Evaluation criteria for Green Materials

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Abstract:

Due to increased environmental concern all over the world, practice of sustainable buildings or Green Buildings is being encouraged. The practice of green building can lead to benefits including reduced operating costs by increasing productivity and using less energy and water, improved public and occupant health due to improved indoor air quality, and reduced environmental impacts. Besides various other requirements, one of the essential requirements of the green building is to use enivrionment friendly building materials – Green Materials. At present, there seems to be lot of confusion in defining green materials and manufaturers will have claims qualifying their products as green materials. There is a need to have evaluation criteria for qualifying materials as green materials. An attempt has been made in this paper to propose a scale for evaluation of building materials considering various factors that are essential for sustainable development, based on which classification of materials can be made in to different categories of green materials.

Introduction:

Due to industrilizartion process over a period of last 200 years and uilization of fossil fuels such as coal and petroleum, the concentration of green houses gases (such as carbon dioxide and methane) in the atmosphere is increasing rapidly. This has resulted in to increase in global average temperature (global warming) which is the major point of concern all over the world. The kyoto Protocol has been agreed to by several nations, committing to specified, legally binding reductions in emissions of six "greenhouse gases." Approximately 30-40% of total energy consumption is accounted for building sector. It is hence essential to explore energy efficient building alternatives in order to help in mitigation efforts to the effects of global warming. Green building or environmental sustainable building technologies are gaining the attention of all the stack holder of the construction industry. Factors considered for green building designs include appropriate site selection, use of environmental friendly building materials (Green Materials), energy efficient building practices such as passive cooling, use of maximum day lighting, use of energy efficient building materials, appropriate use of lighting fixtures, etc., use of water efficient technologies, rain water harvesting, use of renewable energy sources, recycling of waste water, efficient solid waste management, etc. there are number of rating agencies encouraging green building movement and bench marking /standardizing green building technologies. As one of the criteria is use of green materials and there seems to be lot of confusion about designating any material as green material, there is a need to have some evaluation criteria for the same. In present paper, efforts have been made to develop a scale which can help in classifying building materials as green materials.

Evaluation Criteria for Green Materials:

Due to phenomenal growth in the construction industry, there is tremendous pressure on depletable earth resources such as soil, sand, stones, wood, etc. Production of building materials leads to irreversible environmental impacts. Using environmental friendly building materials is the best way to build a eco-friendly building. Following criteria can be used to identify the green materials.

i) Local availability of materials
ii) Embodied energy of materials
iii) % of recycled/waste materials used
iv) Rapidly renewable materials
v) Contribution in Energy Efficiency of buildings
vi) Recyclability of materials
vii) Durability
viii) Environmental Impact

Using above mentioned criteria and assigning certain rating (R1-R8) to each of the criteria, overall evaluation of the material can be made by summation of score obtained by any material in these ratings. Guidelines for assigning rating to each criteria is discussed in following text.

i) Local availability of materials

As far as possible locally available materials are to be preferred so as to minimize the energy spent in transportation of the building materials. Energy consumed in transportation should be considered as total energy spent on transporting materials starting from the place of manufacturing. Depending upon distance from the place of manufacturing of the material, points for rating R_1 can be allotted to the materials, based on following guidelines:

Table-1 Rating R_1 for Local availability of materials

Distance from place of manufacturing	R_1
0-20 km	10
21-50 km	08
51-100 km	05
101-200 km	02
>200 km	00

ii) Embodied energy of materials

Embodied energy is an assessment of the energy required to manufacture any building material, which include energy required to extract raw materials from nature, energy used to transport raw materials to manufacturing unit and the energy used in manufacturing activities to provide a finished product. Every building is a complex combination of many processed materials, each of which contributes to the building's total embodied energy. Embodied energy is a reasonable indicator of the overall environmental impact of building materials, assemblies or systems. Embodied energy of some building materials is mentioned in Table-2. Depending upon embodied energy of the materials, points for rating R_2 can be allotted based on guidelines given in table -3.

Table 2 Embodied Energy of Different Construction Materials

Sr. No.	Materials	Embodied Energy (MJ/Kg)
1	Cement	5.85
2	Mild Steel	26.37
3	Steel	32.00
4	Aggregates	0.10
5	Stones	0.79
6	Burnt Bricks	2.50
7	Concrete Blocks	0.94
8	Normal Concrete	1.30
9	Precast Con crete	2.00
10	Clear Glass	15.90
11	Alluminium	227.00
12	Aluminium (Recycled)	8.10

Sr. No.	Materials	Embodied Energy (MJ/Kg)
13	Steel (Recycled)	8.90
14	Timber Planks	2.50
15	Particle Board	8.00
16	Asphalt	9.00
17	Mosaic Tiles	8.10
18	Plywood	10.40
19	Fiber Glass (Insulation)	30.30
20	Copper	70.60
21	Zinc	51.00
22	Brass	62.00
22	PVC	70.00
23	Paint	93.30

Table-3 Rating R_2 for Embodied Energy

Value of embodied energy of materials	R_2
0 - 2 MJ/kg	20
2.1 - 5 MJ/kg	18
5.1 - 10 MJ/kg	15
10.1 – 25 Mj/kg	10
25.1 – 40 MJ/kg	5
40.1 – 100 MJ/kg	2
> 100 MJ/kg	0

iii) % of recycled/waste materials used

Building materials can be manufactured using recycled materials or using waste materials. Use of recycled materials helps the environment and the economy in several ways. A significant effect is that of lessening the need for manufacture with virgin, non-renewable resources, which saves precious resources, energy and cost. Waste materials that would have ended in landfills after its useful life, instead can be reprocessed for use in other products. Use of number of waste materials such as fly ash, blast furnace slag, red mud, waste glass, marble dust, cinder, rice husk, coconut husk, banana leaves, jute fibers, rubber from automobile tires, etc. is demonstrated by research. Table -4 specifies guidelines for rating R_3 for this criterion.

Table-4 Rating R_3 for % of Recycled/Waste Materials Used

% of Recycled/Waste Materials Used	R_3
91 - 100 %	20
51 - 90 %	15
21 – 50 %	10
1-20 %	5
No use of recycled/waste materials	0

iv) Use of renewable resources

Materials manufactured with resources that are renewable (i.e. wood or solar power) rather than non-renewable (i.e. fossil fuels) shall be preferred. Depletion of the earth's resources is occurring at an alarming rate. Entire ecosystem is affected due to continuous extraction of raw materials from the earth. As stock of fossil fuel is limited, it will be exhausted very soon. By utilizing renewable energies, such as wind, solar, tidal, as well as renewable materials, such as wood (certain certified species which are rapidly renewable), grasses or sand, impact on biodiversity and ecosystems can be lessen.

Table-5 Rating R_4 for use of renewable resources

Use of renewable resources	R_4
Use of renewable energy or materials by > 50% of the total requirement	10
Use of renewable energy or materials by < 50% of the total requirement	5
No use of renewable energy or materials	0

v) Contribution in Energy Efficiency of buildings

Construction and operation of buildings utilizing major portion of total energy produced. With little careful efforts, designers and builders can reduce energy loads on structures, reducing energy requirements and the strain on natural resources. With proper orientation of building with reference to solar radiation to receive maximum day lighting, operable windows for natural cross-ventilation, use of passive cooling techniques, (eliminating or lessening the need for air conditioning), walling unit with lower U values, roof insulation, water-saving devices and more efficient appliances can all work to lessen energy needs. Consideration of alternate energy source use, such as wind, solar and tidal power, can help alleviate reliance on traditional fossil fuel sources. Bureau of Energy Efficiency (BEE) has been set up by Govt. of India, who has formulated Energy Conservation Building Code (ECBC), which is defining certain minimum energy performance standard for buildings. ECBC specifies minimum values for U-factor(U-factor is thermal transmittance which is the rate of transfer of heat through unit area of a structure for unit difference in temperature across the structure., unit is W/m^2-°C), Solar Heat Gain Coefficient (SHGC - the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space) and Visual Transmittance(VT – it indicates percentage of visible portion of solar spectrum that is transmitted though a given glass)) with guidelines to be Table 6 specifies guidelines for rating R_5 for this criterion.

Table-6 Rating R_5 for contribution in Energy efficiency of buildings

Details	R_5
Materials conforming to ECBC guidelines for U-factor for Wall, roof and windows including SHGC/Visible transmittance values for glass	10
Materials not conforming to ECBC requirements	0

vi) **Recyclability of materials**

The recyclability of the materials can be judged from quantity of materials recovered for reuse after the useful life of materials/products or after demolition of the building. Table - 7 specifies guidelines for rating R_6 for this criterion.

Table-7 Rating R_6 for use of recyclability of materials

% of recyclable material recovered	R_6
> 50	5
< 50	3
Not recyclable materials	0

vii) **Durability**

Materials which are long lasting and needing little maintenance are preferred. Material replacement puts a strain on the earth, its resources and inhabitants. In making materials more durable and easy to maintain, manufacturers can help in eliminating a costly, damaging and time-consuming process of replacement. Rating R_7 for this criterion can be considered as mentioned in Table-8

Table-8 Rating R_7 for Durability of materials

Materials life in years	R_7
> 75	5
75 – 25	4
25 - 5	3
< 5	0

viii) **Environmental Impact**

All materials used for construction of buildings must not harm the environment, pollute air or water, or cause damage to the earth, its inhabitants and its ecosystems during manufacturing process, use or subsequent disposal after end of life. Material should be non-toxic and contribute to good indoor air quality. Worldwide industrial production uses billions of tons of raw materials every year. Pollution caused in excavation, manufacturing, use or disposal of a product can have far reaching consequences on the Earth's ecosystem. Poor indoor air quality caused by VOC emission costs billions in medical bills and lost productivity to companies every year. The manufacturing, use, and disposal of PVC pose substantial and unique environmental and human health hazards because of its uniquely wide and potent range of chemical emissions throughout its life cycle. It is virtually the only material that requires phthalate plasticizers, frequently includes heavy metals and emits large numbers of VOCs. In addition during manufacture it is responsible for the production of a large number of highly toxic chemicals including dioxins (the most potent carcinogens measured by man), vinyl chloride, ethylene dichloride, etc. When burned at the end of life, whether in an incinerator, structural fire or landfill fire, it releases hydrochloric acid and more dioxins. Products made with PVC may be avoided as far as possible. Following points should be considered for evaluating environmental impact of the building materials, allocating rating R_8.

Table-9 Rating R_8 for Durability of materials

Factor to be considered	R_8
Manufacturing process, care taken for preventing pollution of air, water and land, waste generation, care taken for workers health, etc.	Allot points from maximum 10 from qualitative assessment of all factors
VOC content less than 5 g/m^3	5
Presence of hazardous compounds such as heavy metals, PVC, etc.	-5
Disposal : Biodegradable	5
Non biodegradable	0

Classification of materials based on scale:

After evaluating the material for above mentioned criteria and allocating points for rating R_1-R_8 , totaling maximum to 100 points, materials can be classified based on total points scored, as per following guidelines:

Table 10 Classification of materials based on scale

Total Points Scored	Classification	Remark
> 70	A	Total Green Material
70-30	B	Intermediate materials
<30	C	Not a green material

Using the criteria some of the materials are classified assuming certain data as mentioned in Table-11.

Table -11 Classification of the materials

Materials	R1	R2	R3	R4	R5	R6	R7	R8	Total	Classification
Bricks	08	18	00	05	10	00	05	10	56	B
Flyash Bricks	08	20	15	05	10	00	05	15	78	A
Coarse Agg.	05	20	00	00	10	00	05	12	52	B
Steel	05	02	00	00	00	05	05	13	30	B
Cement	00	15	00	00	10	00	05	10	40	B
Plywood	00	15	00	00	10	03	04	12	44	B
Glass	00	10	00	00	00	03	03	12	28	C
Recycled Agg.	08	20	20	00	10	05	05	15	83	A
Aerated Concrete block	08	18	15	05	10	00	05	15	76	A

Conclusions:

There is a need for standardized procedure for evaluting the green materials. A scale has been suggested for this purpose. However, a lot of standardied data to be generated for the parameters such as emodied energy of some traditional building materials, U-factor of the materials, VOC content of some of the materials like paints, wood based productes, carpets, etc., to use the scale effectively.

References:

i) Alternate Building Materials and Technologies by K. S. Jagdish, B. V. Ventkarama Reddy & K. S. Nanjunda Rao, New Age International Publishers

ii) Draft Eenergy Conservation Building Code, published by Bureau of Energy Efficiency.

iii) Embodied Energy Computations in Buildings by Krishnakedar. S. Gumaste, Journal of Advances in Energy Research (AER – 2006).

iv) Embodied Energy of Building Envelopes and its Influence on Cooling Load in Typical Indonesian Middle Class Houses by Agya Utama and Shabbir H. Gheewala, 2nd Joint International Conference on "Sustainable Energy and Environment (SEE 2006)" 21-23 November 2006, Bangkok, Thailand