronomy and the Search for Ancient Observatories" http://www.uiowa.edu/anthro/webcourse/lost/projects97/Archae.html, accessed 16/10/2002
24.	**March, Andrews and Raines, Caroline,**	"Square One", www.Squ1.com, accessed 1/2003.
25.	**March, Andrews John**	"Performance Analysis and Conceptual Design", thesis presented for the degree of Doctor of Philosophy, The University of Western Australia School of Architecture and Fine Arts, 1997, www.squ1.com/research/papers/thesis/part_A.htm, accessed 25/2/2004
26.	**Millard Lesley,**	"Multimedia support for architectural education: the potential of interactive simulation techniques in bioclimatic design.", Faculty of Design and the Built Environment, Leeds Metropolitan University, accessed 4/1/2003.
27.	**Milne, Murray,**	"Energy Design Tools", Department of Architecture and Urban Design, University of California, Los Angeles, www.aud.ucla.edu/energy-design-tools, accessed 6/9/2002.
28.	**National Oceanic and Atmospheric Administration,**	"Solar Calculator", http://www.srrb.noaa.gov/highlights/sunrise/azel.html, accessed 5/9/2002

29. **NREL,** "Energy-10 Software Home Page", www.nrel.gov/buildings/energy10, accessed 8/1/2002.

30. **Office of Energy Efficiency and Renewable Energy,** "EREC Brief, Solar Radiation for Energy: A Premier and Sources of Data", www.eren.doe.gov /consumerinfo /refbreifs/ vi38.html, p.2, accessed 10/2002.

31. **Oh, John K.W & Harbell, Jeff S.,** " New Educational Software for Teaching the Sunpath Diagram and the Shading Mask Protractor" , Texas A&M University, www.hvav.okstate.edu/pdf/ bs97/papers/p203.pdf , accessed 1/2003

32. **Oklahoma State University, Research Group,** "Building & Environmental Thermal Systems", http://www.hvac.okstate.edu/HomeFrame. html, accessed 2/2003

33. **Pacific Energy Center Fact sheet** "Energy-Efficient Window Glazing Systems", http://www.pge.com, accessed 20/2/2003

34. **Pilkington Eclipse Reflective Glass** "Exceptional glass Solutions" ,www. pilkington.com, accessed 14/12/2003.

35. **Renewable Energy World,** "Urban reality- solar design and refurbishment", http://www.jxj.com/magsandj/rew/2001_06/urban_reality.html- accessed 19/2/2004.

35. **Southey, W.** "The Great Pyramid, Facts about the Great Pyramid" http://www.infinitetechnologies.co.za/articles/thegreatpyramid.html, accessed 16/12/2002.

36. **The Pacific Energy Center,** "Architectural Site Survey: Predicting Shading with a Fish Eye Lens", www.pge.com/003_save_energy/003c_edu_train/pec/toolbox/tll/app_notes/arch_site. html, accessed 5/9/2002.

37. **Thomas M. Crawford,** "Passive Solar Design Using Computer Generated Suncharts", www.srv.net/~tm_crw4d/opt/sunchrt.html, accessed 5/9/2002.

38. **Vital Signs,** "A Tale of Two Buildings" http://arch.ced.berkeley.edu/vitalsigns/workup/two_houses/two_ method.html - accessed 25/6/2003.

39. **University of Colorado Solar Decathlon October 2, 2002,** "Adaptable Design Strategies for Market Housing", http/solar.colorado.edu-pdf-oct2news.pdf, accessed 20/2/2003.

40. **University of Oregon, Solar Radiation Monitoring Lab.** "Solar radiation basics", http://solardat.uoregon.edu/SolarRadiationBasics.html, accessed 1/2003.

39. **Ward, John and Folkard, Margaret ,** "Sundials", for the Royal New Zealand Institute of Horticulture, 2001

40. **Witcombe, Chris ,"** "Sacred Places, Abu Simbel-Egypt", Sweet Briar College, http://www.arthistory.sbc.edu/sacredplaces/abusimbel.html accessed 21/10/2002.

41. "History of Roman Architecture" http://web.kyoto-inet.or.jp/org/orion/eng/hst/roma/pantheon.html, accessed 23/12/2002.

42. "The Ways of Heaven"
http://www.geocities.com/elchasqui_2/ZSitchin book4h1.html
accessed 21/10/2002.

44. "Archaeoastronomy, a Short Background Description of Archeoastronomy, also Called Astro-archaeology.",
http://www.stonesofwonder.com/archaeoa.htm,
accessed 16/12/2002.

46. "Building Energy Simulation",
www.inf.bauwesen.tumuenchen.de/personen/christop/bsim/building_energy.htm, accessed 26/2/2004.

47. "Earth Radiation Budget ",
http://marine.rutgers.edu/mrs/education/class/yuri/erb.html,
accessed 2/2003

48. "Energy & Climate, MS building design: links",
www.caed.asu.edu/msenergy/resources-links.html,
accessed 20/2/2003.

49. "Giza Sphinx & Pyramids"
http://www.delange.org/Giza_Pyramids -
accessed 21/10/2002

50. "Pv Software",
www.pvresources.com/en/software.html,
accessed 20/2/2003

51. "Solacalc, a Passive Solar Design Software",
www.solacalc.freeserve.co.uk, accessed 2/2003.

53. "Solar Radiation",
http://almashriq.hiof.no/lebanon/600/610/614/solar-water/idrc/01-09.html,
accessed 2/2003.

54. "Solarbuzz, Solar Energy Links", www.solarbuzz.com/Links/Technical.htm, accessed 2/2003.

55. "Spectrally - Selective Glazings", http://www.advancebuildings.org , accessed 2/2003.

56. "The Architecture of the Ancient World" http://www.geocities.com/SoHo/Workshop/5220/ancient.html, accessed 16/10/2002

57. "The Nubians and the Dam", http://carbon.cudenver.edu/stc-link/aswan2/culture.html, accessed 2/2004

58. "The Solar Analyst 1.0", www.hemisoft.com/doc/sa_manual/solarext.htm accessed 20/2/2003.

59. "Tinted Window Glazings for Comfort", http-www.pge.com-003_save_energy-003b_bus-pdf-window_glazing.pdf, accessed 20/2/2003.

60. http//www.indiabuildnet.com/arch/sangath.htm, accessed 20/2/2003.

61. http://4egypt.info/nubian.htm, accessed 2/2004

62. http://www.african-angler.co.uk/lake.html, accessed 12/2003.

63. http://www.dcue.dk, accessed 17/8/2003

64. http://www.ilec.or.jp/database/afr/afr-19.html, accessed 12/2003.

65. http://www.media.uwe.ac.uk/masoud/cal-97/papers/millar.htm,
accessed 1 / 2004.

66. http://www.najaco.com/islam/fun_illustrations/4.htm ,
accessed 12/2002

67. http://www_tagpapoplys_dk-images-tagpapogarkitektur.htm - accessed 17/8/2003.

68. New Gourna Village
http://www.geocities.com/egyptarchitect1/hasanfathi/ngourna/gmosque1.htm - accessed 20/2/2003.

69. www.diydata.com, also www.ibiblio.org , accessed 11/2003.

70. www.hvac.okstate.edu/pdfs/bs99/papers/PB/16.pdf , accessed 8 / 2003.

Courses Attended

"Computer Applications in architecture"- Excel Applications - Preparatory year for Master Degree of Science, Ain Shams University – 2000/2001 – Dr. Samir Sadek Hosni.

Journals

Wild, Simon & Fogarty, Alan "How much do U- value glazing", The Architect's Journal, 17 January, 2002.

Periodics

Housing & Building Research Centre, "Energy Efficiency Residential Building Draft Code- (EERBC) – For New Residential Buildings, Additions and Retrofits", June 2003.

Thesis :

1- **م.عباس محمد عباس الزعفرانى،** "العمارة الشمسية فى المناطق الحارة"، رسالة ماجستير، كلية الهندسة، جامعة القاهرة ،**2000 م**

2- **م. رماح ابراهيم محمد سالم،** "تصميم الفراغات العمرانية فى المناطق الحارة"، رسالة ماجستير، كلية الهندسة، جامعة القاهرة، **1984 م**

3- **م. حسن قطرى محمد نزهت،** "تأثير البيئة على المسكن المصرى المعاصر"، رسالة ماجستير، كلية الهندسة، جامعة القاهرة، **1972 م**

- **The appendix shows the core of the application performed in the research, which is represented by an Excel sheet that carry out all calculations in the background of the visual basic interface previously shown in chapter V.**

- **The application consists of 12 sheets that contribute together in an integrated way, where all calculations are based on the previous theoretical data in part II.**

1-Site Properties

a) Location

Code	City	Latitude	Longtude	Avarage temperature 21-Jun Max.	21-Jun Min.	21-Sep Max.	21-Sep Min.	21-Dec Max.	21-Dec Min.	21-Mar Max.	21-Mar Min.
1	Cairo	30.8	31.34	35.4	21.5	29.8	17.8	19.1	8.6	28.2	13.9
2	Giza	30.02	31.13	35.8	20.5	30.6	16.1	20.2	6.1	28.7	11.7
3	Helwan	29.52	31.2	35.3	21.5	30.1	18.6	18.8	8.6	28.3	14.2
4	Alexandria	31.12	29.57	29.6	22.7	27.7	17.8	18.3	9.3	23.6	13.5
5	Ismaillia	30.36	32.14	36.4	22.2	30.7	17.8	20.4	8.1	27.6	13.6
6	Fayed	30.2	32.17	35.9	20.9	30	16.8	19.9	7.9	28.3	12.9
7	Port Said	31.17	32.14	30.4	24.1	27.4	21.8	18	11.3	22.6	16.1
8	Suez	29.56	32.33	36.5	22.3	31.1	18.5	20.3	8.7	28.2	14.3
9	Damietta	31.25	31.49	31	21.2	27.6	18.7	18.4	8.2	23.2	13.7
10	Mansoura	31.03	31.23	34.9	20.7	30.3	17.6	19.6	7.3	27.3	12.3
11	Damanhur	31.02	30.28	32.5	20.2	29.5	17	19.6	7.7	26.4	12.3
12	Tanta	30.47	31	34.5	19.1	30.1	15.4	19.7	6	27.6	10.7
13	El Arish	31.07	33.45	30.6	21.1	28.6	17.9	19.3	8.3	23.6	13.2
14	El Tor	28.14	33.37	34.9	24.4	29.9	18.6	21.3	8	28	16.3
15	Hughada	27.17	33.46	32.6	24.8	28.5	19.7	20.6	9.6	26	16.1
16	Qusier	26.08	34.18	33.3	26.3	30.3	23	22.7	13.8	27.3	19.4
17	Fayoum	29.18	30.51	36.7	21.2	31.2	17.1	20.3	6.1	30.1	12.9
18	Beni Suef	29.04	31.06	36.8	20.1	31.8	15.8	20.8	5	30.1	12
19	Minya	28.05	30.44	36.9	20.2	31.2	15.6	20.6	4	30.6	11.8
20	Asyout	27.11	31.06	36.9	22.3	30.9	18	20.8	6.6	31.9	14.8
21	Kena	26.1	32.43	40.8	23.7	35.1	18.9	22.7	6.7	35.4	15.9
22	Luxor	25.4	32.42	40.7	23.6	35.1	17.8	23	5.4	34.8	15.7
23	Aswan	24.02	32.53	41.9	26.1	37.5	21.7	24.2	9.5	35.7	18.6
24	Adindan	22.3	32	38	28	37	24	28	9	29	15
25	Siwa	29.12	25.19	38	20.7	31.7	14.9	19.7	4.1	29.9	12.1
26	Baharia	28.2	28.54	36.8	20.6	31	15.9	19.9	4.7	30	12.7
27	Dakhla	25.29	29	38.6	23.1	33.2	17.4	21.4	4.4	32.7	14.3
28	Kharga	25.26	30.34	39.1	23.3	34	18.6	22.3	5.9	33.1	15.7

code= 24

City	Latitude	Longtude	Avaragetemperature 21-Dec Max.	21-Dec Min.	21-Mar Max.	21-Mar Min.	21-Jun Max.	21-Jun Min.	21-Sep Max.	21-Sep Min.
24	22.3	32	28	9	29	15	38	28	37	24

b) Site terrain

Code	Terrain	r	
1	Bare ground, dry	0.15	0.15
2	Bare ground, wet	0.09	0
3	Sand, dry	0.25	0
4	Sand, wet	0.15	0
5	Mold, black, dry	0.14	0
6	Mold, black, wet	0.08	0
7	Rock	0.14	0
8	Dry grass	0.32	0
9	Green fields	0.08	0
10	Green leaves	0.28	0
11	Dark forest	0.05	0
12	Desert	0.26	0
13	Salt flats	0.42	0
14	Brick, depending on	0.3	0
15	Asphalt	0.15	0
16	City area	0.1	0
			0.15

code= 1

Terrain	r
	0.15

Sheet 1: selects different properties identifying the site

2- Building Geometry

Length	a	=	20	m						
Breadth	b	=	5	m						
Hight	h	=	4	m						
area/floor	A/f	=	100	m^2						
no of floors	n	=	1							
Total area	A_f	=	100	m^2						
peremiter	P	=	50	m						
wall areas					Net wall area					
Aw_a		=	80	m^2	Net Aw_a	68				
Aw_b		=	20	m^2	Net Aw_b	18				
Aw_c		=	80	m^2	Net Aw_c	64	A_W	=	168	m^2
Aw_d		=	20	m^2	Net Aw_d	18				
						168				
glazing area										
	%									
Ag_a	15	=	12	m^2						
Ag_b	10	=	2	m^2						
Ag_c	20	=	16	m^2	Overall glazing area		A_{glz}	=	32	m^2
Ag_d	10	=	2	m^2						

3- Building Orientation

Wall Azimuth		
Za	=	0
Zb	=	90
Zc	=	180
Zd	=	270

7- Building Enclosure

$\hat{U}_{wall}$	=	1.932
$\hat{U}_{roof}$	=	0.28
$\hat{U}_{glz}$	=	1.472
$\hat{U}_{gr}$	=	2.5
$\hat{U}_{vent}$	=	0.85
$\hat{U}_{bldg.}$	=	7.034

Sheet 2: calculates different geometrical relations as a result of input data
Sheet 3: calculates orientation angles for different facades as a result of supplying it with the orientation of façade (A).
Sheet 7: calculates heat gain <u>rates</u> from the building envelope

4- Building Materials and Color

Code	Wall Material	U-value		
1	Flat metal, no insulation	6.8	0	26
2	Flat metal, 2.5 cm fiber insulation	1.25	0	26
3	Flat metal, 5 cm fiber insulation	0.68	0	26
4	Flat metal, 7.5 cm fiber insulation	0.51	0	26
5	Flat metal, 10 cm fiber insulation	0.397	0	26
6	Flat metal, 15 cm fiber insulation	0.28	0	26
7	Flat metal, 20 cm fiber insulation	0.23	0	26
8	Flat metal, 30 cm fiber insulation	0.15	0	26
9	25 cm solid brick - no finish	1.87	0	26
10	30 cm solid brick+plaster on lathe	1.22	0	26
11	12 cm solid brick - no finish	3.74	0	26
12	17 cm solid brick+plaster on lathe	2.44	0	26
13	Hollow clay tile 10cm	5	0	26
14	Hollow clay tile 15cm	3.7	0	26
15	Hollow clay tile 20cm	3	0	26
16	Poured concrete, 15 cm	1.75	0	26
17	Poured concrete, 20 cm	1.4	0	26
18	Poured concrete, 25 cm	1.19	0	26
19	Poured concrete, 30 cm	1.02	0	26
20	Hollow concrete blocks 20cm	5.6	0	26
21	Wood 2.5 cm	3.6	0	26
22	Wood 5 cm	1.8	0	26
23	Plywood 12mm	9	0	26
24	Mineral fibers batts 9cm	0.5	0	26
25	Mineral fibers batts 15cm	0.3	0	26
26	Stone 40 cm	1.15	1.15	26
			1.15	

code= 26

U_{wall} = 1.15

$\hat{U}_{wall}$ = 1.932

(4-1)Roof

(4-1-1) Roof Material

code	Material	U-value		
1	Well insulated	0.28	0.28	1
2	Moderate insulated	1.15	0	1
3	Poor insulated	2	0	1
4	Non insulated concrete roof	2.8	0	1
			0.28	

code= 1

U_{roof} = 0.28

$\hat{U}_{roof}$ = 0.28

(4-1-1) Walls' color

code	Material	absoptivity		
1	Whitewash, new	0.15	0	3
2	White, dirty	0.3	0	3
3	White paint	0.2	0.2	3
4	light (Gray, Green, Brown)	0.45	0	3
5	Dark (Gray, Green, Brown)	0.75	0	3
6	Black paint	0.85	0	3
7	Aluminium foil, polished	0.05	0	3
8	Aluminium foil, oxidized	0.15	0	3
9	Aluminium paint	0.5	0	3
			0.2	

code= 3

a = 0.2

(4-2-1) Roof's color

code	Material	absoptivity		
1	Whitewash, new	0.15	0	3
2	White, dirty	0.3	0	3
3	White paint	0.2	0.2	3
4	light (Gray, Green, Brown)	0.45	0	3
5	Dark (Gray, Green, Brown)	0.75	0	3
6	Black paint	0.85	0	3
7	Aluminium foil, polished	0.05	0	3
8	Aluminium foil, oxidized	0.15	0	3
9	Aluminium paint	0.5	0	3
			0.2	

code= 3

a = 0.2

Sheet 4: selects material and color for both walls and roof, and gives numerical values related to these properties.

5- Building glazing

				Glazing for façade A		code	Glazing for façade B		code	Glazing for façade C		code	Glazing for façade D		code
code	type	U	Sc	U	Sc	7	U	Sc	7	U	Sc	7	U	Sc	7
1	Single clear	6	0.82	0	0	7	0	0	7	0	0	7	0	0	7
2	Single-reflective-bronz	6	0.2	0	0	7	0	0	7	0	0	7	0	0	7
3	Single-tinted-bronze	6	0.57	0	0	7	0	0	7	0	0	7	0	0	7
4	Single-tinted-green	6	0.56	0	0	7	0	0	7	0	0	7	0	0	7
5	Single low-E (bronze)	4.6	0.42	0	0	7	0	0	7	0	0	7	0	0	7
6	Single low-E (clear)	4.6	0.66	0	0	7	0	0	7	0	0	7	0	0	7
7	Single low-E (green)	4.6	0.41	4.6	0.41	7	4.6	0.41	7	4.6	0.41	7	4.6	0.41	7
8	Double clear	3	0.65	0	0	7	0	0	7	0	0	7	0	0	7
9	Double-tinted (bronze)	3	0.48	0	0	7	0	0	7	0	0	7	0	0	7
10	Double-tinted (green)	3	0.46	0	0	7	0	0	7	0	0	7	0	0	7
11	Double-tinted (gray)	3	0.45	0	0	7	0	0	7	0	0	7	0	0	7
12	Double, Reflective	3	0.16	0	0	7	0	0	7	0	0	7	0	0	7
13	D. low-E, clear	2.3	0.45	0	0	7	0	0	7	0	0	7	0	0	7
14	D. low-E,(bronze)	2.3	0.35	0	0	7	0	0	7	0	0	7	0	0	7
15	D.low-E, (green)	2.3	0.37	0	0	7	0	0	7	0	0	7	0	0	7
16	D. low-E (gray)	2.3	0.34	0	0	7	0	0	7	0	0	7	0	0	7
				4.6	0.41		4.6	0.41		4.6	0.41		4.6	0.41	
				$U_{glz\,A}$ =	4.6		$U_{glz\,B}$ =	4.6		$U_{glz\,C}$ =	4.6		$U_{glz\,D}$ =	4.6	
				$Sc_{glz\,A}$ =	0.41		$Sc_{glz\,B}$ =	0.41		$Sc_{glz\,C}$ =	0.41		$Sc_{glz\,D}$ =	0.41	
				$U_{glz\,A} X (A_{gA} / Af)$			$U_{glz\,B} X (A_{gB} / Af)$			$U_{glz\,C} X (A_{gC} / Af)$			$U_{glz\,D} X (A_{gD} / Af)$		
				=	0.552		=	0.092		=	0.736		=	0.092	
							$\hat{U}_{glz}$ =	**1.472**							

Sheet 5: selects glazing type individually for each façade, and calculates related numerical values.

6- Shading Devices

	External Shading	Sc	Façade A Sc	code	Façade B Sc	code	Façade C Sc	code	Façade D Sc	code
			Sc	15	Sc	4	Sc	15	Sc	4
1	Exterior Venetian	0.1	0	15	0	4	0	15	0	4
2	Horiz. Adjustable	0.1	0	15	0	4	0	15	0	4
3	Vertical Adjustable	0.1	0	15	0	4	0	15	0	4
4	Vertical Fins	0.3	0	15	0.3	4	0	15	0.3	4
5	Eggcrate (narrow)	0.1	0	15	0	4	0	15	0	4
6	Eggcrate (Wide)	0.3	0	15	0	4	0	15	0	4
7	Canvas Awning (light)	0.2	0	15	0	4	0	15	0	4
8	Canvas Awning (Dark)	0.35	0	15	0	4	0	15	0	4
9	Mashrabia (narrow)	0.15	0	15	0	4	0	15	0	4
10	Mashrabia (wide)	0.42	0	15	0	4	0	15	0	4
11	Overhang	0.2	0	15	0	4	0	15	0	4
12	Trees (dense)	0.2	0	15	0	4	0	15	0	4
13	Trees (medium)	0.4	0	15	0	4	0	15	0	4
14	Trees (light)	0.6	0	15	0	4	0	15	0	4
15	None	1	1	15	0	4	1	15	0	4
			1		0.3		1		0.3	

	internal Shading	Sc	Façade A Sc	code	Façade B Sc	code	Façade C Sc	code	Façade D Sc	code
			Sc	10	Sc	10	Sc	10	Sc	10
1	Venetian Blinds(ref.)	0.45	0	10	0	10	0	10	0	10
2	Venetian Blinds(light)	0.58	0	10	0	10	0	10	0	10
3	Venetian Blinds(dark)	0.75	0	10	0	10	0	10	0	10
4	Roller Blinds (light)	0.39	0	10	0	10	0	10	0	10
5	Roller Blinds (medium)	0.6	0	10	0	10	0	10	0	10
6	Roller Blinds (dark)	0.81	0	10	0	10	0	10	0	10
7	Draperies (light)	0.4	0	10	0	10	0	10	0	10
8	Draperies (medium)	0.65	0	10	0	10	0	10	0	10
9	Draperies (dark)	0.8	0	10	0	10	0	10	0	10
10	None	1	1	10	1	10	1	10	1	10
			1		1		1		1	

Sheet 6: selects external and internal shading devices individually for each façade, and calculates related numerical values.

Sheet 8: calculates internal heat gain rates from lights, occupancy and Equipments.

Sheet 9: detects different solar angles for the selected site, it is based on table [5-2a] and [5-2b] previously mentioned in chapter V

21-Dec

	Local time	6.27	8	12	16	17.13
	A	0	17.74	44	13.9	0
	Z	–	125.7	183.2	236.9	–
	IDN	0	940	1100	885	0
	cosA	–	0.952449	0.71934	0.970716	–
	SinA	–	0.304698	0.694658	0.240228	–
	Za	–	125.7	183.2	236.9	–
	Zb	–	35.7	93.2	146.9	–
	Zc	–	–54.3	3.2	56.9	–
	Zd	–	–144.3	–86.8	–33.1	–
	cos Zi	–	–0.58354	–0.99844	–0.5461	–
		–	0.812084	–0.05582	–0.83772	–
		–	0.583541	0.998441	0.546102	–
		–	–0.81208	0.055822	0.837719	–
Direct (W/m2)	I_{Da}	0	0	0	0	0
	I_{Db}	0	727.06	0	0	0
	I_{Dc}	0	522.4456	790.04	469.1475	0
	I_{Dd}	0	0	44.17009	719.6708	0
	I_{DH}	0	286.4162	764.1242	212.6018	0
Diffuse (W/m2)	I_{da}	0	56.4	66	53.1	0
	I_{db}	0	56.4	66	53.1	0
	I_{dc}	0	56.4	66	53.1	0
	I_{dd}	0	56.4	66	53.1	0
	I_{dH}	0	112.8	132	106.2	0
Reflected (W/m2)	I_{Ra}	0	29.94121	67.20932	23.91014	0
	I_{Rb}	0	29.94121	67.20932	23.91014	0
	I_{Rc}	0	29.94121	67.20932	23.91014	0
	I_{Rd}	0	29.94121	67.20932	23.91014	0
	I_{RH}	0	0	0	0	0
Global (W/m2)	I_{Ga}	0	86.34121	133.2093	77.01014	0
	I_{Gb}	0	813.4013	133.2093	77.01014	0
	I_{Gc}	0	608.7869	923.2493	546.1576	0
	I_{Gd}	0	86.34121	177.3794	796.681	0
	I_{GH}	0	399.2162	896.1242	318.8018	0

Sheet 10: the previous figure shows one of ***four*** sets forming the sheet, where global solar radiation is calculated for the five orientations 3 times a day, for the four seasons, showing sunset and sunrise time.

11- Solar Heat Gains

(11-1) Direct Gain from glazing

21-Dec

	Local time	6.27	8	12	16	17.13
$Q_{sol\ A}$ =	$I_{Ga}XSc_a(A_{glza}/Af)$	0	4.247988	6.553898	3.788899	0
$Q_{sol\ B}$ =	$I_{Gb}XSc_b(A_{glzb}/Af)$	0	2.000967	0.327695	0.189445	0
$Q_{sol\ C}$ =	$I_{Gc}XSc_c(A_{glzc}/Af)$	0	39.93642	60.56515	35.82794	0
$Q_{sol\ D}$ =	$I_{Gd}XSc_d(A_{glzd}/Af)$	0	0.212399	0.436353	1.959835	0
$Q_{sol\ Roof}$ =	$I_{Gr}XSc_r(A_{glzr}/Af)$	0	0	0	0	0
Q_{sol} =	Sum	0	46.39777	67.8831	41.76612	0

(11-2) Indirect Gain from Opaque Surface

(11-2-1) Calculating Solar Air Temp.

	Local time	6.27	8	12	16	17.13	4
1.58333	Ambient temp.(Ta)	12.59417	15.33333	21.66667	28	26.21083	9
T_{sa} (A) =	$Ta+(a*I_{Ga}/20)$-LWR	0	14.19675	20.99876	26.7701	0	0
T_{sa} (B) =	$Ta+(a*I_{Gb}/20)$-LWR	0	21.46735	20.99876	26.7701	0	0
T_{sa} (C) =	$Ta+(a*I_{Gc}/20)$-LWR	0	19.4212	28.89916	30.23168	0	0
T_{sa} (D) =	$Ta+(a*I_{Gd}/20)$-LWR	0	13.06016	20.77255	32.73691	0	0
T_{sa} (R) =	$Ta+(a*I_{GH}/20)$-LWR	0	14.3255	25.62791	26.18802	0	0

Assuming $T_{themostst}$ = 24 °c

	Local time	6.27	8	12	16	17.13	
ΔT(Tsa- Tther.)	**Elev A**	-	-9.80325	-3.00124	2.770101	-	
	Elev B	-	-2.53265	-3.00124	2.770101	-	
	Elev C	-	-4.5788	4.89916	6.231678	-	
	Elev D	-	-10.9398	-3.22745	8.736911	-	
	Roof	-	-9.6745	1.627909	2.188018	-	

(11-2-2) Calculating Indirect Solar Gains From Opaque Envelope.

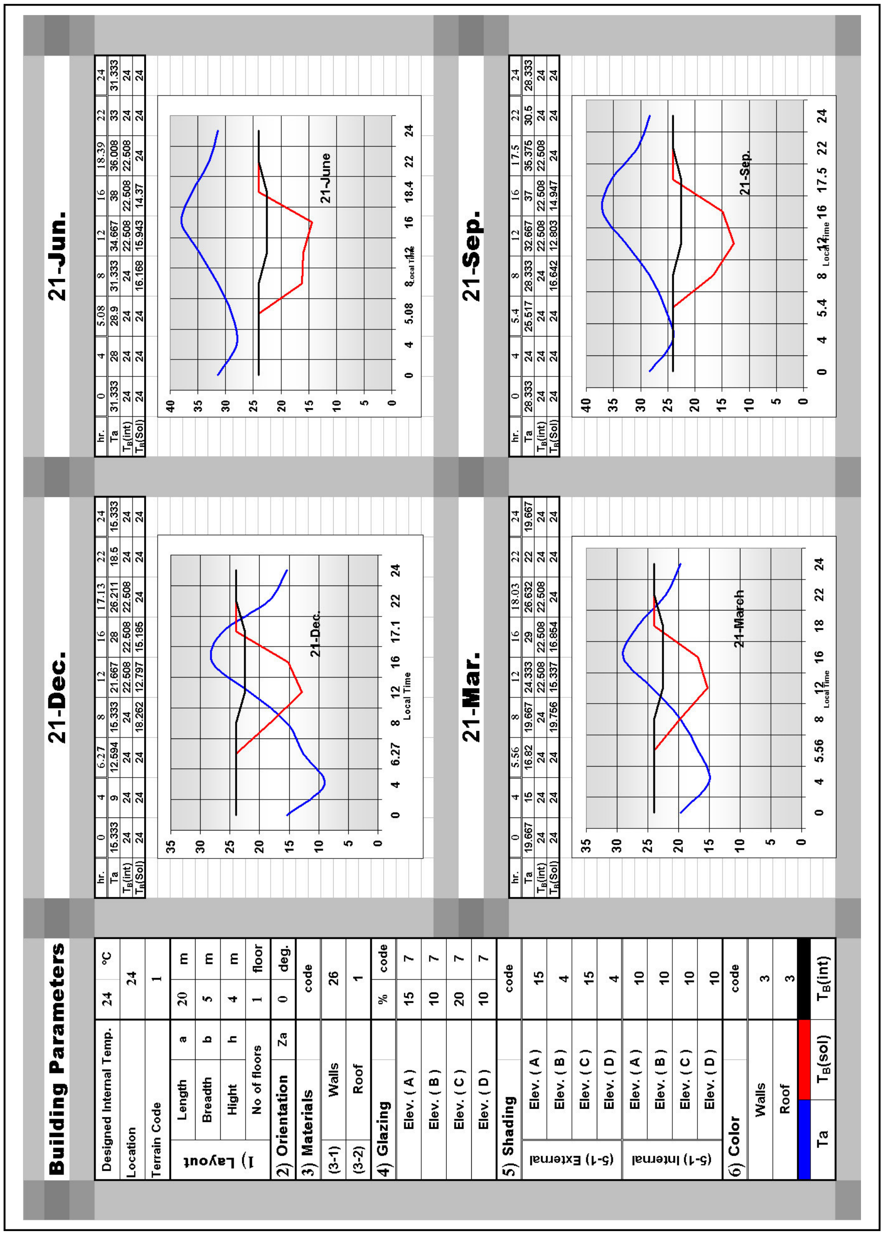
	Local time	6.27	8	12	16	17.13	$\hat{U}_{wall(i)}$
$Q_{sol\ A}$ =	$(T_{sa}-T_{th})*A_{wa}*U_{wa}/A_f$	-	-7.66615	-2.34697	2.166219	-	0.782
$Q_{sol\ B}$ =	$(T_{sb}-T_{th})*A_{wb}*U_{wb}/A_f$	-	-0.52426	-0.62126	0.573411	-	0.207
$Q_{sol\ C}$ =	$(T_{sc}-T_{th})*A_{wc}*U_{wc}/A_f$	-	-3.37	3.605782	4.586515	-	0.736
$Q_{sol\ D}$ =	$(T_{sd}-T_{th})*A_{wd}*U_{wd}/A_f$	-	-2.26455	-0.66808	1.808541	-	0.207
$Q_{sol\ Roof}$ =	$(T_{sr}-T_{th})*A_r*U_r/A_f$	-	-2.70886	0.455814	0.612645	-	0.28
Q_{sol} =	Sum	-	-16.5338	0.425288	9.747331		

(11-3) Total Solar Heat Gains

	Local time	6.27	8	12	16	17.13	
	Qsol (W/m^2)	0	29.86396	68.30839	51.51345	0	
		0	29.86396	68.30839	51.51345	0	

Sheet 11: the previous figure shows one of ***four*** sets forming the sheet, where total solar heat gains are calculated 3 times a day, for the four seasons, showing sunset and sunrise time.

Designed indoor temperature is also set in this sheet.



Sheet 12: is the final output of the application, showing the balance point graphs on the right, whilst a table with the codes of the selected parameters is given on the left.

مقدمة

- يتناول البحث تأثير الاشعاع الشمسى على تشكيل الغشاء الخارجى للمبانى السكنية، و دور المعمارى فى اختيار الخواص المناسبة لهذا الغشاء بدءاً من المراحل الاولى للعملية التصميمية بهدف توجيه التصميم لتحقيق بيئة حرارية مناسبة لراحة الانسان داخل المبنى.

- اعتمد البحث بصفة أساسية على مجموعة من الخواص الرقمية و المعادلات النظرية التى تصف المراحل المختلفة لعملية الانتقال الحرارى، (خارج المبنى، خلال الغشاء الخارجى للمبنى، و داخل المبنى).

- لجأ الباحث إلى تصميم برنامج حاسب آلى يجمع كل الخواص الرقمية و المعادلات السابقة بهدف مساعدة المعمارى غير المتخصص فى بداية العملية التصميمية، حيث يمثل هذا البرنامج أداة لدعم اتخاذ القرار التصميمى لتشكيل الغشاء الخارجى للمبنى، مع امكانية التطبيق فى 28 مدينة فى مصر.

- تم استخدام برنامج الحاسب الالى كأداة بحثية فى موقع الدراسة، حيث خلص الباحث الى طرح أحد الحلول الممكنة للغشاء الخارجى للمبنى، مع توضيح كيفية تحليل الاداء الحرارى للمبنى من خلال استقراء النتائج.

أ) التعريف بالمشكلة

المشكلة البحثية

- نشأت المشكلة عندما أدارت العمارة ظهرها للطبيعة معتمدة اعتماداً كلياً علـــى الميكنـــة لتصحيح البيئة الداخلية للمبنى.
- أدى بريق العمارة الحديثة إلى الانتشار غير الواعى في المستعمرات و الدول الناميـــة ، حيث لم يراعى اختلاف الظروف من مكان الى آخر طبيعياً و أجتماعياً و ثقافياً.
- فى مصر : ظهرت نفس المشكلة بطريقة مماثلة حيث تم وضع تصميمات ثابتة لنمـــاذج سكنية، مبانى إدارية ، أسواق ..الخ ، والتى انتشرت بطول الـــبلاد وعرضـــها بـــنفس المواصفات دون مراعاة للظروف المناخية و الثقافية.

نستنتج مما سبق : أن المشكلة نتجت عن الانفصال التام للمبنى عن البيئة المحيطة.

تحليل المشكلة :

المشكلة البحثية ذات شقين:

1- إقتصادياً :

- إستهلاك الطاقة بشكل كبير لتشغيل هذه المبانى يتطلب تكاليف باهظة.
- التبديد السريع لمصادر الطاقة فى العالم أدى الى تزايد أسعار الوقود بشكل كبير.
- فشل الكثير من المشاريع التى عدلت أو هجرت من جانب المستخدمين لعدم توافقها مـــع الاحتياجات الفعلية أو عدم ملائمة ظروفها الداخلية.

2- إنسانياً :

- الظروف الحرارية الداخلية غير المريحة.
- تجاهل العمارة الحديثة لثقافة و شخصية الشعوب .

كيفية حل المشكلة:

- طورت الكثير من النظريات العلمية لاستغلال الطاقة الشمسية منذ أزمـــة الطاقـــة عـــام 1973.

1- إما عن طريق استخدامها كمصدر نظيف و متجدد للطاقة (العمارة الشمسية الموجبة).

2- أو عن طريق تكامل تصميم المبنى مع البيئة المحيطة بأعلى كفاءة ممكنة للوصول إلى أقصى درجة من الراحة الحرارية للانسان داخل المبنى (العمارة الشمسية السالبة).

الغرض من هذا البحث : استخدام الوسيلة الثانية فى الوصول الى أفضـــل تصـــميم ممكـــن لتطوير العمارة التقليدية فى إقليم البحث ، بمساعدة برنامج حاسب آلـــى مصـــمم خصيصـــاً لغرض تقييم مدى كفاءة الحلول القترحة.

(ب) أهمية حل المشكلة :

- تكمن أهمية حل هذه المشكلة فى توفير ظروف مناخية ملائمة لراحة الانسان داخل بيئة المبنى.
- المنهجية المتبعة لحل المشكلة البحثية فى موقع الدراسة (أديندان، على بحيرة ناصـــر) يمكن أن تمثل اتجاهاً جديداً نحو العمارة البيئية فى مصر.
- الدمج ما بين الموروث الثقافى و العلم الحديث يؤدى الى ناتج جديد ، يتكامل مع المكان و يعبر بصدق عن كل العوامل المؤثرة فى الموقع.

(ج) الهدف من البحث

الوصول الى تصميم مناسب للغشاء الخلرجى لوحدة سكنية فى موقع الدراسة (أديندان علـــى بحيرة ناصر) بحيث تمثل نواه لمجتمع كامل، و ذلك باستخدام مزيج من المـــوروث الثقـــافى المعمارى الكيفى و العلوم الحديثة القياسية .

(د) الهيكل العام للبحث

الرسالة مكونة من ثلاثة أبواب:

الباب الاول

يتناول مقدمة تاريخية عن نشأة العمارة الشمسية و يحتوى على فصل واحد.

الباب الثانى

يتناول التقييم الكمى للمراحل المختلفة لانتقال الطاقة الحرارية، و يحتوى على ثلاثة فصول:

الفصل الثانى: يتناول التقييم الكمى للاشعاع الشمسى الساقط على الاسطح الخارجية للمبنى.

الفصل الثالث: يتناول التقييم الكمى للأداء الحرارى لعناصر الغلاف الخارجى للمبنى.

الفصل الرابع: يتناول التقييم الكمى للحالة الحرارية داخل المبنى.

الباب الثالث

يتناول دور الحاسب الآلى فى مجال المحاكاه الحرارية، ويتكون من فصلين:

الفصل الخامس: يتناول تقييم لاستخدام المحاكاه الحرارية فى مجال العمارة الشمسية وتقديم للاداة البحثية (برنامج حاسب آلى)

الفصل السادس: تطبيق باستخدام الاداة البحثية على موقع الدراسة (أديندان،جنوب بحيرة ناصر)

كلـــــيه الهندســـة
جامعة عين شمس

العمارة الشمسية و الحاسب الآلى

(تأثيرالعوامل الطبيعية على تشكيل المبانى السكنية بإقليم بحيرة ناصر)

مقدم من

م/ احمد صفوت مصطفى عيسى

بكالوريوس الهندسة المعمارية ، 1999

كلية الهندسة – جامعة عين شمس

رسالة مقدمة للحصول على درجة الماجستيرفى الهندسة المعمارية

تحت اشــــراف

أ.د.م / ياســــر منصور

الاستاذ بقسم الهندسة المعمارية

كلية الهندسة – جامعة عين شمس

د.م/ سمير صادق حسنى

الاستاذ المساعد بقسم الهندسة المعمارية

كلية الهندسة – جامعة عين شمس