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Abstract: Use of the sustainable material is a part of the sustainable development. The word was popularized in Our Common Future, a report published by World Commission on Environment and Development in 1987. Sustainable development is the development which meets the needs of the present without compromising the ability of future generations to meet their own needs. In 1992 the principles of sustainable development were formulated at the United Nations Conference on Environment and development in Rio de Janeiro, Brazil. Three bottom line concept of sustainability model given by John Elkington also explained to economic development, social equity and environmental protection. In this context green buildings are sustainable building are sustainable or green. The components of the green building include material efficiency, water efficiency, energy efficiency, indoor air quality efficiency, waste reduction, HVAC design and sustainable site planning. An attempt has been made in this paper to describe the characteristics of the green material as material efficient and the environmental philosophy behind each of this characteristic.

Key words: Material efficiency, Green buildings, reusable, recyclable, Regional material, Materials Reuse

1. INTRODUCTION

India is the second largest country in population in the world. At present the cost of infrastructure and expansion of cities in India is haphazard. In order to extricate from the present scenario India must follow the principles of sustainability. There is a dire need to protect the environmental resources. Green building is one of the important solutions of sustainable development.

The sustainable building incorporates many strategies during design, construction and operation of a building project. Using "green building materials "in construction is said to be "sustainable design". The green materials are environmentally responsible materials as they help in reducing environmental impact.

A green building is defined as the high performance building which uses less water, energy, generates less waste, maintains indoor air quality for the occupants and uses efficient building materials. Rick Fedrizzi, Chairman of World Green Building Council has said that the green building has inspired countless material product and process innovation that have speeded up the adoption of green building design, construction, and operation across the globe. Today green building is a half-trillion dollar industry in the United States and more than a trillion dollar industry worldwide. (Rick Fedrizzi in Forward of The business case for Green

Building) Green building design aspects are site planning, building envelope design, building HVAC design, indoor environmental quality (thermal, visual comfort, and air quality), and use of ecological sustainable, high recycled and renewable materials. World shortage of power, water and environmental factors are the factors, encouraging building industry's focus on green building. Buildings annually consume more than 20% of the electricity used in India. (Soni etal, 2013)

Fig.1 Typical Green Building. Source: http://www.ecochicliving.ca/reno.html

2. COMPONENTS OF GREEN BUILDINGS

According to GRIHA, building activities contribute an estimated 50% of the world's air pollution, 42% of its green- house gases, 50% all water pollution, 48% of all solid wastes and 50% of all Chlorofluorocarbon CFCs to the environment. (GRIHA Manual Volume-1, 2010)

Green design and construction aims at using resources more efficiently. The main objective of green building is to enhance positive impacts on the environment. If all urban buildings were green, our nation could have saves more than 8400 MW of power a year.

Following components of green building needs to be studied

1. Material efficiency (using sustainable construction materials and such other strategies)
2. Water efficiency (using low flow plumbing fixtures, roof top rain harvesting, porous paving system and such other strategies
3. Energy efficiency (using energy conservation Building Code ECBC 2007, Smart lighting fixtures with control and renewable strategies)
4. Indoor environment quality (using microbial resistant materials, heating & cooling system ensuring ventilation and such other strategies)
5. Waste management (using green architecture standards, producing less amount of waste, harvesting waste and reusing material , deconstruction and such other strategies)

Green Building Materials

A green building needs special materials and systems to adapt sustainability compared with a conventional building. In line with the growing trend of green building development the industry of green building materials and services is also developing in India. The sustainable building incorporates many strategies during design construction and operation of building project. Using green building material is one of the sustainable design construction and operation strategies. The green materials are environmentally responsible materials as they help in reducing environmental impacts (Greenomics)

The sustainable building materials should have resource efficiency, indoor air quality energy efficiency and affordability. Green building rating for integrated habitat assessment GRIHA also recommends selection of ecological sustainable material. Ecological sustainable materials are those which have high recycled content, rapidly renewable resources with low emission potential. For example, low volatile organic compound (VOC) pint is a sustainable material. Similarly, door frames and flooring tiles made using recycled materials are the examples of sustainable materials.

While planning green buildings, modular plan should be used. Dimensional planning is an important material strategy of green buildings For example, designing interiors of rooms in such a way that the module follows standard sized plywood as well as wall board will eliminate cut construction cost. . Dimensional planning and other material efficiency strategies are used to reduce the construction cost. (Materials and Resources)

3. IDEAL GREEN BUILDING MATERIALS

Ideal green building material is a material which has no negative environmental impacts. Possibly it should have positive environmental impacts. Further such material should be infinitely reusable or recyclable. But such ideal materials are rarely available. However materials which can eliminate or reduce negative impacts can be considered as green building materials.

The acid test for considering the materials to be green building materials should satisfy following criteria:

- The material should be renewable and resource efficient.
- The material should support environmental health. In other words, it should provide healthier environment to public. Indoor air quality should be excellent.
- The material should be appropriate for application for which it is proposed to be used and should be economical to use.

Extensive research is required to decide on the above criteria of the green building materials. The research needed considering the impact of the material throughout its life cycle. At each stage in life cycle of the product, it should not show any significant impact on environment.

Materials for Enhancing Indoor Environmental Quality

The indoor environmental quality can be achieved using less toxic interiors, adhesives, paints and composite wood.

Life cycle analysis (LCA) is said to be analysis of building products. It is 'Cradle to Grave' analysis- from raw material to the ultimate disposal point. The stages include selection of raw materials, manufacturing, distribution and installation to ultimate reuse or disposal.

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In case of green materials, life cycle should not exhibit that any stage the material

- does not emit volatile organic compound (VOC)or emit minimal VOCs
- has low emission of toxic or carcinogenic or irritant chemicals
- free of toxic materials such as chlorine, lead, mercury, arsenic, chromium, cadmium, asbestos, chlorinated polyethylene and chloro-sulphonated polyethylene, Chlorofluorocarbons (CFC) , polyvinyl chloride (PVC), halogenated flame retardants, phthalates, creosote, penta- chloro phenol, petrochemical fertilizers and pesticides as well as formaldehyde

In short the indoor air quality is enhanced by utilizing the materials which are simple, non-toxic, non-carcinogenic and low VOC materials. Though the materials do not cause toxicity about the air quality for the occupant of building, it can still carry toxicity risk for construction workers and manufacturing workers.

4. CHARACTERISTICS OF GREEN BUILDING MATERIALS

In general, following characteristics of the building materials are considered 'green' and research can be avoided if materials are quickly required to be selected (Quick Guide)

Rapidly renewable materials

Rapidly renewable materials are natural, non-petroleum-based building materials (petroleum based materials are non-renewable) that have harvest cycles under 10 years. The duration could be maximum 10 years. (Rapidly renewable material)

The philosophy to use rapidly renewable material is to save trees. Deforestation of long renewable material is responsible for loss of diversity and destroying the habitat and earth's land animals and plants. Fewer forest means larger amount of GHG entering environment as forest act as carbon sink absorbing CO_2.

Fig. 2 Rapidly renewable materials, low emitting materials, certified wood and regionally-sourced Source:woodhttp://www.jetsongreen.com/2010/09/fossilized-bamboo-floor-indestructible.html#post/0

Although the renewable materials have the ability to grow back, the time it takes to reestablish the ecosystem increases the GHG. For these reasons, 10 year life cycle is considered as rapidly removable materials. (Rapidly Renewable Materials | Poplar Network)

A component of sustainability includes the distance traveled from extraction to manufacturing to the project site. Transporting materials requires energy and contributes greenhouse gas emissions. The further the distance traveled, the more energy used and greenhouse gas emitted. In order to minimize these environmental impacts, the local or Regional Materials within 500 km of the project site is given credit by GRIHA and LEED rating systems The goal of using regional materials is to support use of indigenous resources, help the local economy, and reduce transportation impacts.

Utilization of rapidly renewable materials includes bamboo flooring and veneers, wool carpets, strawboard, cotton ball insulation (made from denim scrap), genuine linoleum flooring etc.

Using rapid renewable materials helps the use and depletion of finite raw material. Thus it conserves the resources.

The USGBC defines "rapidly renewable" as a material that's able to regenerate itself in 10 years or less. That includes bio-based products made from plants harvested on a 10-year (or shorter) cycle. The goal of using rapidly renewable content is to reduce the number and quantity of products made from fossil-fuel derivatives. Rapidly renewable materials include linseed, straw, cotton, wheat, sunflowers, natural rubber, bamboo, and cork. These feed stocks are often used in green building products, like linoleum, straw bales, wheat board panels, bamboo cabinetry, cork flooring.

Fig. 3 Kitchen flooring manufactured using linseed oil and 45% post-industrial- recycled content installed without glue.
Source: Regional and rapidly renewable materials http://www.buildings.com/article-details/articleid/9123/title/regional-and-rapidly-renewable-materials.aspx

The material shown in the figure has the aesthetics, durability, and sustainability features of materials. Rapidly renewable products, like cork and bamboo, represent something new, different, aesthetically pleasing, and kind to the environment.

Easily recyclable or reusable

The green buildings are required to reduce waste in landfills. This is possible by recycling metal, glass, paper, plastic and cardboards. Reusing the material or reusing the recycled material is innovative and highly effective and is known as sustainable design. Reusing the material found at the existing site or adjacent to the site such as the elements like trees, structures, paving all are said to be acceptable green strategy in India.

Concrete, steel, metal, glass, brick and some types of plastics are common building materials and used after recycling. This can be used as a part of built environment by architects in India.

Use of waste material in construction

Construction waste can be recycled and used in other projects. The philosophy behind using waste material in construction is to ensure that the load at the landfill is reduced. Material if not reused or recycled will go to landfill or incinerators. This needs to be changed by green buildings. In India fly ash disposal is an important environmental issue.

The waste materials in construction that can be used are as under

- Partial replacement of clinker or Portland cement by slag, fly ash, straw silica fumes.
- Partial replacement of natural materials that require little processing such as pozzolana calcined clays
- Use of rice husk ash in concrete
- Palm oil shell aggregate for light weight concrete

5. FLY ASH AS CONSTRUCTIONAL MATERIAL

Concrete can recycle fly ash from coal fired plants and slag from the blast furnaces of steel production. But these materials may contain toxins like mercury. The toxins should not be directly exposed to occupants.

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At present there are more than 40 thermal power plants in the country producing over 5 million tonnes of fly ash per annum. The ash content of coal is found to be ranging from 17% to 45% at most of the plants. Indigenous fly ashes for partial replacement of cement as an admixture for concrete have already been successfully exploited IS 3812-1981

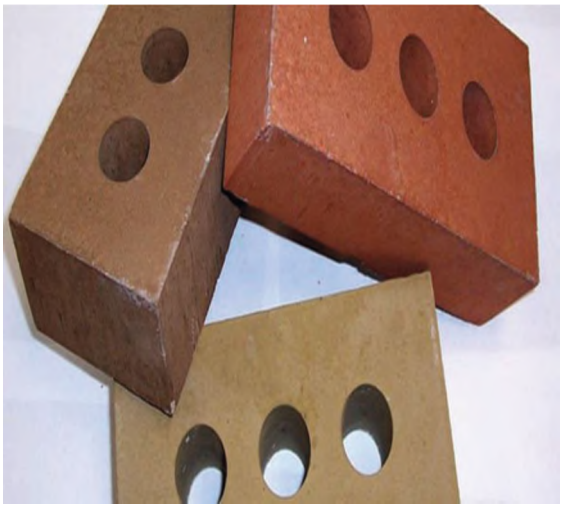

Fig.4Green building product from fly ash Source:http://designtoimprovelife.dk/green-building-products-from-flyash/

India produces about 70 million tons of coal ash per year from burning 200 million tons of coal per year for electric power generation. Extensive research work is carried out for developing appropriate technology for disposal and utilization of fly ash. IIT Kanpur has developed a technology wherein almost 10% of ash is utilized in dyke construction and land filling.3% is used in other industry. So to say 80% or more fly ash in India is not utilized properly. In developed countries, the fly ash can be used in manufacturing bricks, cellular concrete blocks, road construction, land fill application, ceramics etc. As per IIT Kanpur report currently one acre per MW of land is required for ash disposal.
It has been successfully demonstrated that fly ash can be utilized in major infrastructural projects such as dams, ash dyke, roads and pavements; bricks manufacture cement tiles and paint industry. A law has been enacted in 1999 projecting 100% utilization of flyash within a stipulated period and making it mandatory to use fly ash for the purpose of road construction, bricks etc within a radius of 50 km from coal based thermal power plant. (SAVE SOIL, USE FLY ASH, IIT Kanpur)

IS 10153-1982 is a guidelines for utilization and disposal of fly ash. Fly ash is a suitable raw material for a variety of products and may be utilized for the production of:

- Portland pozzolana cement using fly ash as pozzolana
- Cement –fly ash concrete and ready mixed ash concrete
- Precast fly ash concrete building unit
- Sintered fly ash light weight aggregate and concrete
- Lime – fly ash cellular concrete
- Cement/lime/silicate bonded and clay – ash building bricks
- Portland cement clinker, cement

For road and airfield pavement construction using:

- Lime fly ash concrete
- Lean cement fly ash concrete,
- Cement fly ash concrete
- Lime fly ash soil stabilization
- Lime – fly ash bound macadam

It can also be used:

- As fill material in embankment construction,
- As filler material in bituminous concrete and
- Insulating and semi – insulating bricks

Fig.5 Concrete made with fly ash Source: http://www.recycleworks.org/greenbuilding/gbg_concrete.html

The particulars are all given in IS 10153-1982. All these uses are considered as 'green' as it conserves natural resources.

Constructional waste materials

Most structural steel contains 90% recycled content can be considered as green building material. The use of waste products is not only partial solution to environment and ecological problems but it significantly improves microstructures and consequently durability of concrete is achieved.(Satish Chandra)

Reusing elements of previously constructed building help in conserving resources. By reusing floors, roofs, walls green building can help diverting the million tons of waste materials otherwise reaching the landfills. It is always desirable to use demolition or renovated building materials rather than using new housing materials.

Fig 6 Block to be used as walling material manufactured using ash.
Source
https://civilsolution.wordpress.com/tag/aerocon-blocks/

Material Reuse

The material reuse means using reused materials, salvaged or refurbished materials. This will obviously reduce the requirement of the virgin market. This will not only reduce the waste but also reduce the stress on the environmental resources. Material reuse is thus different from material recycled or reused. It is the material that is salvaged or waste once reused is again used in its original form.

Energy efficient in use

The discarded tiers of vehicles constitute solid waste and are disposed of into landfills. This can be reused –the tire rubber particles partially replace natural aggregates used in the production of concrete. Using recycled coarse aggregate concrete is another example of energy efficiency in use.

By using waste materials rather than new materials, the producer can save the cost of processing, transporting the material and thereby saving on energy.

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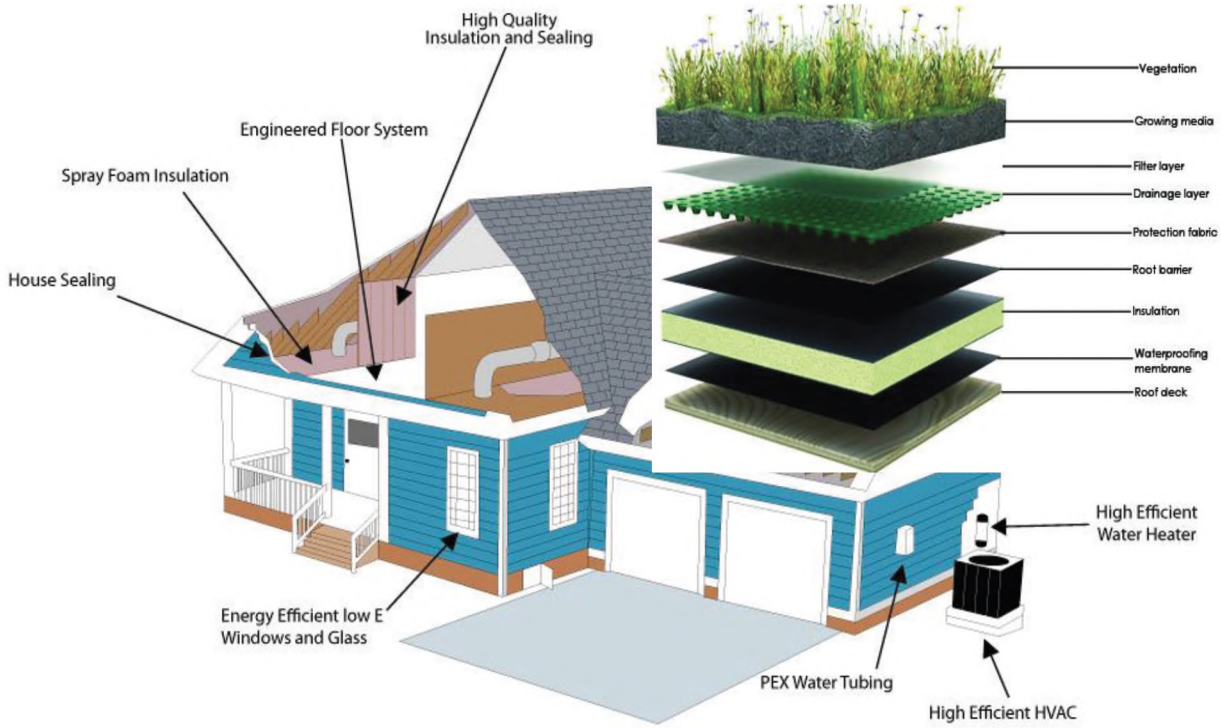

Fig.7 Energy Efficient Building Source:http://beavercountybuilders.com/buyers-toolkit/energy-efficiency/

Low embodied energy

Embodied energy is the total energy required for the extraction, processing, manufacture and delivery of building materials to the building site. Energy consumption produces CO_2, which contributes to greenhouse gas emissions, so embodied energy is considered an indicator of the overall environmental impact of building materials and systems. Recycled "secondary" aluminum has 90% less embodied energy than virgin primary aluminum. It is desirable to use such recyclable material.

Other considerations

- Thermal insulated roof

Moreover, green building material practices should take into following considerations:

- Building landscape to minimize grading and retain native soils and vegetation and turfing

Fig.8 Roofs with vegetated surfaces have been in use for centuries as an effective thermal insulator and watertight building technology. In the 20th Century, modern green roofs were made possible by advances in membrane and waterproofing materials, and in horticulture.
Source:http://dcgreenworks.org/programs/rainwater-conservation-and-reuse/green-roofs-2-0/

Pervious paving which allows rain water to pass through the ground below for recharging the ground water. Pervious concrete has started getting acceptance I India very recently

6. SUMMARY

One of the principles that are adopted is using materials that are sustainable or green. As per IGBC "A green building uses less energy, water and natural resources, creates less waste and is healthier for the people living inside compared to a standard building."

The components of the green building include material efficiency, water efficiency, energy efficiency, indoor air quality efficiency, waste reduction. From the above it is crystal clear that all efforts made for conservation of environmental resources is considering a step forward towards Green and sustainable materials. The rating systems -GRIHA or LEED certification therefore demands the use of sustainable materials.

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