STRATEGIES FOR SUSTAINABLE BUILDING DESIGN, MATERIALS AND CONSTRUCTION TECHNIQUES

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Abstract

The architectural fraternity is deeply caught up in a vigorous state to cope with the increasing needs and demands of the people. In this burgeon process, the energy consumption, proper resource management and deteriorating natural environment, has been omitted miserably, which results in the increased carbon footprint and other pollutants.

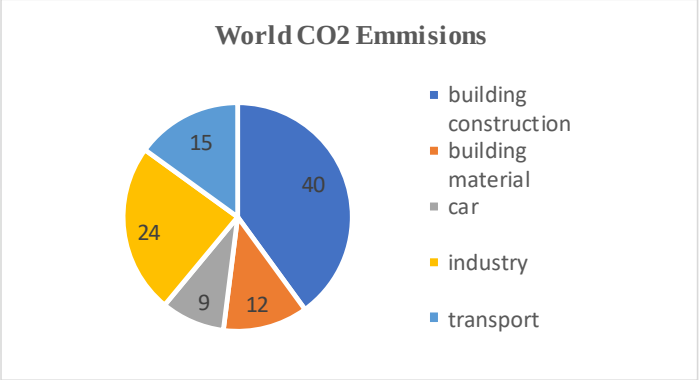
The paper elaborates the role of each step taken while designing a built form along with defining its execution phases to promote sustainability in each aspect; the site as well as the building development and modifications in conventional materials and construction techniques to assure lesser environmental dilapidation. It deals with the emerging ideas of Green Architecture and comprehends a broad review of the literature on sustainable site planning, protection of landscape and conserving resources with new construction methodologies. Consistently, the climatic conditions during design process are being neglected. Therefore, the concepts under Solar Passive Building Design, energy conservation in building system and waste management will also be explored.

The paper strongly emphasizes that such a perceptible movement can be brought about only through the collective will of the entire architecture and construction community.

Key Words: Green Architecture, sustainable site planning, landscape protection, solar passive building design, energy conservation

1. Introduction:

The construction and infrastructure sectors have shown a rapid growth for the development of economy in last decade. According to census 2011, about 32% of population in India lives in urban areas; moreover, the projections indicate that it could reach up to 39% in the next decade. With growth in the urban population trends, there is a thriving need and demand for housing, services, consumptions and a better lifestyle. This clearly prognosticates on the dependency of human on resources and their utilization. The aggravating conditions have compelled the planners and policy makers to explore green and sustainable concepts in the building designing and construction. India is a country with diverse climatic conditions which harvested different building and construction styles over the years in different parts of the country. The sustainable solutions and techniques that have roots in the earliest civilizations are today called as "vernacular practices". From the past, it is evident that early settlements reflected the basic necessities; they were built in the vicinity of the resources that occupants desired. The strategies that can be adopted from step one of designing to the last stage of operation and maintenance of building has been included in the paper. Starting from the sustainable design strategies for wellbeing of the occupants to the emerging green methodologies in construction and every detail at these stages should contribute to the sustainable development.



Source*: International Energy Agency (GRAPH 1)*

The graph evidently shows the CO2 emissions due to building construction are the highest.

1. Understanding major design principles for a built space:

Sustainability is an integrated concept of various components. The following points should be contemplated while designing a built space:

1.1 Balance between built – unbuilt

This design parameter includes a relationship between health and environment, which is usually overlooked while developing the spaces. For the purpose of clarity, following terminologies need to be understood:

- Health: Health is defined in accordance with WHO (1946): "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity" (cited in Commonwealth Department of Health and Aged Care, 1999, p.3).

• Environment: The 1998 Draft Commonwealth Environmental Protection and Biodiversity Conservation Bill defined 'environment' as including:

(a) ecosystems and also the constituent elements, including people and their communities; and

(b) natural and physical resources; and

(c) the qualities and characteristics of locations, places and areas; and

(d) the social, economic and cultural aspects of a thing mentioned in paragraph (a), (b) or (c) (cited in CDHAC, p. 6).

• Built environment: Health Canada (1997) defined the built environment as: ... part of the overall ecosystem of our earth. It encompasses all the buildings, areas and merchandise that are created, or a minimum of considerably changed by folks.

• Environmental health: Environmental health has been defined as "those aspects of human health determined by physical, chemical, biological and social factors of the environment" (CDHAC, 1999, p. 3).

In the era of unprecedented growth rate of construction, the ignorance of inter relation between built form and natural features imparts its adverse effects on environmental health of the users. The indoor quality of spaces affected by elements, colors, ventilation, light and sound, is equally important as beautifying the façade to attain the sustainability goals.

1.2 Balance between grey – green

The buildings being constructed today are exploiting whole of the land resource, concretizing the greener grasslands which results in reduced catchment area. The natural and artificial components coexist for a sustainable life. The space in a city is limited; thus the green cover squeezes with the increase in infrastructure at an unprecedented rate. This results in an uneven distribution between the gray and green spaces in the city, causing an imbalance in the ecosystem. One major reason of emission of greenhouse gases is construction growth with lack of attention to green coverings. Moreover, the occupants in the buildings develop a perception of being captivated in a concrete cell which incites adverse effects on human intellect and physical health altogether.

The growing need and hence the rising frame of infrastructure is inevitable. The scenario calls for a sustainable vision that mitigates the repercussions and ameliorates the persisting situation. Soft landscaping and green coverings in vertical dimension proves to be one of the effective solutions. Buildings that have built-in greenery help to suck up carbon, filter air pollution, dampen noise, and keep cities cooler. Green buildings envelopes can contribute significantly and thus become a default design approach for building design.

1.3 Balance between artificial – natural

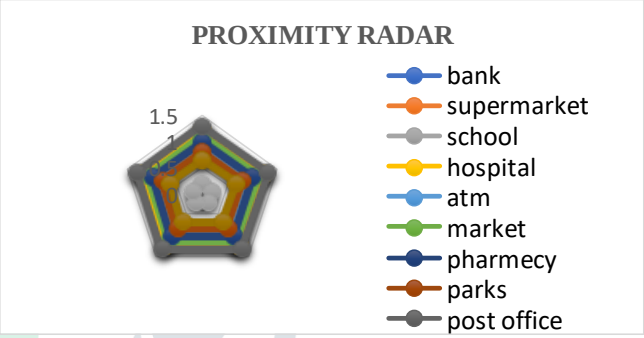
The phenomenon of biophilia suggests that humans possess an innate tendency to seek connections with nature and the human brain is evolved in a way to fascinate towards the natural elements and an environment akin to it. Being close to nature makes you calm, ameliorates your thinking capacity and strengthen you're well-being.

In the process of site development, the existing green spaces are uprooted for laying the foundation of a building, and later landscaping is done for the account of beautification. The buildings no longer blend with the surrounding landscape and stand alienated amongst the ambiance. Hence, the landscaping around a building plays a major role in amalgamating it with the nearby settings. Also, it should be convenient to the nature of occupants residing inside the building, be it a space for educational, medical, official, residential or an industrial use.

2. Sustainability in site development

2.1 Selecting a site

Access to basic amenities like hospital, school, supermarket, ATMs, etc. should be at a walking distance of 1 km from the entrance to reduce the impact of automobile usage. To attain the goal, the architect should crosscheck these amenities and prepare proximity radar which will not only help the users to get easy accessibilities but will enhance the environmental prosperity.



Source: *IGBC (GRAPH 2)*

2.2 Retaining site features

• Using natural slope of site for rainscaping: This practice helps to increase catchment area for rainwater collection ultimately replenishing the ground water.

• Using trees of the site for shade and cooling: The existing vegetation on the site helps in producing the 'evapo-transpirative cooling'

• Using existing debris for filling in plinth: Filling of plinth and foundations can be done using the materials obtained in excavations which will reduce the dependency on virgin materials.

2.2.1 Preservation and Protection of Landscape during Construction

Conservatory forestation: The existing vegetation on the site should be conserved during and post construction. The vegetation, water bodies and natural slope contributes to the microclimate of the site that helps in designing of built masses in accordance with these features promoting the idea of climate responsive architecture.

Depository forestation: Depositing what has wasted is equally important. To protect natural contour and soil erosion and degradation, it is vital to plant further

vegetation and design the built spaces accordingly. Indigenous plantation is preferred and extensive care has to be taken while planting these trees.

2.2.2 Soil Conservation (till post construction)

- Temporary seeding: Growing vegetative cover for a short period of time on disturbed site areas that are prone to soil erosion referred to as temporary seeding.
- Fast growing grasses are used in this system whose roots hold the soil together so that they aren't carried away by storm water run-off and wind.
- Temporary seeding also helps in reducing the problem of dust from bare soil due to construction.

2.2 Reducing Hard Surfaces Using Porous Paving

- The presence of voids in porous pavements and concrete pavers are intentional that enables storm water to drain through a stone base layer.
- Porous paving is designed to allow water to soak through the paving and seep back into the ground.
- Reduces the volume of storm water runoff.
- Reduces the volume of pollutants entering the groundwater.
- Benefits nearby plants and trees by allowing both air and water to reach the root zone underneath the paved area
- 25% of the landscaping of the site should be done with permeable concrete paving.

3. Construction related problems

- Lack of spaces
- Park poverty and lack of green spaces
- Water scarcity
- Decreased level of water table
- Smog and dust around the neighborhood
- Open disposal of construction wastes
- Increased temperature
- Energy consumption

Following measures are the few options that could be adopted while phases of construction.

3.1 Self-water Spraying System

An inexpensive self-water spraying system can be developed to control dust emission from the use of machines. The setup is simple with the following steps-

- Fix a 200 L empty diesel drum to the machine.
- Install a set of sprinkle nozzles in the breaker head.
- Connect the sprinkle nozzle to a small submersible water pump by a rubber tube.
- Put the water pump into the diesel drum.
- Connect the water pump to the power supplier of the hydraulic breaker.
- Surround the breaker head with four pieces of waste acoustic mat.

The sprinkler nozzles deliver water mist to the work area to wet the breaking surface and contain airborne dust. Treated run-off all stream water collected within the construction site can be used in self water spraying system.

3.2 Silt fence

- A silt fence is a temporary solution for sedimentation control. This system consists of a filter material that is supported by posts. It controls sediment run off from the site from entering into the receiving waters.
- Silt fencing can be done through jute bags and tarpaulin to reduce adverse environmental impacts of sediments on the surrounding areas and the existing vegetation.

3.3 Sediment trap

- A sediment trap can be made by excavating a pond across a low-lying area on the site.
- The trap should retain the run off to allow the sediment to settle before they are released.
- The outlet is made using large stones and aggregate to slow down the release of run off.

4. Energy Efficient and Sustainable strategies for Built space:

4.1 Solar passive building design

The design concept focuses on resource friendly methodologies that can be adopted by various building designs to facilitate the existing services and infrastructure for energy simulation as well as judicious use of materials for construction.

Before putting the climate responsive elements in a design, one should make sure the potentiality and efficiency of them, crosschecking with following considerations:

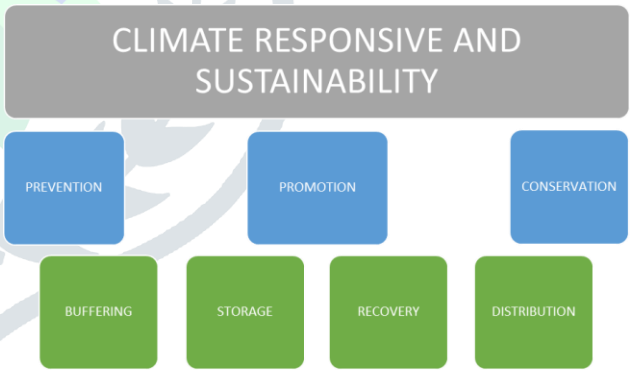


Figure 1

This goal can be achieved only if the architect and construction firms are having updated information from LEED, GRIHA, ECBC etc. which are usually omitted while designing. Let us consider the designing process of any 30 sq.m built up in composite climate having basic necessities like kitchen, living spaces and bathroom, supposing owner has a vehicle.

4.1.1 Light shelves

These are passive architectural devices used to reflect daylight deep into the building. The sunlight bounces off a horizontal surface and is diffracted within a space. They have been proven to reduce need of artificial lighting and energy consumption in the building. They also help in heat gain in winters owing to the low angle of the sun.

4.1.2 Thermal mass effect

To provide thermal comfort within a space, dependency on appliances can be reduced with the aid of material selection as well.

- AAC Blocks: They offer superior thermal insulation compared to normal weight concrete due to pores created by aluminum powder.
- Bamboo: The structure of bamboo's fiber and cells has low heat conduction, making it almost a fire-resistant material and reduces energy consumption for heating and cooling.
- Fly Ash Bricks: These bricks do not absorb heat, they reflect heat and give maximum light reflection without glare.
- Marble has the capacity to absorb, store and release the sun's heat energy. Its density and levels of physical phenomenon facilitate to maintain the inner temperature of a building stable.

4.1.3 Natural ventilation

Utmost care has to be taken in placing the fenestrations such that each space remains naturally ventilated.

4.1.4 Evaporative Cooling

It is a passive cooling technique in which outdoor air is cooled by evaporating water before it is introduced in the building. The basic principle lies in the fact that the heat of air is used to evaporate water, thus cooling the air, which in turn cools the living space in the building.

This will be accomplished by two ways:

- Direct Evaporative Cooling through the water body in premises of built space
- Passive Indirect Evaporative Cooling through water body present in proximity of building.

4.1.5 Ventilation

- Cross ventilation
- Stack ventilation through atrium or courtyard planning can be provided
- Wind scoops

Facing the opening towards prevailing winds: This allows evaporative cooling to take place due to the movement of the air but the air itself is not necessarily cooled.

4.1.6 Wind Catchers

These are traditional, energy free, passive ventilation systems. Wind towers can save the electrical energy used to provide thermal comfort during the warm months of the year, especially during the peak hours.

4.1.7 Direct radiant cooling

- Paint
- Reflective Surface

A major part of the roof can be covered by the solar panels which will also act as the reflective surface for the direct solar radiance keeping the houses at relatively lower temperatures

- Roof Garden

Buildings should be designed to optimize direct radiation cooling; the building roof acts as a heat sink to absorb the daily internal loads. Radiating heat transfer with the night sky will remove heat from the building roof, thus cooling the building structure.

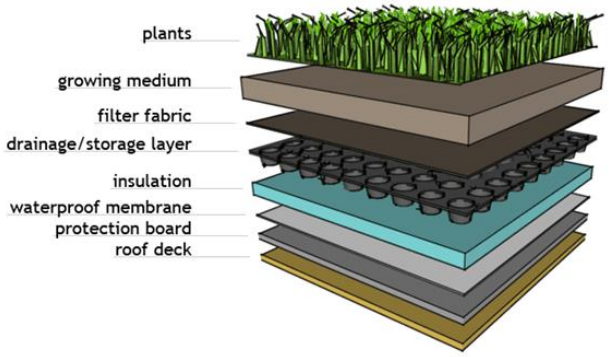


Figure 2

5. In built 'water cycle':

5.1 Water Management

5.1.1 Aquaponics

A combination of aquaculture and hydroponics grows fish and plants together in one integrated system.

Process

- Before construction, a tank should be constructed for storage of water treated in the on-site STP. This water can be used for construction purposes.
- After construction, soil-less growing plants like epipremnumaureum, will be planted on the periphery of the tank. These plants absorb nutrients from the water and will refill the water from the tank.
- Also, clariasgariepinus, a kind of bacteria consuming fish will be put in the tank to purify the water.

5.1.2 Rainwater harvesting

Providing rainwater harvesting in form of following ways:

Rainscaping

Rainscaping, a type of rain water harvesting, is a combination of plantings, water features, catch basins, permeable pavement and other activities that manage storm water as close as possible to where it falls, rather than moving it someplace else.

Rainscaping will be done using the natural slope of the site using bio-swales which are linear, vegetated ditches which allow for the collection, conveyance, filtration and infiltration of rainwater.

Recharge of water bodies

Through rainscaping most of the rainwater can be collected in the water tank to maintain the aquaponics process as well as to be used in various day to day activities like irrigation and at car washing unit.

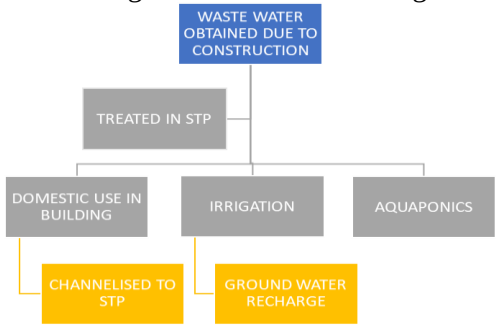


Figure 3

6. Choosing a suitable material

The concept of green building is still emerging in India while the concept of construction of sustainable building with environment friendly materials is quite ancient like stone, timber, thatch, mud etc. but the perception of people regarding strong and durable materials has been changed in recent years with new construction materials like steel, bricks, cement etc. These materials require huge amount of fuel energy for their production. Further, the transportation, assembling of these materials require more energy contributing to increased amount of embodied energy of these materials.

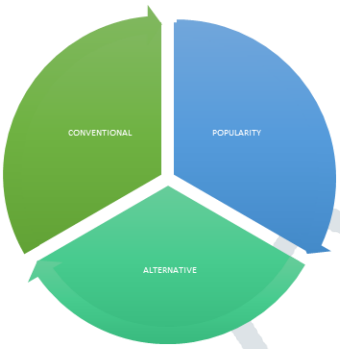


Figure 4

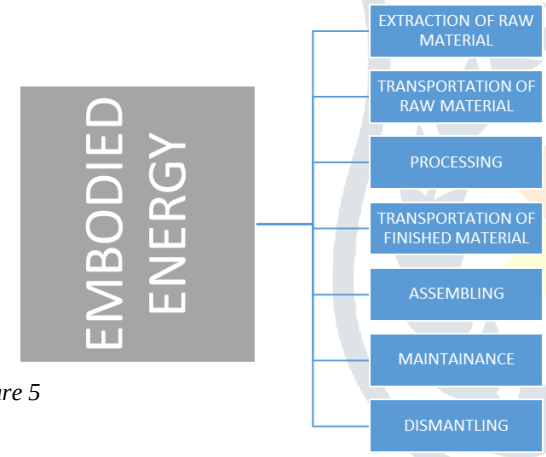
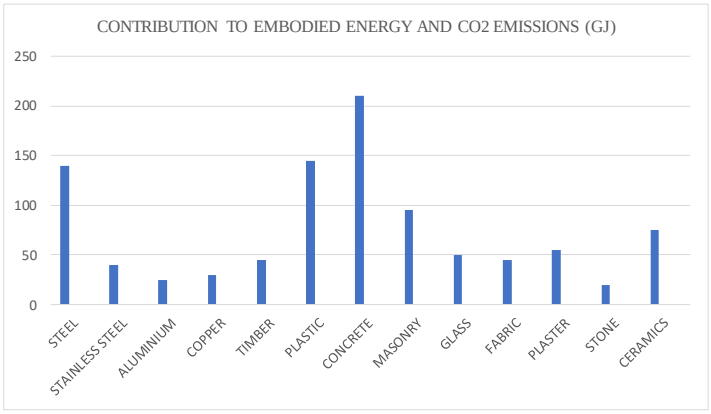


Figure 5

Source: (5)

Quantity of embodied energy based on CSIRO report is calculated and represented below. It can be concluded that embodied energy in bricks worked out to be much more and needs to be taken care of. Similarly, another major contribution of embodied energy is from cement concrete. Hence these two materials are required to be replaced with some alternative materials, which can save significant amount of energy.

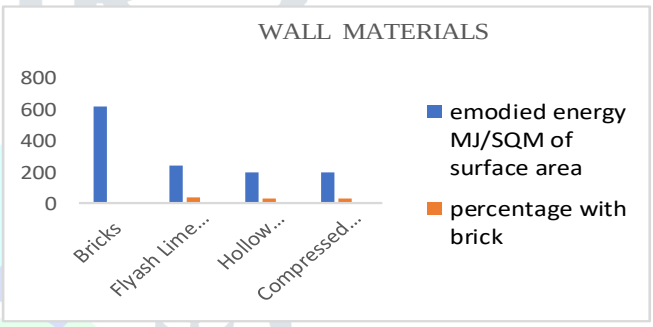


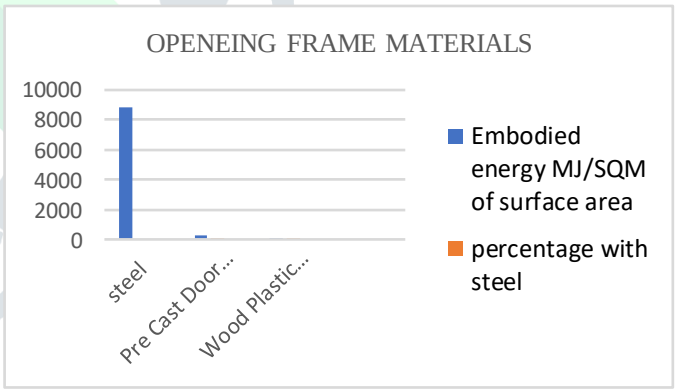
Graph 3
Source:

6.1 Alternative material recommendation

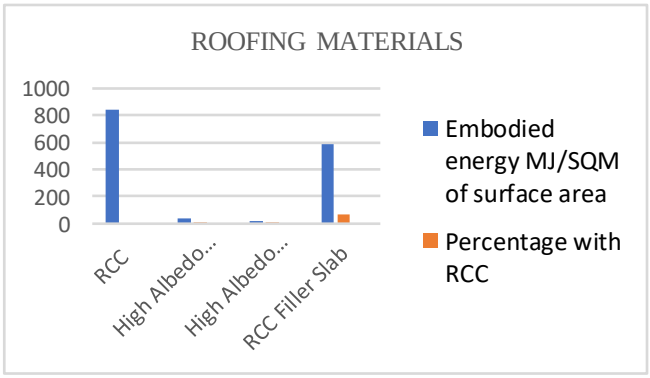
Following graphs give the quantity of embodied energy for various materials that can be used in wall, roof and door/window frames respectively.

Graph 4





Graph 5



Graph 6

Cement, Steel and Bricks and Glass are the materials which contributes majorly to the total energy consumption in RC buildings.

1) The utilization of other building units like hollow concrete blocks for masonry construction reduces the energy consumption by sixty-nine percent as compared to brick masonry.

2) The conventional RC roof is energy intensive with embodied energy values of 847 MJ/SQM. The RCC filler slab roof nearly saves thirty-one percent energy as compared to the RC roof, wherever as White Paint and Reflective tiles uses embodied as low as 4 % and 2.7% of RCC roof.

3) About 99% of embodied energy can be saved using Pre Cast RCC Door Window frame or Wood Plastic Composite frame.

7. Conclusion

The topic has been chosen in order to understand sustainability in a way that it can be the next holistic design paradigm. The idea that denounces the thought that in order to achieve sustainability, states "There must be sacrifice".

The idea also aims at the current mindsets of the communities and the architectural fraternity that sustainability comes with cost and idea of beautification is always disregarded and compromised once the approach becomes green and ecological. The chosen topic tried to comprehend the elaborated view of sustainability and will promote the idea that it helps to improve quality of life and human enjoyment.

Hedonistic approach in sustainability is an emerging topic, currently directed specially to help the future development of sewage treatment plants and promote the idea to develop comprehensive, realistic and efficient waste related operations and maintenance strategies in waste management plan.

8. Acknowledgements

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9. About the Author(s)

Shubham Mishra is a 4th year student at MANIT, Bhopal, currently working on collecting data regarding Green Architecture and Sustainable Habitat and has worked on finding various sustainable solutions for building design and construction and incorporated them in competition projects of HUDCO, GRIHA etc

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