International Journal of Advanced Technology in Engineering and Science
Vol. No.3, Special Issue No. 01, November 2015
www.ijates.com
ijates
ISSN 2348 - 7550

SIGNIFICANCE OF EMBODIED ENERGY AND U-VALUE IN GREEN BUILDINGS: AN OVERVIEW

Anwar Hussain

Assistant Professor, Architecture Section, University Polytechnic,
Faculty of Engineering and Technology, AMU, Aligarh, (India)

ABSTRACT

The Building materials have a very important role in construction industry. The increase in use of building materials has high environmental impact because of which it has become a matter of concern. To make the development sustainable, the energy issues should be checked at all parameters. Making green buildings is one of the solution for promoting sustainable development. Green materials play an important role in making buildings sustainable. This paper aims to review the important properties of green materials and the significance of their embodied energy and U-value to optimise the energy resources. This paper also highlights the alternative materials and different assemblies having low U-value.

Keywords: Green Buildings, Green Materials, Embodied Energy, U-Value

I. INTRODUCTION

The process of development brought the revolution in the construction industry and this has incurred many new innovations and advancements in the building materials industry also. These new developments are accompanied by some serious environmental impacts. The rising concern in energy areas gain the attention of building materials also, as construction industry alone contributes 22% of total carbon emission. Building materials form the envelope of the buildings and hence influence the indoor environment. Also it contributes to energy usage right from the extraction –usage and finally demolition.

Buildings that uses less /optimises energy are Green buildings. Out of many factors that make a material green, the two important one are –embodied energy and U-value. Embodied energy contributes to capital energy and knowledge of U-value helps to optimise the energy usage for heating and cooling loads. The knowledge of Embodied energy and U-value helps the Architects to choose and analyse different materials.

II. GREEN BUILDINGS

“Green Building” is the one that considers and also reduces its impact on the environment and human health. It is also termed as “high performance building”. Making a building green does not mean only to assemble green technologies and materials, but it is an entire process related to the Life Cycle of building [1]. Firstly the design has to be optimised, in all senses and then its impact and relationship between the different systems (both inside and outside the building) is optimized to obtain a Green solution.

Various organisations are working at national as well as international level to reduce the environmental impact and achieve green building solution. To name a few, there are organizations like USGBC, LEED, IGBC, GRIHA, TERI, BEE etc. which are actively involved in the process.

2.1 The Five Elements of Green Buildings

In general, the Green buildings are worked upon in five basic categories, which can be read as;

Sustainable site planning, Water and waste management strategies, Optimized energy performance, Indoor environmental quality, efficient materials and construction practices [2].

1.1.1 Sustainable site planning

Sustainable site design includes the usage of existing topography on site. It is very important that the site should be preserved in its natural setting, including the existing vegetation. Besides this, the employment of existing topography will also prevent the harmful effects caused by landfills. Proper balance should be achieved between the open and build spaces during the site planning. The aim of design should be to facilitate public transport, which would in turn help in saving the environment by reducing the private vehicles on road. Storm water management is another important issue in this category. Scarcity of proper vegetation and rain water collection on site results in soil erosion and loss of valuable source of water. Unmanaged site designing, containing too much of build up space without giving due concern to open spaces and soft landscaping can lead to “heat island” effect.

1.1.2 Water and waste management strategies

Water is one of the important natural resources. It is important to conserve water and manage the waste water. The water from rain is the best quality water that can be preserved through rain water harvesting techniques. Waste water in the form of grey water can be converted to usable water for washing, flushing and landscaping purposes, after some treatment. The sewage systems should be on site and sewage treatment plants can also help in managing waste water. Reuse and recycling are the important tools to conserve and save water.

1.1.3 Optimized energy performance

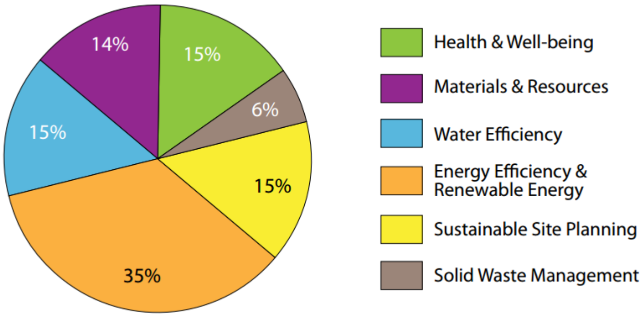
The promotion of renewable sources of energy is an appropriate method of saving energy from fossil fuels, which is being spent at a fast rate. There is an emergent need to reduce the usage of chlorofluoro carbons and other such agents, because they are causing the depletion of ozone layer and are responsible for global warming. The renewable sources of energy provide an unlimited alternate source of energy and their usage still needs to be examined on a large scale. The energy from sun, wind and water can be utilized for various purposes. The solar photovoltaic panels, solar heaters, wind mills, hydroelectricity are some of the known means of energy utilisation.

1.1.4 Indoor environment quality

The green buildings are also concerned about the indoor environment quality. The major areas for consideration are improved ventilation in the building interiors. This will help improving the indoor air quality of the buildings. The green buildings focus on the optimization of HVAC systems. The energy required and the waste produced, the recycling of water etc. are some of the important considerations being employed by the planners. The building interiors are to be proposed with low VOC paints and finishes to maintain the air quality and create a harmless environment.

1.1.5 Efficient materials and construction practices

The green buildings employ materials with distinguished qualities of saving energy. The green materials are used in the buildings. The embodied energy of the materials is considered before its adoption. Reusability and recycling of the building materials after the useful life of material is overshould be taken into account at the time of planning. Use of agriculture based materials is also important. Local building materials and techniques of construction save energy.



Source-Majumdar,M.(2008).TERI

Fig. 1 -Weighing of various criteria as per GRIHA

III. GREEN BUILDINGS VS. CONVENTIONAL BUILDINGS

The green as well as conventional buildings may look alike externally and same on the functional basis but there is a lot of significant difference in terms of operational cost and concern for human comfort and indoor environment. The benefits of green buildings can be measured in two ways; tangible and intangible benefits. The tangible benefits can be counted in terms of Energy saving from 40-50% and Water savings from 20-30%. The intangible benefits are health and safety concern, enhanced occupant comfort and improved productivity of occupants etc. The initial cost of green buildings may be slightly high but it results in long term savings, in terms of operational cost and health concern. Most green buildings cost a premium range of 2-20%in India but yield 10 times much over the entire life of building. The saving comes from optimum use of resources which results in decreased bills [3]. Some of the examples of buildings and their energy savings are:

Table 1. Performance of green buildings in India

S. No.	Buildings	Built-up Area (ft^2)	Rating of Green Building	% increase in cost	Pay back (years)
1	CII, Godrej, Hyderabad 2004	20,000	Platinum	18%	7
2	ITC, Gurgaon,2004	1,70,000	Platinum	15%	6
3	Wipro, Gurgaon,2006	1,75,000	Platinum	8%	5
4	Technopolis, Kolkata,2006	72,000	Gold	6%	3
5	HITAM, Hyderabad,2007	78,000	Silver	2%	3

Source –CII, India

IV. GREEN BUILDING MATERIALS

The materials used in building construction industry have high environmental impact due to uncontrolled use of resources, consumption of energy and waste generation during extraction, use and demolition. On the contrary, the building materials should be non-polluting, local and recyclable. A green building material is one that simultaneously does the most with the least energy, fits harmoniously with eco-system and contributes to the service based economy. It is about to set the balance in nature and in the economy. The context in which a material is used is crucial point of decision making process. A green material may be employed or installed in destructive ways that completely negate their positive characteristics. By being salvaged and reused, a very conventional material can become green material [4]. There are a few criteria, which are commonly used in the selection and evaluation of building materials. These criteria can be listed as follows:

- Low Embodied energy of the material.
- The pollution caused by the material and waste generated during its usage and after use.
- Local availability of material and the techniques employed.
- Reusability and recyclability of materials.
- Proper waste management on site.
- Motivate the use of suitable alternative materials, which are eco-friendly.
- Performance of the material in terms of structural, indoor air quality and thermal comfort.
- Contribution to community development.

The selection of appropriate material lies totally on the wisdom of designer and the innovating construction techniques.

V. ENERGY ASSOCIATED WITH BUILDINGS

Energy is associated with each and every activity performed in the building construction. The environmental changes are measured in terms of CO_2 generation (Green House Gases i.e. GHG). Building industry is responsible for a lot of such emissions. In U.S. the building industry is responsible for 39% of CO_2 emissions in comparison to 29% from industry and 33% in transportation. The buildings alone consume 70% of electricity load in U.S.[5]

In India, total energy consumption in manufacturing the building materials by 2020 is estimated to be 5000 x 10^6MJequivalent of 150 x 10^6 t of coal. In India building industry contributes to 22% of total CO_2 emission [6]. An approach to reduce the CO_2 contribution of building industry is to use and promote the materials with low embodied energy.

VI. ENVIRONMENT CONCERN

The concern for environment has certain goals which have to be achieved by management of energy. The objectives that come out from various summits and conferences all over the world can be summarised as follows-**GHG emission reduction, Energy conservation/ Conservation of resources and Reducing the Carbon foot print.**

Different organisations are working all over the world at different levels to target these objectives. Various points/credit systems have been generated like LEED, GRIHA, ASHARE etc. to rate the buildings based on actual performance.

In India BEE has developed ECBC norms for building (Table 2) that helps to reduce/check and hence to optimise the energy usage [7]. The building performance is evaluated after one year of occupancy based performance. Energy performance Index in kwh/sq. m/year is considered for rating the buildings.

Table 2. ECBC norms for Building

ECBC Compliant Design Strategy for a Building			
Heat/Moisture Losses	**Walls**	**Roof**	**Window**
Minimise Conduction Losses	Use Insulation with low U-value	Use Insulation with low U-value	Use Material with low U-value
Minimise Convection Losses and moisture Penetration	Reduce air leakage and use vapour barrier	Reduce air leakage and use vapour barrier	Use prefabricated window and seal the joints between windows and walls
Minimise radiation Losses	Use light colored coating with high reflectance	Use light colored coating with high reflectance	Use glazing with low Solar Heat Gain component

Source-BEE, India

VII. BUILDING DESIGN AND BUILDING ENVELOPE

Case studies have shown that following the ECBC norms, resulted in EPI reduction from 240 kw/m2/year to 98kw/m2/yearin IIT, Kanpur and 605 kwh/m2/year to 312kw/m2/year.in Fortis, New Delhi.

Increasing the building performance is a result of joint effort from all the stakeholders of building industry- Architect, Mechanical and Electrical Engineers etc. The building envelope plays a very important role in reducing the EPI of a building. In other rating systems also the building envelope holds significant position. The building envelope constitutes of building materials and their assemblies. In the above mentioned buildings, only by controlling the architectural design criteria(envelope and optimization of lighting) contributes to lowering the EPI of 72 and 129 units respectively [8].

The envelope of the building is mainly responsible for the insulation of buildings. By providing proper insulation, the energy performance of the buildings can be optimised. Out of the enormous properties of building materials that lead to green and sustainable buildings, **Embodied Energy** and **U-value** of materials are two important criteria's from energy point of view.

VIII. EMBODIED ENERGY

Embodied energy is defined as the energy used to draw raw materials, convert them to usable projects, transportation of raw materials as well as products and build them into structural forms. It lies totally on the wisdom of designer as to what combination is selected. Aluminium has the highest energy and cement the lowest. The aim should be to use materials with less embodied energy.

8.1 Materials Used in Bulk Quantities

Some of the common building materials employed in building construction are burnt clay bricks, cement, steel, aggregates and sand. The annual consumption of these building materials is likely to be doubled by 2020. Hence, the amount of energy associated with the production and processing of these materials can be estimated(Table -3) [9].It is an alarming situation and needs attention today.

Table 3. Consumption Predictions of Building Materials

Type of material	CurrentAnnual Consumption	Annual Consumption by2020
Burnt clay bricks	170×10^9 Nos.	246×10^9 Nos.
Cement	110×10^6 t	255×10^6 t
Structural Steel	12×10^6 t	25×10^6 t
Sand	300×10^6 m^3	750×10^6 m^3

Source [9]

8.2 Calculating the total embodied energy of building types

Table 4-Energy in basic building materials

Type of Material	Energy MJ/kg
Cement	4.5
Lime	5.63
Lime-Pozzalana	2.33
Steel	42.0
Aluminium	236.8
Glass	25.8
Mangalore Tile	6-15 per tile

Source [9]

Table -5 Energy in Production and Transportation [9]

Type of Material	Unit	Energy in (MJ)		
		Production	Transportation	
			50km	100km
Sand	m^3	0.0	87.5	175
Crushed aggregate	m^3	20.5	87.5	175
Burnt clay brick	m^3	2550	100	200
Cement	Ton	5850	500	100
Steel	Ton	42,000	50	100

Source [9]

Table -6 Energy in Different Roofing Systems

For Span of 3.6 m

Building roof type	Energy/m2 of roof (plan) (MJ)
Composite beam-panel roof	500
R.C. ribbed slab roof	556
Brick masonry vault roof	601
Soil-cement block masonry vault	469
Ferrocementpanel roof	111
SMB filler slab roof	686
Mangalore tile roof	221
R. C. roof	847

Source [9, 10]

Table -7 Total Embodied Energy in a Building

Type of building	No. of story & built-up area	Embodied energy per $100m^2$ (GJ)	Equivalent amount of coal (tonnes)
R. C. frame with brickin-filled walls	8 5120 m^2	421	21
Load bearing brickwork, R.C. slab, Mosaic floor	2 149.5 m^2	292	15
Soil-cement block masonry, filler slab, terracotta tile floor	2 160.5 m^2	161	8

Source [9, 10]

Conclusion-A knowledge of this analysis will help the designer to select the appropriate building material.

IX. U-VALUE

U value is the inverse of thermal resistance of each building material.

U=1/R, units for measuring U-value W/m^{2}K

In case of assemblies the total U value is the inverse sum of the resistances of each material and surface resistance of the outer and inner surface of the assembly.

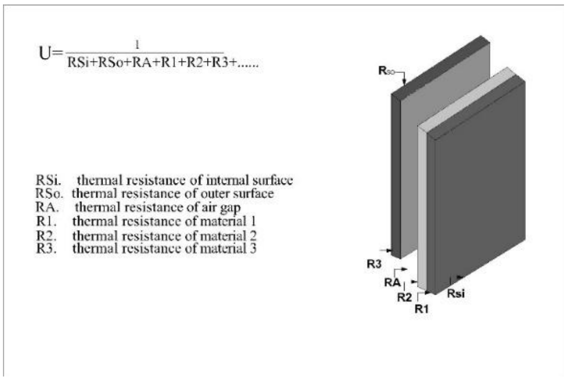


Fig.2- Calculation for U-value

U value is a measure of heat loss in a building element such as a wall, floor or roof. It can also be referred to as an ‘overall heat transfer co-efficient’ and measures how well parts of a building transfer heat.A low U-value usually indicates high levels of insulation.

A U-value of 1 W /(m^2 K) means a 1 meter square area of the material with 1 K temperature difference across the material will conduct heat at a rate of 1 joule per second.

9.1 Importance of U-Value

- U values are important because they form the basis of any energy or carbon reduction standard.
- Knowledge of how to simply calculate U values at an early stage in the design process, avoids expensive re-working later on in a project.
- It allows the designer to test the feasibility of their project at an early stage to ensurethat it is fit for purpose and will comply with regulatory frameworks.

Insulating the envelopes helps a lot to lower the U value of the surfaces of the envelopes. Architects need to know how well different materials willinsulate the buildings they design. To help them with this, they need to know the U-values of different materials.**U-values** measure how effective an insulator is. The lower the U-value the better the material is at insulating properties.

9.2 The Ideal Approach to Control U-value

After understanding the various components that contribute towards heat gain in a building, the plan for reducing this value, is also to be studied. There are various elements that can be worked upon to control the value and a systematic approach has been adopted as follows[11]:

a) **Orientation**

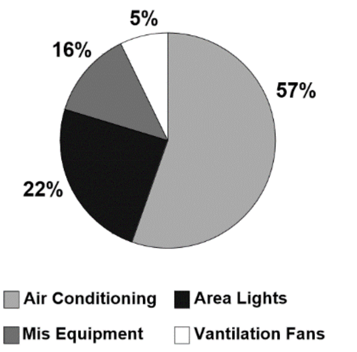
b) **Envelope measures** *Wall, Glazing, Fenestration, Shading, Skylighting, Roof*

c) **Equipment & systems** *Chiller,VFD,Lighting*

d) **Controls** *BMS,Temperature,Humidity*

e) **Commissioning**

These are 5 areas having scope ofcontrolling the U-value. Out of these, the orientation and envelope measure are related to architectural works and the rest are MEP.



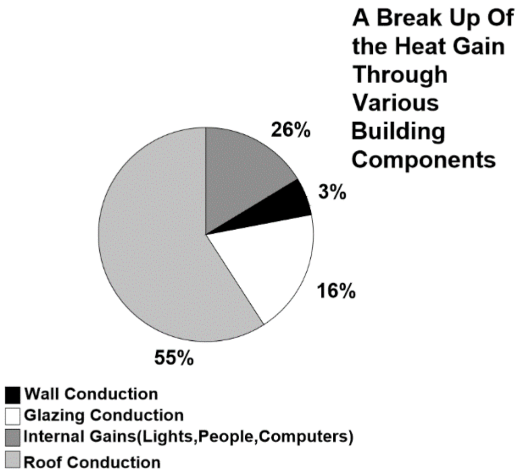


Fig. 3-Building Energy consumptionFig.4 - Cooling load components [11]

Source[11] *Source[11]*

A discussion about the architectural approach is as follows:

9.2.1 Orientation

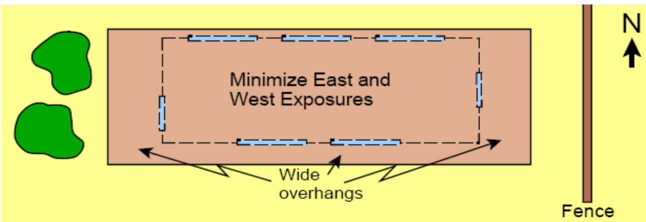


Fig. 5-The suggested orientation

The best orientation of building is to be decided upon the site considerations and climatic conditions

The solution lies in intelligent placement of various activities. Buffer EastandWestExposureswithgarages,utility rooms etc. are suggested.

- Saving potential: 2-3 % for 90%rotation

9.2.2 Envelop Measures

A -Walls and Roofs

The walls and the roofs provide medium for heat transfer by conduction/radiation. In this case better insulation of walls and roofs will help to optimise the energy usage for a comfortable living.

U value for uninsulated exposures are as follows [12]:

RCC Walls 1.95W/m2degK

Concrete Roof 2.5– 3.0W/m2degK

This can be improved by different insulating options like-

- Brick wallwithinsulation *(*Extruded polystyrene, Expanded polystyrene, Glass wool etc.)
- Brick wallwithaircavity
- Interiorgypsumorplaster
- Hollow blocks
- Fly ash bricks
- AutoclavedAeratedConcrete Blocks

Anumber of insulating materials are available in market. Careful decision is to be taken for choosing /designing proper assemblies-

U values for few insulating materials are as follows [12]:

- Glass wool stuffed :0.25 W/m2 .C (150mmthick)
- Thermocol : 0.3W/m2.C (100mm)
- Extruded Polysterene : 0.028 W/m2 .C(60 mm)

In case of roof, insulation may be provided over-deck / under-deck or may be sandwiched

The decision of roof insulation is to be taken:

- Saving potential 3-8%

B-Windows and Glazing

In case of windows and glazing the important factors that require attention are like -function to be performed inside, how much glazing, tremendous day lighting, Heat ingress etc.

There is a need to balance the following:

LowU-value, Low Shading Coefficient, High VLT (Visual Light transmittance)

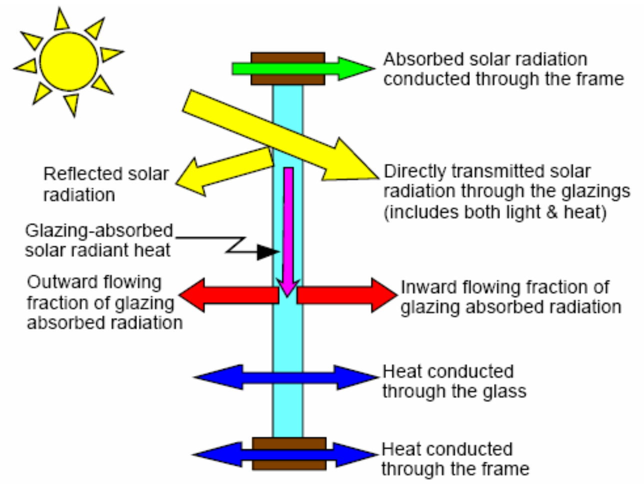


Fig.6-Heat Flow through Window

Source[11]

- In this case heat gain is by two mediums – gain through glass and gain through frames.

Conductive heat gain 10%

Direct heat gain 90% (this component is called Solar Heat Gain Coefficient-**SHGC**)

Hence U value of both the elements are important-Glass and Frames.

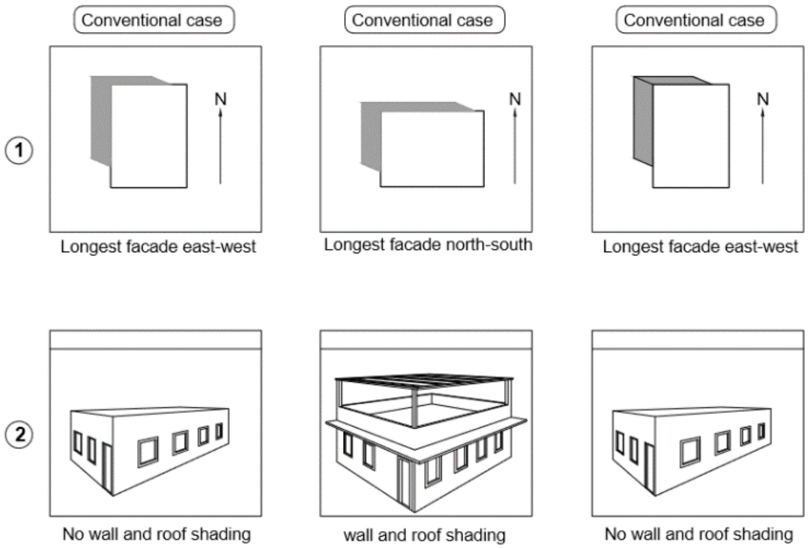
*Typical U values*are [13]-

- Singleglazed glass(6mm):5-6
- HighPerformanceglass:1.7– 3.0 (6mm+airgap+6mm)

SHGC Typical values are[13]-

- Singleglazed6mmglass :0.5– 0.8
- Highperformanceglass :0.1– 0.4

Building design-plan/orintation



Building Envelope

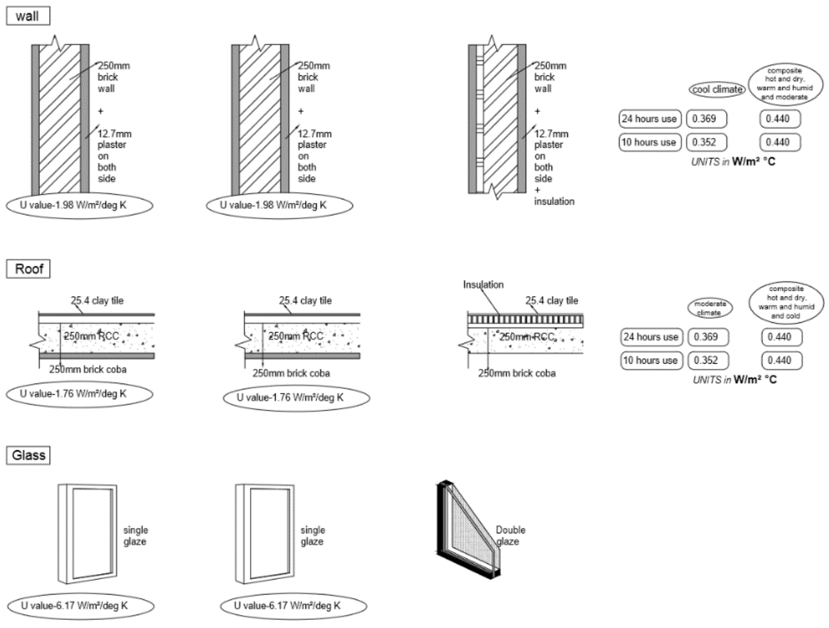


Fig. 7 - Building Design recommendation by ECBC

Source [14]

X. CONCLUSION

A variety of building materials are available in the industry. The choice of building material lies on the wisdom of designer which he has to take keeping in view the capital energy, maintenance energy, cost, social factors etc. The knowledgeof embodied energy and U-value of the materials helps to reduce the CO_2emission levels.Different assemblies of materials are also employed for lowering the U value and for better insulation. This helps in reducing the heating and cooling loads of the building.

The choice of vernacular materials and techniques contributes a lot for making buildings Green. A variety of materials produced from waste (fly ash, rice husk etc.) can be employed to reduce the energy usage. Life Cycle Assessment of Building Materials should be studied.

Organisations like TERI, BEE, IGBC, are providing guideline /manuals to design the buildings, to make them green and reduce the carbon emission. HUDCO and BMTPC are involved in research activities in developing energy efficient sustainable building materials (AAC blocks, cement paints, low VOC paints etc.).

Applying these information, an Architect can choose building materials as per need and function and suggest to make a building green that uses less energy. After all energy saved is energy produced.

REFERENCES

[1] Yudelson.J, “Green buildings through Integrated Design” (McGraw Hill), 2009

[2] Majumdar, M. (2008). An assessment of LEED-India NC and GRIHA Version 1, presented to the Ministry of New and Renewable Energy, Government of India.

[3] Garg.A.K“Financial Aspects of Green Buildings”, Journal of Engineering, Science and Management Education/vol4,2011/12-15.

[4] Hussain.A.,“Energy efficient sustainable building materials”,M.Arch thesis,2012.

[5] Project proposal on “Energy efficient and renewable energy sources in India”, Development Alternatives, New Delhi, 1995.

[6] http://www.eesi.org/

[7] https://beeindia.gov.in/

[8] Project document “Energy efficiency improvements in commercial buildings”,UNDP India, agreed by BEE,2011

[9] Reddy.B.V.V., “Embodied energy in Buildings”,ppt

[10] Reddy.B.V.V.,“Sustainable building technologies”, Current Sciences,Vol 87,No 7,10,oct 2004

[11] http://www.cii.in/,“Energy efficiency through Green building concepts”, ppt

[12] “Bulletin-Building insulation”,IGBC,CII,April 2008

[13] “Bulletin-High performance Glass”,IGBC,CII,April 2008

[14] Manual “High performance Commercial buildings in India”-projects findings supported by BEE and US Dptt of State.