

Sustainable Construction Materials & Technology in Context with Sustainable Development

Dr. S. Sivaprakasam¹, Dr. V. Sathish Kumar², Dr.P.R.Dhevssena³, Dr. S. Syed Enayathali⁴

¹Assistant Professor, Department of Civil Engineering, Government College of Engineering Dharmapuri

²Assistant Professor, Department of Civil Engineering, Government College of Engineering Dharmapuri

³Assistant Professor, Department of Civil Engineering, Government College of Engineering, Srirangam, Trichy

⁴Assistant Professor, Department of Civil Engineering, Anna University, BIT Campus, Trichy

¹sivasu61268@gmail.com

²aspro_sathish@hotmail.com

³senaadheva@gmail.com

⁴enayathali2013@gmail.com

Abstract In India tremendous environmental problems are arising in construction industry due to rapid urbanization. Increase in demand of residential dwelling units which leads to consume more energy, resources, raw materials which are responsible for the rise in the carbon footprint. All metros are already facing environmental impact issues such as change in weather pattern, destruction of ecology. The solution lies in the sustainable development use of sustainable materials & technologies. Sustainable development is the one which meets the needs of present without compromising the ability of future generations to meet their own needs. This paper elaborates the concept of sustainable development that has come to the fore front in the last twenty years. This development is achievable through use of sustainable construction materials & technology. The concept recognizes that human civilization is an integral part of natural world & that nature must be preserved, perpetuated if the human community itself is to survive.

Sustainable development articulates this idea through designs that exemplify the principals of conservation & encourages the application of those principals in our daily lives. Sustainable development must use an alternative approach to the traditional design. The new approach must recognize impacts of every material & technology choice on natural & cultural resources of the local regional & global environments.

Keywords Sustainable Development, Sustainable Materials, Sustainable Technologies, Embodied Energy, Recycle, Reuse, Bio-Degradable, Life Cycle Design, conservation, CO₂emission.

Introduction The pursuit of sustainable development brings the built environment and construction industry into sharp relief. It is a well-known fact that the construction industry is a major contributor to socio-economic development in most of the countries (C.I.B, 1999) ^[1]. Statistics show that the construction industry normally constitutes more than half of the total national capital investment, and represents as much as 10% of G.N.P. in every country (C.I.C.A. & U.N.E.P. 2002) ^[2]. The building and construction industry makes a major contribution to the consumption of resource, for example, in the European Union, buildings are responsible for more than 40% of total energy consumption and the construction sector is estimated to generate approximately 40% of all manmade waste (C.I.B., 1999) ^[1]. Sustainable construction development has become a major subject of policy, research and innovation, globally. Green building movements in India are Establishment of institutions by Formation of IGBC, TERI launch of LEED and TERI-GRIHA ^[3].

The sustainable development uses locally available building materials which are energy efficient and durable. It provides an opportunity to living inhabitants to live with healthy, comfortable conditions throughout the buildings full life cycle. The life cycle consists of material production, construction planning, design, construction, operation and maintenance processes. The objective of sustainability is to achieve efficient use of resources, viz. energies, water, and construction materials with minimum impact on the environment of buildings. However, because of the complexity of sustainability and the fragmentation of the construction industry, the level of implementation of sustainable construction practices is still low. At a conceptual level, sustainable construction can be divided into four dimensions: ^[4], 1. Economical, 2. Social, 3. Environmental and 4. Technical. Economic sustainability includes the use of full-cost accounting methods and real-cost pricing

to set the prices and tariffs of goods and services to achieve a more efficient use of resource

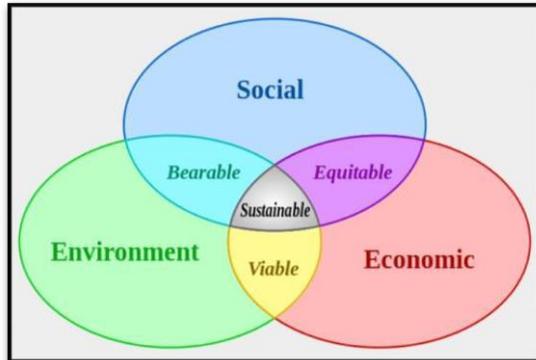


Figure 1: Conceptual level representation of sustainable development

Social sustainability highlights improvement in the quality of human life, and the human living environment, which includes culture, health, education, and intergenerational equity. Environmental sustainability includes the notion that sustainable construction needs to protect the natural environment rather than pollute it by encouraging the use of renewable resource and reducing the use of water, energy, materials and land at each stage of project. Technical sustainability requires high performance, durability, quality and mixed use of a building. This paper examines the concepts of sustainable development by adoption of sustainable construction materials and technologies. To be more particular we have shortlisted five sustainable materials.

Defining Sustainability

Buildings are by far the greatest producers of harmful gases such as CO₂ and this 'eco footprint' can only increase with the large population growth predicted to occur by 2050 [5].

Sustainability in construction is all about following suitable practices in terms of choosing materials, their sources and construction methodologies as well as design philosophy, so as to be able to improve performance, decrease the environmental burden of the project, minimize waste and be ecologically friendlier, taking into consideration environmental, socio-economic and cultural values. All materials are ultimately derived from the bio-geo-sphere. They are everything between the take and waste and are the key to sustainability. The choice of materials for construction controls whole of life cycle impacts such as emissions, gross take, properties of wastes returned to the bio-geo-sphere, use of recycled wastes and their own recyclability. Materials also strongly influence lifetime energies, user comfort and durability [6].

Countries with mature economies are in the position of being able to devote greater attention to creating more sustainable buildings by upgrading the existing building stock through the application of new developments or the invention and use of innovative technologies for energy and material savings. While developing countries are more likely to focus on social equality and economic sustainability, [7].

Material selection profoundly affects many value properties relevant to sustainability including weight, embodied energies, fuel related and chemical emissions, lifetime energies, user comfort and health, use of recycled wastes, durability, recyclability and the properties of wastes returned to the geo-sphere- biosphere.

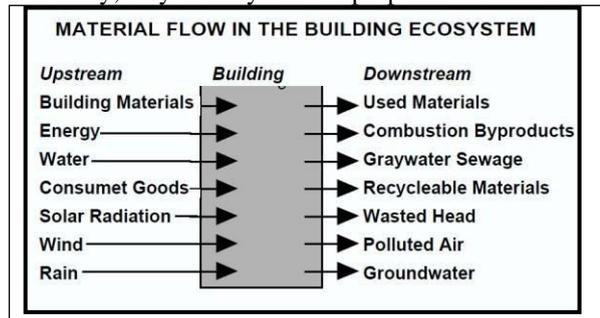


Figure 2: Schematic representation of upstream to downstream flow of products, energy in the building ecosystem

Technology can make it possible to achieve a greater measure of sustainability, to economically reduce, re-use and recycle. The potential multipliers from spending on research and development are huge [6]. Identifies technologies which can be used during construction to improve efficiency and reduce waste [8]. As long as sustainability in construction projects is considered it is generally achieved by, [8]: 1) Defining clear goals

sympathetic to sustainability issues.

2) Concentrated effort at design stage to achieve these goals. 3) Focusing on decisions like site selection, building layout, design etc. 4) Choosing the right materials which are recyclable after their useful lives.

5) Choosing the right methods of construction in terms of energy and resource efficiency. 6) Creating an efficient and integrated building envelope harnessing the gifts of nature.

Methodology

Careful selection of environmentally sustainable building materials is the easiest way for architects to begin incorporating sustainable design principles in buildings. Traditionally, price has been the foremost consideration when comparing similar materials or materials designated for the same function.

However, the “off-the-shelf” price of a building component represents only the manufacturing and transportation costs, not social or environmental costs. The three principles of sustainability in architecture.

1) **Economy of Resources:** It is concerned with the reduction, reuse, and recycling of the natural resources that are input to a building.

2) **Life Cycle Design:** It provides a methodology for analyzing the building process and its impact on the environment.

3) **Humane Design:** It focuses on the interactions between humans and the natural world. These principles can provide a broad awareness of the environmental impact, both local and global, of architectural consumption.

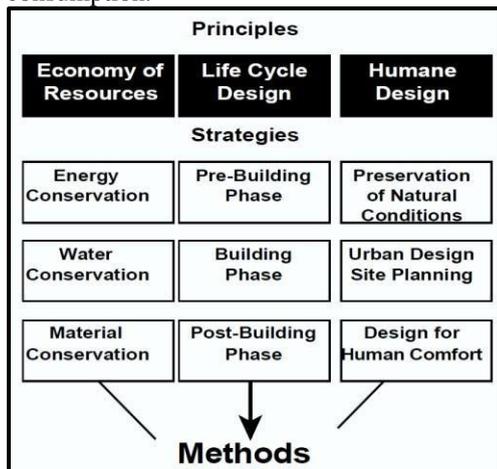


Figure 3: The three principals of sustainability

Each of these principles embodies a unique set of strategies. Studying these strategies leads to more thorough understanding of architecture’s interaction with the greater environment. This allows further disaggregating and analyzing specific methods architects can apply to reduce the environmental impact of the buildings they design. [9]

Life Cycle Design

A “cradle-to-grave” analysis of building products, from the gathering of raw materials to their ultimate disposal, provides a better understanding of the long-term costs of materials. These costs are paid not only by the client, but also by the owner, the occupants, and the environment.

The principles of Life Cycle Design provide important guidelines for the selection of building materials..

An essential role of architecture is to provide built environments that sustain occupant's safety, health, physiological comfort, psychological well-being, and productivity. The following three strategies for humane design focus on enhancing the coexistence between buildings and the greater environment, and between buildings and their occupants,

- 1) Preservation of Natural Conditions
- 2) Urban Design and Site Planning
- 3) Human Comfort

Sustainable Building Material

Sustainable building materials can be defined as materials with overall superior performance in terms of specified criteria. For Selection of Sustainable building materials the following criteria are commonly used:

1. Locally produced and sourced materials
2. Transport costs and environmental impact
3. Thermal efficiency
4. Occupant needs and health considerations
5. Financial viability
6. Recyclability of building materials and the demolished building
7. Waste and pollution generated in the manufacturing process
8. Energy required in the manufacturing process
9. Use of renewable resources
10. Toxic emissions generated by the product
11. Maintenance costs

Few of the materials are described below

1) Lime:

Lime is our chief material which replaces the cement in building construction. It gives the good air quality by absorbing the carbon and emitting oxygen in the atmosphere. The cost of lime is comparatively less than that of Cement. Life span of lime building is much more as compared to cement building.^[10] Depending on the mix of aggregate and water hydrated lime can be used to manufacture a lime Concrete, mortar, plaster or stucco Color Lime Plaster.

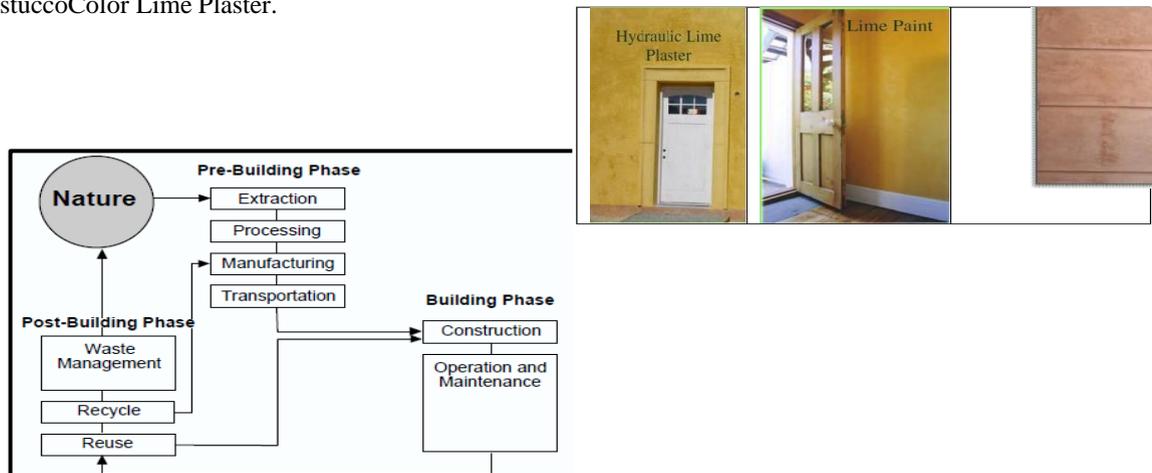


Figure 5: Lime Plaster

The Volatile Organic Compounds (paints) are available by using coloured lime plaster as paint. It reduces the painting for whole structural life. It is maintenance free, washable and water proof. Its shine and glossiness increases as the time passes. It gives better aesthetics look than conventional painting work.

Figure 4: The sustainable building life cycle

A material's life cycle can be organized into three phases: Pre-Building; Building; and Post-Building.

Humane Design Strategies:

2) Fly Ash Bricks: Fly ash is one of the naturally- occurring by products from the coal combustion process and is a material that is nearly the same as volcanic ash.

There are following types of fly ash bricks :

1. Fly ash Lime/Gypsum Bricks
2. Clay Fly Ash Bricks
3. Sand Fly Ash Bricks
4. Red Mud- Fly ash bricks



Figure 6: Fly Ash Blocks

Environmental and Social Benefits Of Using FlyAshBricks:

The environmental and social benefits of using Fly ash bricks and its positive environmental effects are:

1. Eliminate carbon emissions.
2. Saves top soil.
3. Source of all the year round employment.
4. Prevention of dumping of fly ash in ponds.

3)Eco-Friendly Tiles:

An Eco-friendly tile replaces the conventional flooring and uses less energy in their production. It is cheap as compared to the conventional tile. They are available as per the client requirement in various patterns and also easy to place. This tile improves performance of indoor environment quality. Eco- friendly tiles are cheap in cost as compared to regular tiles; these tiles are manufactured on the construction site so that its transportation charges are reduced.



Figure 7: Eco-friendly tiles

4) Bamboo:

Bamboo is the fastest growing plant on earth. It is a member of the grass family and can be found in many regions throughout the world in a diverse range of climates from cold mountains to hot tropical regions

⁽¹⁾As a natural cellulose fiber, bamboo fabric can be 100% biodegraded in soil by microorganisms and sunlight”

⁽²⁾ showing that not only is bamboo an environmentally sustainable natural resource but also that disposal of the material has no damaging effect on the environment. Bamboo provides bamboo products suitable for use as roofing or cladding materials.

In Asian countries, it is used as a substitute to steel reinforcement in concrete and more recently bamboo has been manufactured for use as household flooring

systems whereby the bamboo is steamed, flattened and glued together into flooring panels.



Figure 8: Bamboo as material

5) Ferro Cement:

Ferrocement has a very high tensile strength to weight ratio and superior cracking behavior in comparison to reinforced concrete. Prefabricated ferrocement cavity walls present a series of possibilities for the solution of building construction at maximum reduction of the electrical energy.

Advantages of ferrocement as a construction material may be summarized as follow: 1. Very high quality control. 2. Pre-Fabricated products. 3. Easy production and installation. 4. Shading devices to provide shading and day lighting to the building (use light weight and low cost environmental element).

5. Fast construction. 6. Manpower can be easily trained at site. 7. Improved structural performance.

8. Cost reduction, 15-50% cheaper than conventional techniques. 9. Less maintenance. 10. Reduction in dead weight, 50-75% lighter than conventional techniques



Figure 9: Buildings constructed with ferrocement

Sustainable Construction Techniques With green building becoming a critical part of today’s world, more and more new construction technologies are being developed to keep up with this escalating shift to sustainability. The following list is the commonly adopted some of the techniques recognized in sustainable construction: 1. Low volatile organic compounds (V.O.C.) paint. 2. Plywood processed without using formaldehyde. 3. Install big

windows that provide plenty of fresh air and natural light. 4. Install energy and water efficient appliances. 5. Install low-emitting carpet. 6. Proper site selection and prevention of pollution on the construction site.

Following is brief discussion about sustainable technology adopted in context to the sustainable

development. **1) Water Systems Store, Recycle, Reuse** [12] This includes using low water use appliances, toilets, and faucets, recycling grey water (water produced by sinks, showers, and laundry), and eliminating irrigation. Recycled grey water can be used to irrigate the landscape rather than being discharged into the municipal sewer system. **Flush Toilets:** These Specialized Water Saving Toilets produce a 10 to 15 Liters per flush toilet, some speciality flush systems save 90% water savings compared to conventional toilets. **Composting Toilets:** These can reduce the waste volume by 90%. When human wastes are mixed with enough plant matter (i.e. kitchen scraps, garden wastes, etc.) and when exposed to enough air, will decompose and become nutrient-rich fertilizer. **Water Heating:** All water pipes, cold and hot, should also be insulated. A bottom board can also be installed beneath the heater to prevent the loss of heat into the floor. A timer can be installed on the tank to automatically turn it off at night when the hot water is not needed. A tankless heater or “demand” heater can be used. Solar energy can be used to help supplement the energy input required. **Solar Water Heating:** In this system the panels collect heat from the sun and transfer it to a glycol solution in copper coils. The coils travel to a heat exchanger to deliver heat to the water tank. Simple steps can be taken to reduce energy consumption: Insulate the water tank, insulate the interior/exterior piping, install water-saving fixtures, and lower the thermostat setting. **Solar Water Heating Systems:** Most systems use flat plate collectors that are mounted to face the sun.

- a) Closed Loop Systems
- b) Thermo siphoning
- c) Open Loop Systems
- d) Drain Back Systems
- e) Batch Heater Systems

2) Heating, Cooling, and Ventilation ^[12]In this new technique there is push towards using an integrated mechanical system. This means that space heating and cooling, water heating, ventilation, and heat recovery work together as one unit. Furthermore, energy efficient air tight homes require a ventilation system to retain high indoor air quality. The mechanical system provides space heating, water heating, passive solar storage, heat recovery from grey water, and partial cooling. It is based on a heat recovery pump that moves heat between an ice water storage tank and a hot water tank. In the winter, heat is extracted from the ice water and delivered to the hot water tank. Space heating requirements are met via a fan coil unit.

3) Indoor Air Quality The best strategy for improving indoor air quality is through controlling the pollutants at their source. Sustainable ways to improve indoor Air Quality are 1. Select low-emission materials, 2. Plants as Environmental Air Cleaners

4) Use Sustainable Building Materials If building a green home is your goal, then using environmentally or eco-friendly products should be on your list which can reduce the impact of construction on the environment. Each and every part of house such as roofing material, building material, cabinets, counters and insulation to flooring should be environmentally friendly. Use products such as reclaimed lumber, recycled plastic, recycled glass or natural products such as bamboo, cork and linoleum which are made of natural, renewable materials.

5) Cool Roofs A cool roof is a roof designed to maintain a lower surface temperature in bright sunshine than a traditional roof. The surface of a cool roof reflects more sunlight and releases more heat than a so-called hot or dark roof.

6) Zero-energy Buildings ^[13]

Zero-energy buildings are specially designed and engineered to rely on renewable sources of energy, such as solar and wind power, allowing them to operate independent of the electric grid. This green scheme not only saves energy, but it also prevents additional greenhouse gas emissions. A zero-energy design utilizes solar cells and panels, wind turbines, and biofuels, among others, to provide for the building's electricity and HVAC needs.

Discussion

The role of materials for greater sustainability is discussed. A number of ways are suggested to make the construction industry more sustainable including reducing the energy it takes to run buildings (lifetime energy), reducing the high level of waste in construction, utilizing wastes to make construction materials, reducing emissions during the production of building materials, sequestering carbon by utilizing carbon containing materials and building using more durable materials. There are no economic disadvantages of any of these methods and some, such as reducing embodied energies are clearly economic.

Underlying all is technological change, particularly in relation to materials. Materials are the key to sustainability in the built environment and innovative new materials will allow architects and engineers to build structures that have great value as they are more pleasing to use, live in or look at, healthier and much more sustainable.

Technology can make it possible to achieve a far greater measure of sustainability, to economically reduce, re-use and recycle.

Future Scope:

1) Technological innovation in the field of automation with higher level of micro-processor based controlling systems leads to better performance of technologies like solar panels, Integrated HVAC & Electrical systems. 2) In context to the Indian scenario new experimentation for the application of agro-waste as substitute for the sustainable construction material shall be explored. 3) Non-conventional materials for a sustainable construction material with bio-construction system reinforced with cellulose fibers can be considered. Example of such system can be metakaolin + lime + hemphurds + waste paper pulp in place of conventional concrete. 4) A digital computer based sustainable design tool for the building material applications for a particular building project involves integrated design approach. This involves Life Cycle Analysis based on CAD model. However present technological limitations do not provide a correct/optimum solution to the problem. Advancements in algorithm & more realistic data for the analysis engine can fine tune such tools. It will change the scenario of present building design technology.

Conclusion

Sustainable building materials are those which are produced or sourced locally. These materials are containing recycled & industrial waste materials and byproducts. Sustainable materials have a lower impact on environment & are thermally efficient. The production of these building materials require considerably less amount of energy in production when compared to the modern or traditional construction materials.

The advantages in selection of sustainable building material lies in the fact that they are not only economically viable but also reduce toxic emissions thereby reduce overall environment impact. Sustainable building material & technology should be utilized appropriately & contextually in each neighborhood development. The use of sustainable material & technology not only reduces transport & production cost, carbon emissions but also provides avenues for employment & skill development for community members.

References:

- [1] CIB. (1999). "Agenda 21 on sustainable construction", CIB report publication 237, CIB, Rotterdam, the Netherlands.
- [2] CICA & UNEP., "Industry as a partner for sustainable development: construction", UK. Gilman, R. (1992). Design for A sustainable Economics, Dancing toward the Future, (2002).
- [3] Sinem Korkmaz, Duygu Erten, Matt Syal, and Varun Potbhare. "A Review of Green Building Movement Timelines in Developed and Developing Countries to Build an International Adoption Framework".
- [4] Hill, R., and Bowen, P. (1997), "Sustainable construction: Principles and a framework for Attainment, Construction Management and Economics 15", 223 –239.
- [5] A. B. Ngowi, "Creating competitive advantage by using environment-friendly building processes," Building and Environment. 2001.
- [6] C. J. Kibert, "Sustainable construction," The First International Conference of CIB TG, Tampa, Florida, U.S.A. 1994.
- [7] L. Bragança, M. D. Pinheiro, S. Jalali, R. Mateus, R. Amoêda, and M. C. Guedes, "Portugal SB07, sustainable construction, materials and practices, delft university press, center for excellence in sustainable Development," Construction Research Centre. 2007.
- [8] M. H. Pulaski, "Field Guide for sustainable construction, partnership for achieving construction excellence the Pennsylvania state university-university park, PA," Pentagon Renovation and Construction Program Office Arlington, VA. 2004, [9] Jong-Jin Kim, and Brenda Rigdon. "Qualities, Use, and Examples of Sustainable building Materials", (December 1998).
- [10] EPA-600/7-86-031, U. S. Environmental Protection Agency, Cincinnati, OH, September 1986.
- [11] <http://en.wikipedia.org/wiki/bamboo>
- [12] Grady Wayne: Green Home : Planning and building the environmentally advanced house , amdenhouse, Camden East ON [13] (<http://www.triplepundit.com/2013/11/title-24-launches-california-net-energy-buildings/>)