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Green Cities: a Path to Sustainability

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Paper Title: **Innovations and sustainability in modern architecture**

- The impact of Building materials selection -

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Abstract

Innovative building materials and technologies are one of the fundamental forces, which guide architectural evolution; formulate its new trends and styles all over building history. Nowadays, there are constant innovations in building industry, resulting enormous products of building materials available in market. These new materials introduce different distinctive practical applications for designers. The huge options of available products from building materials confuse the architects, who faced the problem of choosing the appropriate ones for their designs and projects. This problem is may be due to the lack of - or sometimes the huge - information, which make the selection criteria for suitable building materials subjective more than objective ones.

The paper is dealing with problematic of material selections for architectural projects, there potentialities and limitations. Also investigate the relationship between innovations in building materials and issues of building sustainability.

Key words:

Innovation, sustainability, selection criteria, potentiality & limitations, appropriation, Smart materials and intelligent building, use and re-use, Recycled materials, environmental impacts, embodied energy, health and safety

1. Introduction:

Innovations in building materials and technology play a magnificent role among the most effective forces which guided the development of buildings forms and styles.

Before the Industrial Revolution the designer's choice of materials was largely limited to locally sourced materials: stone, bricks and timber were the principal structural materials and organic materials such as reeds were used for finishes. These materials had been used for centuries and the knowledge required for working and applying the materials had been handed down from master to apprentice. Although the choice of materials was limited there was a clear understanding of materials' properties, strengths and limitations. The built environment resulted in harmonious developments which relied for the most part on sustainable materials. Necessity and ease of use resulted in the re-use of materials from redundant buildings; recycling was often a necessity rather than an option.

With the Industrial Revolution came change. Rapid advances in manufacturing and materials development, along with developments in tools and machinery used on building sites, resulted in new ways of doing things with new materials. Designers must understand the nature of materials, their physical & chemical properties, structural properties, their characteristics in a fire, their interaction with other materials, their anticipated durability for a given situation, cost, maintenance requirements, potential for recycling and other environmental issues such as embodied energy, their impact in terms of health and safety, and last but not least their aesthetic properties. The determination of all these necessary information about building materials and its enduring actualization make the choice of appropriate materials for designer a difficult one of the whole design process.

1.1. Problematic issues:

- **Selecting building materials - limitation and potentiality**

At the start of the 21st century designers are faced not only with a bewildering choice of materials and procurement routes from which to choose, but also with an enormous volume of information relating to building materials. This information includes both the physical behavior of buildings and the behavior of their occupants over time. Advances in materials and mass production have given the designer incredible potential in terms of choice. Conversely they also require the designer to have greater knowledge and understanding of materials and technologies. [9]

- **Environmental impact - use and reuse**

Building is a major economic activity throughout the world, employing significant numbers of people, consuming significant quantities of (often finite) resources and adding to the pollution of our natural habitat, through both the process of building and the energy consumption of the building during its lifetime. The balance between improving our built environment, encouraging economic activity and limiting environmental impact is difficult to achieve in practice. [9] It may well inhibit or limit the range of materials used, while pressure to act in a more environmentally responsible manner may lead to the use of new materials or re use of wastes to reduce the environmental impact of the building.

- **Practicing performance – appropriateness of materials utilization**

The architect is forced to take a position on the play between the language of structure and the language of skin. For some clients the façade treatment is the only added value they perceive they will gain from an architect's involvement. The obsession with the external appearance of buildings means materials are often chosen for their appearance alone rather than their appropriateness. [4]

1.2.adopting Methodology

It is a literarily scientific critical investigation to identify the role of innovative building materials and technology in the developing modern sustainable architecture and green building. Also is to identify the most important selecting criteria for sustainable building materials. Elaborating examples have been given to highlight the impact of innovative building materials and technology on achieving sustainable built environment.

2. Innovation in building materials and technology towards sustainability

Technological innovation in building is an area of interest to clients, manufacturers, designers, builders and building users. Innovation can lead to quicker, safer and cheaper ways of doing things; it can also lead to expensive mistakes. [9] However the construction industry as a whole has a poor reputation for innovation, and is often accused of being slow to adopt new technologies. Transcendent technologies are the primary drivers of the 21^{st} century and in the new economy. They include: nanotechnology, microelectronics, information technology and biotechnology as well as the enabling and supporting civil infrastructure systems and materials. The most advances technologies and innovative materials in building construction have been established in the following fields of applications: [2]

- Biomaterials - Fire Retardant Materials and Structures
- Thin films - Materials for electronics, photonics, and magnetics
- Surface and Interface Characterization - Sensor materials and systems
- Nanoparticles, Nanocomposites and Tissue Engineering
- High-throughput/Combinatorial methods - Cementitious and other construction materials

Architecture has embraced technology as a badge of fashion. There is a clear link between architectural fashion and developments in materials and technologies, although which leads the other is often open to debate. There is also a link between larger social concerns, such as sustainable development and architectural detailing. [9] The character of the architectural space therefore depends on how things are done and for that reason it is determined by the technical realization and by the structural composition of the substances and building materials used. [7] In spite of globalization there are still vast regional differences in construction expertise. Therefore architects who are working in an international domain should have to identify the materials, techniques and skills available in the countries in which they are operating.[4] Future challenge for the development of new construction materials and industrialized technologies is underpinned by the desire to create **'sustainable & intelligent'** buildings. Many applications, which express the high-tech development in engineering practice, have been developed in industrial nations employed smart materials and prefabricated assemblies system to create intelligent buildings with improved energy performance, capability to self-monitor, structural integrity and with computerized functions and interactive systems.

Figure 1: example for Surface and Interface Characterization –
Galleria Fashion Mall, Seoul, South Korea,

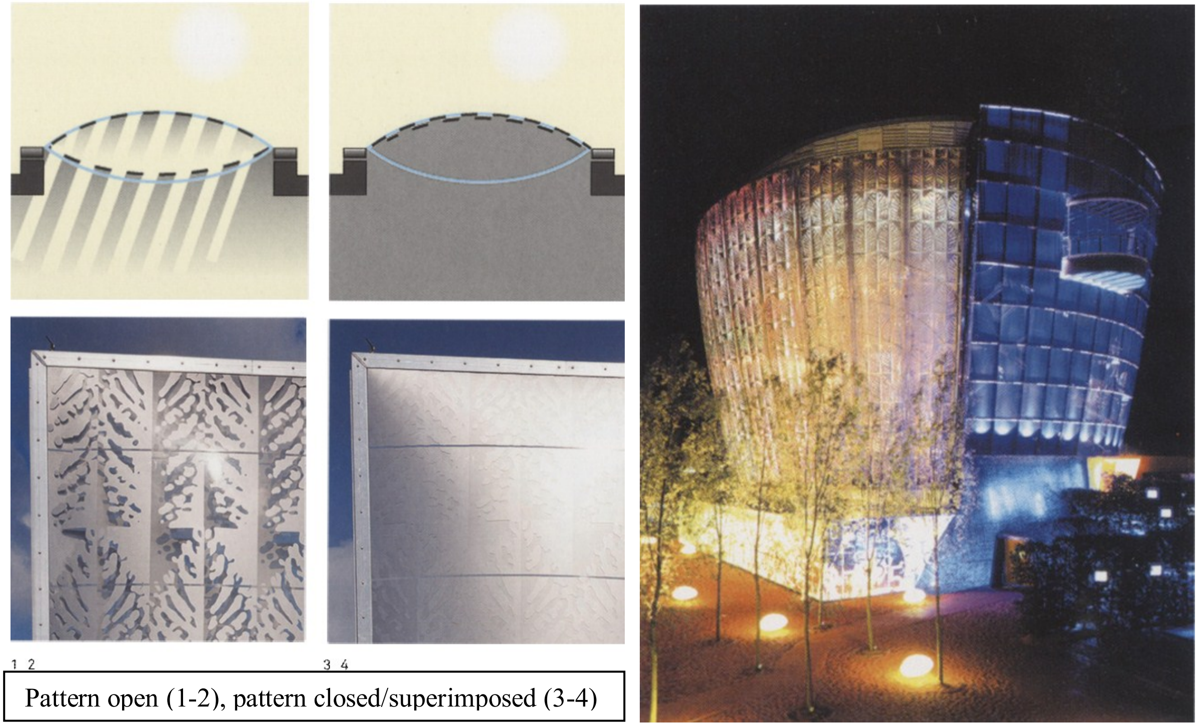


Fig. 2: The first variable ETFE envelope Cycle bowl, Hanover Expo 2000, Atelier Bruckner - an example for controlling inner environment with patterned cushions of three or more foils; variable air pressure moves the middle foil to manipulate the insulation value and shading coefficient of the envelope.

In the other hand many improvements has been introduced in the know-how practicing, by developing of a vegetable-based plastic to replace the petroleum-derived component, and introducing fiber-reinforced composites made with natural fibers such as hemp, ramie and kenaf as the most environmentally friendly materials.[3]

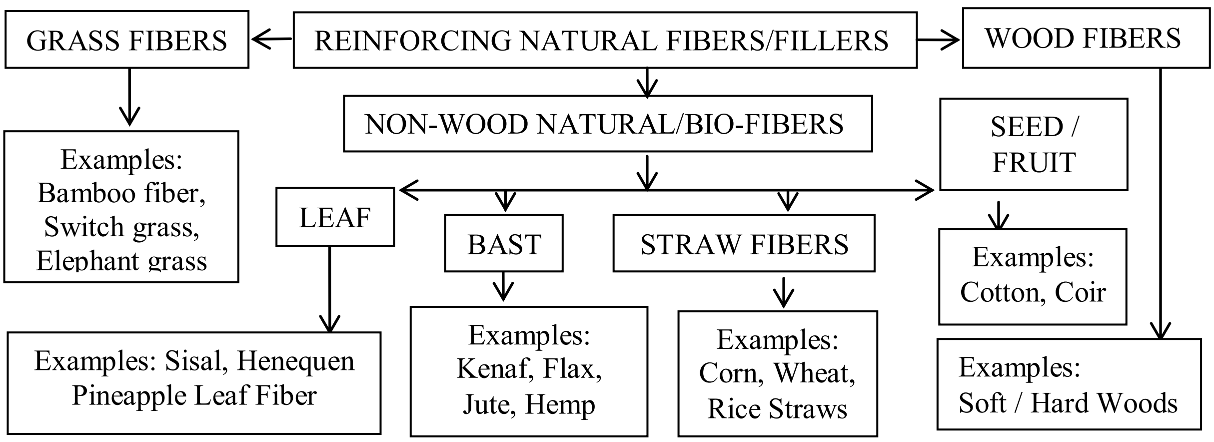
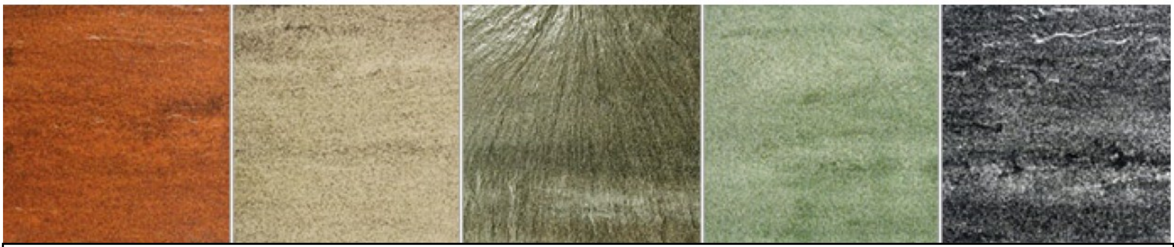


Figure 2: Natural/Bio-fibers in designing bio-composites for Building Products Industry



LIGNASIL TILE - Madera solid surface tile is made entirely from Lignasil, which is a high performance bio-composite material made from recycled natural fibers. The integral-color tile is designed for high traffic applications, and is less expensive, lighter-weight, and warmer to the touch than ceramics or stone.

PALM FIBERBOARD - the fibers which produced from the waste of palm stripped fruit stalks, leaves and parts of the tree trunk have been found to be highly suitable for the manufacture of fiberboard (MDF) for the construction and furniture industries.

Figure 3: tiles and fiberboards from natural/bio-fibers composites

3. Criteria of selecting building materials to achieve sustainable built environment

Present day buildings are responsible for the consumption of large quantities of materials, energy and money during their construction, maintenance and use. Contemporary building constructions are challenging designers and builders to utilize more inventive materials in order to provide building that are environmentally benign and at the same time provides for the requisite occupant environment and operating efficiency. Although, building materials differ in their physical properties and their environmental impact, therefore the selection of materials for sustainable building construction become a critical issue for designer, contractors and clients as well as building users. The objectives of sustainable construction include, for instance, the reduction of the primary energy demand, climate protection, avoiding the use indoors of materials which are harmful to health or building affordable housing. Taking the ISO Technical Specification ISO/TS 21929:2006 [6] as a basis, the three pillars of sustainability, i.e. ecological, economic and social aspects, have been extended by functionality and technical quality. [6]

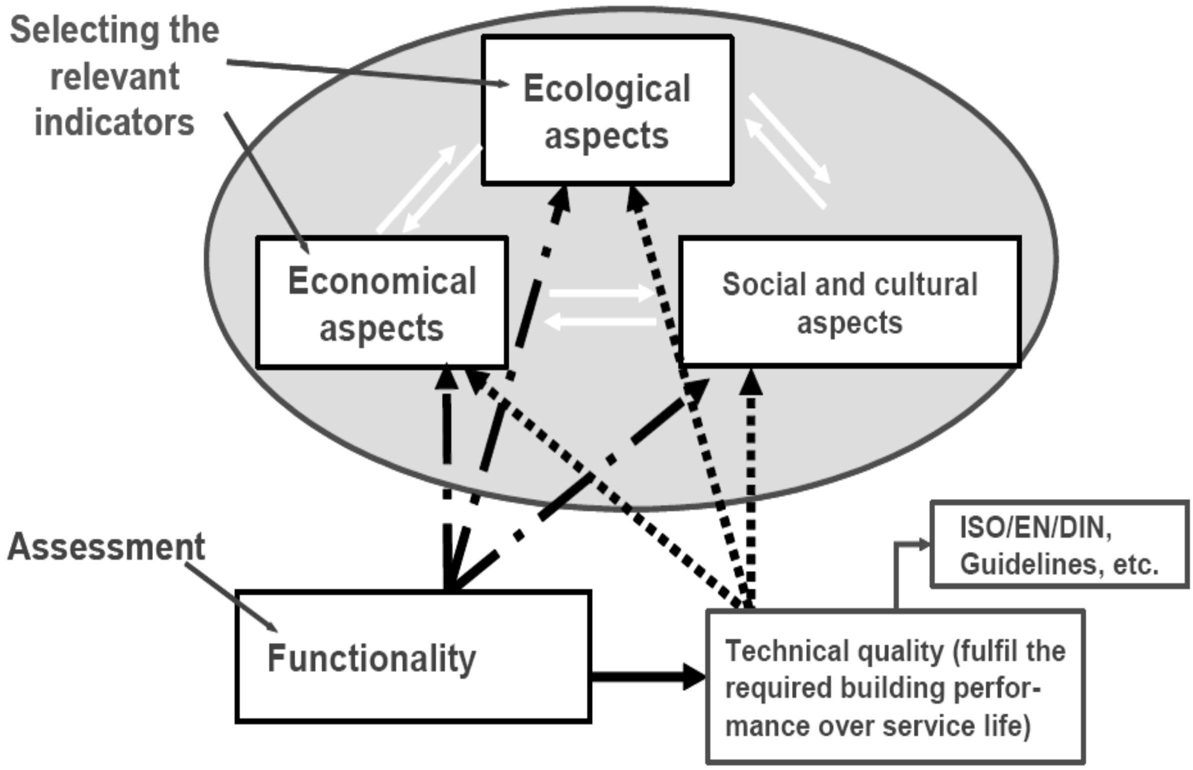


Fig. 4: Extended aspects of sustainability and background of the assessment

3.1. Embodied energy

As a global average, it is estimated that 50–60% of the world's annual energy production is used by the industries of the built environment (Janda and Busch, 1994; Berkebile and McClennan, 1999) of which 36% is consumed directly in the operation of buildings (IEA, 1997). [8]

Embodied energy is a measure of the energy consumed in the production of a particular material. The concept of embodied energy is the energy which is used to extract raw materials, to transport and process those materials into building materials and components, to power the on-site processes of construction and even to demolish and dispose of buildings at the end of their life. [8] There is a strong link between embodied energy and embodied carbon dioxide (CO_2).

3.2. Ecological footprints

It is a concept devised to measure the amount of the earth's surface area taken up in sustaining the material (or service) being consumed (Wackernagel and Rees 1996). [9]

3.3. Conserve and re-use

Conserve and re-use materials has become a major design generator in many industries, including building. Recycling materials can also help to limit further damage and also reduce energy consumption by maximizing the embodied energy in the recovered material. Aluminum has a very high embodied energy and recycling it gives an energy saving of 80–95% [9]

It is essentially that designers as well as all main actors in building construction process should take in their consideration by choosing of building materials the following criteria to achieve sustainable built environment:

- Recovery and re-use of materials existing on site.
- Detailing for future disassembly and re-use of building components.
- The use of materials from managed, sustainable, sources.
- Specifying locally produced materials to reduce pollution caused by transportation.
- The use of materials and products that have low embodied energy levels.
- The use of recycled materials wherever possible. [9]

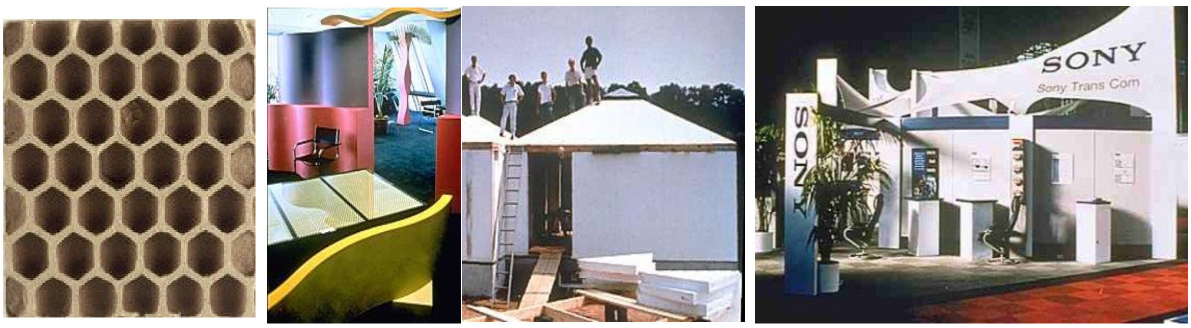


Fig. 5: Commercially available panel products made from waste paper, cardboard and cellulose fiber, can replace timber products from endangered rainforests, or plasterboard (sheetrock) in construction.

3.4. Healthy inner environment – (AQ) air quality guidelines

Many materials used to construct and finish the interiors of new houses like engineered wood products (e.g., particleboard, medium density fiberboard, plywood and OSB) emit VOCs (Volatile Organic Compounds). [2] Formaldehyde, other aldehydes, and terpene hydrocarbons (HCs) were the predominant compounds. These emissions are a probable cause of acute health effects and discomfort among occupants. Ventilation serves as the primary mechanism for removal of gaseous contaminants generated indoors. The trend in new construction is to make house envelopes tighter. This practice improves energy efficiency by decreasing the infiltration of unconditioned outdoor air. Consequently, natural ventilation rates in new houses without supplemental forced ventilation can be relatively low with a related potential for degraded indoor air quality. In such cases those compounds should not be used without applied protective barrier layers on finishing surfaces, also ventilation rates for indoor spaces should be over recommended guidelines (ASHRAE, 1989). [2]

3.5. Fire protection - Combustible and non-combustible materials

Generally speaking Non-combustible materials which used in building are the inorganic materials, such as brick, concrete, stone and steel. Combustible materials are the organic materials, such as timber and timber products (e.g. plywood, paper), fabrics and petrochemical products, including plastics. Combustible materials can be and are used in buildings, but care is required. In such cases the recommended fire protection methods and fire rating which stated in building codes and standard specification should be applied.

Fig. 6: **Paper-Crete** - is innovative sustainable building material made of shredded recycled newspaper, water, cement and sand, which harden to form a material that is virtually non-flammable, has high compressive strength and is an excellent insulator. The material can be dyed in the same way as cement and can be painted.

4. Conclusions and Recommendations

Our planet's resources are being consumed at a rate which is not sustainable and the amount of waste we produce is equally unsustainable. Building has a lot to answer for in terms of the amount of natural resources consumed, the amount of pollution created, the amount of energy wasted and the amount of waste generated. New environmental regulations and societal concerns have triggered the search for new products and processes that are compatible with the environment.

With the growth of information technologies (ITs) has come the potential for dealing with vast quantities of information provided through the monitoring of activities within a building 'data mining' and other 'smart' technologies are essential tools for asset managers in their drive to save energy and manage resources through greater knowledge of the building in use.

There are opportunities for significant reductions in the energy embodied in buildings if designers can make informed choices when selecting from alternative available materials and such choices can contribute to a general reduction in energy use and resultant environmental damage. But there is a danger in selecting materials on the basis of their embodied energy and carbon dioxide emissions without considering their function relative to the building element and building system that they are part of over their life cycle. Discrete mitigation initiatives should always be balanced by an analysis of the implications of each initiative on the total building. The selection of materials and components with less embodied energy will produce capital cost savings. In the short term there is the potential for authorities, via building codes and regulations, to require the use of less energy intensive alternatives in design and construction.

Pollution prevention is one of the crucial aspects in achievement of healthy built environment; therefore designers should consider the use of non-toxic materials in creation of the building projects. To adopt an environmentally responsible approach to building construction, use and re-use of building resources requires the commitment of all concerned.

Issues surrounding 'green building' are complex and continue to change as developments are made and more information is made available to the designer.

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