IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 9, September 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

Sustainability and Greenness of Buildings through Life Cycle Stages: An Overview

Dr.Samir Bajpai
Department of Civil Engineering,National Institute Of Technology.
City-Raipur,State-Chhattisgarh,pin-490024 India,

Er. Manish Sakhlecha
Research scholar, Department of Civil Engineering,National Institute Of Technology.
City-Raipur,State-Chhattisgarh,pin-490024 India,

ABSTRACT
Due to energy use, substantial CO_2 emissions, material consumption, release of pollutants during construction and useful life, buildings have negative environmental impacts, thus affecting the aesthetics, human health, and ecology, not only at the site, but also at the sources of building materials, and also during transportation of materials to site. Due to compound growth, leading to excessive consumption of natural resources, sustainability in the building sector has gained international attention. Currently, due to their growth potential, the focus is on developing countries. By 2050 India is expected to add about 35 billion m^2 of additional built up area of this the urban residential buildings will have major share. India and similar other developing nations need to take immediate measures to ensure sustainability in building sector. This paper gives overviews on need to understand the potential measures and how it can be realized that can encourage adopting sustainability in building sector. This paper gives an overview on various potential measures that can be adopted in the life cycle stages of buildings to encourage sustainability in building sector

Keywords:

1. INTRODUCTION

1.1 Sustainability & sustainable development

The concept of sustainability as defined by the ASCE in 1996 is: "Sustainable development is the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development". Gibberd (2005) stated that in the developing countries the environmental sustainable development objectives should be acknowledged in addressing urgent social and economic priorities. With the rapid growth in urbanization and modernization, building sector has now become one of the highest consumers of natural resources and energy. According to the World Resources Institute (WRI, 2009), direct and indirect contribution of buildings in green house gas emissions accounts for 20–25%. Buildings account for 17% of the fresh water consumption, 25% of the wood harvest, and 40% of material and energy use (Smith 2005; Say and Wood, 2008). A scenario analysis, commissioned by Global Buildings Performance Network (GBPN), done by the Center for Climate Change and Sustainable Energy Policy (3CSEP) of the Central European University (CEU) estimated that if left unchecked, India's growth could easily see a substantial increase in building energy consumption resulting to around 700% growth in CO_2 emissions by 2050. The greatest threats to the sustainable development on earth are population growth and urbanization, city transportation, resulting in a limited supply of resources, excessive waste generation and the subsequent pollution of soil, air, and water (Sabnis, 2012).

To ensure the sustainable development of building sector there is strong need to integrate sustainable measures in the building life-cycle in such a way that measurable sustainable results are obtained. A balanced decision, particularly one concerned with long term strategy, requires objective information about the facts involved and their consequences (Tinsley, 2001). It is now being increasingly realized in the construction industry that the sustainable development concepts, applied to various life cycle stages can enhance both the economic well-being and environmental health of communities(indiaenergy.gov.in/docs/Building%20Envelope-documentation.pdf). Consequently, new buildings and existing buildings must ensure that sustainability is the key consideration to manage its projected growth in a sustainable fashion.

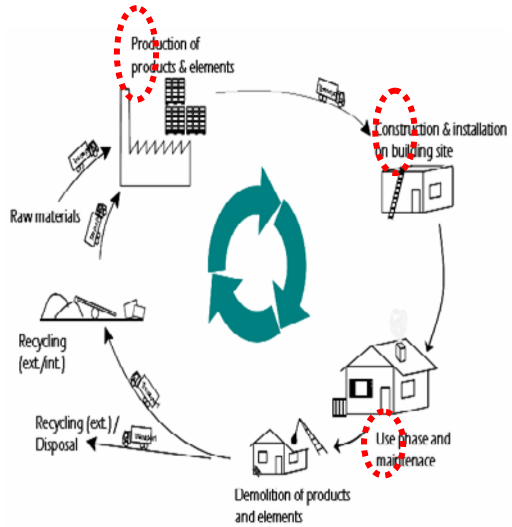
2"SUSTAINABLE MEASURES FOR BUILDING

A sustainable industry should be marked by not only a minimal environmental impact during the manufacturing process, but also during the entire life cycle of the product. Sustainable measures can be realized by analyzing and understanding the impacts of building in its life cycle stages on environment and natural resources. According to Muñoz et al. (2013), various life cycle stages of building can be identified as:

-Planning and construction stage

- Use and maintenance stage.
- Major refurbishment or renovation stage.
- Demolition stage.

Figure 1 Life cycle stages of building



SOURCE -ENSLIC BUILDING Energy Saving through Promotion of Life Cycle Assessment in Buildings

2.1Planning, Design and Construction Stage

The act of planning a building is arranging building elements together to create one integrated whole aimed to fulfill the intended use. Due to hyper development of society, requirements have also changed and demand for comfort and luxury has introduced variety of materials. Efficient use of materials is a fundamental principle of sustainability. It is now quite evident that natural resources are depleting at a faster rate. The selection of material must be based on choosing the best combination of sustainable materials which can work efficiently as a group and could get a significant reduction of resources and energy along the life of the house. Utilization of solid wastes in construction materials can be an effective measure for energy saving, reduction in green house gases and conservation of natural resources. It also has the potential to improve social aspect of increasing employment and reducing cost of material. The waste materials that may be considered for use as partial replacement of various building materials are - blast furnace slag, fly ash, silica fume from Power Plants, recycled aggregates from demolition sites, inert solid wastes, plastic wastes and rubber wastes, rice husk ash etc by reducing consumption of cement and other materials required for the construction activities will help in reducing environmental pollution (Kolisetty & Chore, 2013). This will not only prevent emission of various pollutants emitted during the manufacturing of such materials and during their transportation and use, but also help in preservation of natural resources consumed in manufacturing of such materials, ensuring environmental protection and sustainability.

Application of solid waste into construction materials in real construction Several efforts have been reported regarding conservation of natural resources in building construction by their replacement with waste products.

- Al-Negheismish et al., (1996) reported improvement in the compressive strength of concrete using steel slag, a waste, as a replacement of coarse aggregate, a natural resource.
- Favorable strength and good strength development pattern over the increment ages in concrete with 30 per cent replacement of natural sand with washed bottom ash by weight was reported. (SyahrulHisyam, 2010).
- Natural sand can be effectively replaced by 55 to 75 per cent of the quarry dust, and when combined with fly ash (another industrial waste), 100 per cent replacement can be achieved (ChandanaSukesh 2013).
- 50 per cent copper slag as replacement of sand can be used to obtain concrete with good strength and durability requirements. (Al Jabri 2006)
- GBFS up to 75 per cent can be used as an alternative to natural sand in cement mortar from the point of view of strength.(M C Nataraja 2013.)
- The optimum level of GGBS content for maximizing strength of concrete is about 55%-59%. (Yuksel et al. 2011).
- Construction and demolition waste used as recycled concrete aggregate. (GTAA 2007)
- Rice husk ash used in interlocking blocks (Nasly and Yassin 2009)
- Use of a waste material like coal ash, blast furnace slag, steel slag aggregate can solve problems of lack of aggregate in various construction sites and reduce environmental problems related to aggregate mining and waste disposal (Asi*et al.*, 2007).
- The replacement of 40% steel mill scale with that of fine aggregate in cement mortars increased compressive strength by 40%, drying shrinkage was lower when using steel mill scale(Saud Al-Otaibi, 2008).

Summary of the above mentioned works has been given in table no.1

Another important aspect could be flexibility and adaptability of building components to future changes, wherein design process and materialization play the most important roll. Reductions in home size by optimizing the use of space or floor area can also reduce environmental impact.Designing a building with standard sizes in mind can greatly reduce the waste material created during the installation process. (S. Durmisevic,). Applying locally available materials and avoiding materials that are imported and transported by long distances within the country can also be effective in enhancing sustainability.

Table 1- Utilization of different wastes in building construction

S.no.	Author	Waste material utilized	Natural resources replaced	Result achieved
1	Al-Negheismish et al., (1996)	steel slag	coarse aggregate	improvement in the compressive strength of concrete
2	(SyahrulHisyam, 2010).	washed bottom ash	natural sand	Favorable strength and good strength development pattern over the increment ages in concrete with 30 per cent replacement
3	ChandanaSukesh 2013	quarry dust, and fly ash	natural sand	quarry dust 55 to 75 per cent of the, and when combined with fly ash (another industrial waste), 100 per cent
4	Al Jabri 2006	copper slag	sand	concrete with good strength and durability requirements can be obtained by 50 per cent copper slag replacement
5	M C Nataraja 2013	Granulated blast furnance slag	natural sand	**Good strength in mortar can be achieved** up to 75 per cent replacement
6	Yuksel et al. 2011	Ground granulated blast furnace slag	natural sand	about 55%- 59%of . replacement gives maximizing strength of concrete
7	Nasly and Yassin 2009	Rice husk ash	fine aggregate	used in interlocking blocks
8	Saud Al-Otaibi, 2008)	steel mill scale	fine aggregate	replacement of 40% in cement mortars increased compressive strength by 40%,

2.2 Use and maintenance stage

Construction materials used in buildings and energy consumed during the service life of buildings are the most important aspect of use and maintenance stage. The International Panel for Climate Change (IPCC, 2007) and United Nations Environment Program (UNEP, 2009) reports on Climate Change together have identified the building sector as a main contributor of green house gas emissions responsible for more than 30% of total emissions. A building uses most of its energy during its service life, which is about 90% of the total life cycle energy (Citherlet and Defaux, 2007; Newsham et al., 2009). Studies suggest that 80 percent of greenhouse gas emissions take place during operation phase of buildings to meet various energy needs such as heating, ventilation, and air conditioning (HVAC), water heating, lighting, entertainment and telecommunications (Suzuki and Oka, 1998; Adalberth et al., 2001; Junnila, 2004). Energy for space cooling is the largest contributor (45%) to operating energy followed by area lighting with 29%. The increases in number of households and offices, emergence of digital technology, and changing lifestyle has increased demands for more air conditioning, computers, home appliances etc and is significantly contributing towards increasing energy demand as well. The total building energy demand in India will increase to five times that of 2005 levels by 2050 (an increase of eight times will be seen in the residential sector) representing a lock-in of about 1.2 Gt of CO_2 emissions (Urge-Vorsatz et al., 2012). A study on increase in power consumption by projecting the numbers of electric appliances in use in the residential sector in India to fiscal 2031–32 has been done by the world bank and the results are shown in table 2:

Table2: Total Power Consumed by Appliances (GWh/yr)

Appliances/Year	2011	2016	2021	2026	2031
Lighting	57,786	73,676	91,092	107,890	125,601
Entertainment	29,874	43,767	57,845	69,196	79,989
Kitchen Appliances	35,835	49,152	66,905	85,064	103,435
Heating/Cooling	75,310	112,931	164,011	220,472	279,449
Total	198,807	279,526	379,854	482,622	588,474
Operating	192,491	273,147	373,151	475,330	580,143
Standby	6,316	6,379	6,703	7,293	8,331
Total	198,807	279,526	379,854	482,622	588,474

Source - Background Paper India: Strategies for Low Carbon Growth July, 2008

The Bureau of Energy Efficiency has also stated that the potential to save 30-50 per cent of energy lies even in existing buildings, but transition to a sustainable society will require efficient use of energy and minimization of energy−related environmental impacts. The energy consumption during the operational phase of a building depends on a wide range of interrelated factors, such as location, climatic condition source of energy; function and use of building; building design, type of materials; and the level of income and behavior of its occupants. Design parameters which have good prospects of influencing the building performance include the building orientation, construction, natural ventilation scheme integrated with window type and opening area, shading devices, day-lighting and heating strategy (Pollock et al., 2011). If the houses have a green roof, temperatures can be brought down by at least three degrees Celsius. For an independent dwelling in Malaysia, Shoubi et al., (2014) found that the energy used throughout the year to keep building's temperature between 22 and 26 °C based on usual materials was 17,600 kW h and double brick cavity plaster and reverse brick veneer as alternative materials provided the greatest reductions in annual operational energy consumption, i.e., about 1000 kW h, if they were used instead of brick plaster as the wall component. However, a common aspect is that a reduced demand for operating energy is achieved by increased use of materials, and especially of energy intensive materials, both in the building envelope and in the technical installations **(**Sartori and Hastens, 2006). In some of the cases it has been found that saving in energy was counterbalanced by increase in the embodied energy and has long payback periods for environmental impacts. (Winther and Hestnes, 1999). The benefit of reducing operating energy by increased use of materials should be properly analysed especially by LCA approach to understand the actual advantage.

Construction materials live much longer than most other materials (Milani, 2005; Wadel, 2009). Approximately, 60% of the materials extracted from the earth crust end up in the built environment and they have a life cycle, mostly related to the time when the building is in operation (**Wadel, 2009; Bribian*et al*., 2011**). This tends to make durability and performance of such materials somewhat more important than for many other kinds of products. The Canadian Standards Association *Guideline on Durability in Buildings* (CSA, 2001) provides one of the most recognized definitions of building durability in North America. According to this standard, durability is defined as the ability of a building or any of its components to perform its required functions in its service environment over a period of time without unforeseen cost for maintenance or repair. The strongest opinion regarding sustainable construction was that building materials should be evaluated on the basis of life cycle cost, long-term durability, and maintenance, and not just environmental impact and energy savings(“White Paper on Sustainability”, 2003, p. 17). Durability is a key attribute. A longer lasting product will be manufactured and applied fewer times. and so a less durable material can hardly qualify as a green material. (Sinha et-al 2013).The durability of materials is an important factor in analyzing a building’s life-cycle costs. Longer lasting materials over a building’s useful life will be more cost-effective than materials that need to be replaced more often (Jong-Jin Kim, 2011). Considering the durability, the selection of initially expensive materials like can often be justified by their longer life spans.

2.3 Major refurbishment and renovation stage

One certainty is that buildings will change significantly over their lifetime. the typical rates at which elements of a building are changed vary by building type and function, with some structures lasting 100 years or more, and others lasting a mere 30 years (Brand, 1997). Over the course of a 75-year life span a stage comes when one thinks of changing the internal and external look of building. With the change in generation the overall building outfit requires a change. This can be achieved by constructing a new building and demolishing the old one completely or by reusing the same structure by making renovation and slight modification. Whether to refurbish or replace a building is a complex decision, depending on a range of factors, almost all of which are uncertain. Moreover the service life and the end of life of a building or building element is not a matter of technical lifetime only, but it is also related to a number of other criteria such as functional, technical, economic, aesthetic, ecological and contextual criteria (Bull, 2011). An important aspect for such decision is the time duration after which it is thought off. This can be a critical issue when deciding between two or more options and although the lifespan considered in a typical scope is 50 years (Khasreen et al., 2009). The degree of building degradation is also taken into account, since many of the energy renovations are feasible only when other renovations take place in the building (TarjaHäkkinen, 2012).

Reuse of building offers environmental savings over demolition and new construction. Moreover, for a new, energy-efficient building to overcome, the adverse impacts that were created during the construction process through more efficient operations might take many years. But in one of the study done by Hansen& Petersen, the comparative environmental assessment of a typical Danish renovation project for an older residential building and a new building shows lower energy consumption and lower CO_2 emissions than the renovation example, regardless of life cycle and heat source variations. The simple "pay-back" for CO_2 emissions at demolition and new building, instead of renovation, is 25-30 years . Reusing an existing building and upgrading it to maximum efficiency can offer an important means of avoiding unnecessary pollution and environmental impacts, however it is important to develop methods and concepts for building renovation and analyses for the impacts of alternative renovation scenarios in terms of energy use and carbon footprint. The relative environmental impacts of building reuse and renovation versus new construction is also an important aspect in achieving sustainability in modern living.

2.4 Demolition stage

It is the stage when buildings no longer remain in a condition of living. Buildings are likely to be demolished after the completion of its service life. Demolition wastes are the waste materials that are produced in the process of demolition of different type of buildings. Components of construction and demolition waste typically include concrete, steel, wood, metals, gypsum wallboard, roofing, paper, plastic, bricks and glass etc. Generally, the C&D waste constitutes about 40-50% of total waste generated worldwide (McDonald, 1996; Dolan et al., 1999; Macozoma, 2002; Oikonomou, 2005). Concrete contributes largest portion of the solid waste stream by weight (US PW Technical Bulletin 200-1-27, 2004). The C&D waste (by weight) in Western Europe is composed of masonry (45%), concrete (40%), wood (8%), metal (4%) and study and plastic (3%) (Golton, 1997). Waste from small generators like individual house construction or demolition, are disposed into the nearby municipal storage depots, making the municipal waste heavy and degrading its quality for further treatment like composting or energy recovery. Often it finds its way into surface drains, choking them. It

constitutes about 10-20% of the municipal solid waste (excluding large construction projects). The sustainability principle recommends the maximization of the reuse of the building components and material recycling after the end of life time of the building (Kibert, 2003; Hobbs and Hurley, 2001). Recycling can be defined as a process that contributes to sustainability in the construction industry through using C&D waste as material resource for production of building materials thereby avoiding excessive raw material exploitation (Langston et al., 2001; Meer et al., 2006, Tam et al., 2006; Banar et al., 2009). Reuse means to apply recovered C&D waste without altering its shape. According to Metha (2001), the most efficient way for the construction sector to contribute to sustainability is to reuse waste products as well as to improve the durability (lifespan) of the works. Moyano et-al., 2011 suggested that reuse, recycling and other forms of recovery the waste generated on site should be based on environmental impact generated at the end of the life cycle of products used in construction . Article10 of the Waste Framework Directive (WFD) stipulates, "by 2020, the preparing for re-use, recycling and other material recovery….of non-hazardous construction and demolition waste….shall be increased to a minimum of 70 % by weight".
Following are some of the studies related to recycle and reuse of construction and demolition waste

- According to Das and Kandpal (1997), by using recycled steel, CO_2 emissions can be reduced by about 35% when compared to virgin steel, due to requirement of less energy and combustion to extract impurities in recycled steel.
- Larsen et al., 2009 in their study showed that about 65% of the CO2 emission can be reduced per ton by using the recycled crushed glass which can be added during glass manufacturing process
- In a study of recycling nationally produced building waste by Thormark, 2000, it was reported that the potential energy saving through recycling was about 50% of the embodied energy.
- According to Limbachiya et al., (2004) 30% coarse recycled concrete aggregate (RCA) can be used without any modification in the mix design, in concrete construction with performance similar to natural aggregate concrete.
- Soutsos et al., (2004) found that the coarse fraction of the aggregate can be replaced not more than 20% with masonry-derived aggregates without significantly affecting the desired compressive strength of 7 N/mm^2 (a targeted one).
- According to Tang et al., (2008), the recycled demolition aggregate does not cause a significant reduction in the compressive and tensile strength of concrete blocks, if the replacement levels are kept low (i.e., not more than 25% replacement).
- When reused materials were used in a one-family building, the embodied energy decreased about 45% (Thormark, 2002).

.

3"CONCLUSION

Preservation of the environment and conservation of the rapidly diminishing natural resources should be the essence of sustainable development. Buildings have immense potential in contributing towards sustainable development. The potential to achieve reductions in resource consumption, energy consumption, emissions etc. can be very well achieved by analyzing the life cycle assessment impact of various stages of buildings and implementing measures for each stage. The waste materials like blast furnace slag , fly ash , silica fume, recycled aggregates from demolition sites, inert solid wastes, , rice husk ash etc which are otherwise a threat to environment can be effectively utilized in buildings as partial replacement of coarse and fine aggregates. Retrofitting of existing buildings, especially in urban areas, is the greenest building strategy because it prevents requirement of new land or infrastructure. It also reduces the amount of materials and energy in the construction. Construction and demolition recycling is an important step, a developer can make to sustainable building. Recycling of construction and demolition waste has many benefits such as reduction in transportation cost, keeping the environment clean and reducing natural resource exploitation The various forms of recycling and recovery are likely to become increasingly important over time, due to the overarching targets set for this waste stream. The relationship between the origin and end of life cycle of building materials is direct, as the waste generated depends on the choice of material resources consumed in the implementing the building. Sustainable design should provide possibility to reuse building components or recycle elements when the building reaches the end of its life cycle in maximum possible ways. The measures taken at various life cycle stages of buildings can contribute a lot to reduce the problems related to environment and natural resources over the complete life cycle of the building and improve sustainability at a local, regional and global level for future generations.

REFERENCES

1] Gajanan M.Sabnis **Green building with concrete** **Sustainable Design and Construction** 2012

2] Jenny J Liu **Quantifying and assessing impacts of building processes in a 'triple bottom line approach** University of Technology Sydney, Australia

3] **Mitigation potential from india's buildings** global buildings performance network february 2013

4] The Greenest Building: Quantifying the environmental Value of Building Reuse

5] Cui, H . Z .1, Sham, F. C.2*, Lo, T. Y. 2 and Lum, H. T. 2 **Appraisal of Alternative Building Materials for Reduction of CO2 Emission by Case Modeling.**

6]**Sustainable Development and Green Buildings** Održivirazvoj *2012.*

7] Anna Braune1,*, Bastian Wittstock2, 1PE INTERNATIONAL AG **Measuring environmental sustainability: The use of LCA based building performance indicators,** , Fraunhofer Institute for Building Physics, Stuttgart, Germany

8] **The Impacts of Construction and the Built Environment**

9] Sustainability by strengthening the relation between disciplines involved. S. DURMISEVIC and S. SARIYILDIZ Delft University of Technology, Faculty of Architecture, Department of TechnicalDesign and Computer Science, Delft, The Netherlands E. DURMISEVIC and J. BROUWERDelft University of Technology, Faculty of Architecture, Department of BuildingTechnology, Delft, The Netherlands

10] **Conservation of energy and natural resources by recycling building waste**. International Journal of Resources,Conservation and Recycling. Thormark C.

11] Thormark C. recycling in energy use into the life-cycle of buildings. International Journal of Building Research and Information2000;

12]. Thormark C ,**Environmental analysis of a building with reused building materials**. 1999-2000; International Journal of Low Energy & Sustainable Building.

13] Arijit Sinha1, Rakesh Gupta1, AndrejaKutnar2 **Sustainable Development and Green Building**s.

14] Jong-Jin Kim, Brenda Rigdon **Sustainable Architecture Module: Qualities, Use, and Examples of Sustainable Building Materials.**

15] **Sustainable Buildings** Hal Levin Building Ecology Research Group, Santa Cruz, CA, USA

16] Mollá Muñoz, Clara María. *Academic Director PFG:* Orozco Messana, Javier, **Practical use of Life Cycle Assessment for buildings**

17] **Sustainable Buildings & Climate Initiative UNEP 2009 Buildings and Climate Change *Summary for Decision-Makers***

18] Snehal Anilkumar Kumbhar a, Anilkumar Gupta b ,DadasoBalaku Desaic **,Recycling and reuse of construction and demolition waste for sustainable development** .

19] Mª Pilar Mercader Moyano1,*, Antonio Ramírez de Arellano Agudo2 and Manuel Olivares Santiago **,Calculation Methodology to Quantify and Classify Construction Waste.**

20] Dhiraj Agrawal1,Pawan Hinge1,U. P. Waghe2,S.P. Raut1, **Utilization of industrial waste in construction material – A review.**

21] R.K.Kolisetty, **Utilization of Waste Materials in Construction Activities: A Green Concept**

;