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Review of Climate Responsive and Sustainable Building Materials

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ABSTRACT

Buildings are found to account for 40% of total primary energy in most of the countries. The local climatic conditions have major effect on the thermal performance of the building and its energy consumption pattern. Reducing the use of artificial sources of energy and use of natural resources providing comfortable, healthier and sustainable indoor living space is the objective of climate responsive sustainable buildings. These features seem to be missing in modern building designs and hence these are therefore criticized for lack of sustainable building design. The conventional building materials utilized in modern cement concrete buildings do not respond the extremities of the climate and hence are unsuitable from energy efficiency and self sustainability point of view. Lot of energy and hence the CO_2 emissions are serious environmental concerns during fabrication/ production of such building materials. In the present paper different building materials have been analyzed from their suitability for energy efficiency point of view. Based on the analysis it has been found that the locally available building materials like mud, wood, stone etc. are more energy efficient than modern building materials like cement concrete, brick, steel etc.

Key words: Traditional building, Modern building, Thermal Transmittance, U – value,

Introduction

Energy and environment are major concerns for the society. With the increase in world population, and rapid development and globalization the energy demand is increasing at a rapid rate. In the recent years the rate of consumption of energy has increased manifold. Common consumers of energy are industries, transport and buildings. At present, most of the required energy is derived from fossil fuel based sources such as coal, petroleum and natural gas. As per world energy scenario more than 85% of total energy demand is met from fossil fuels (BP Statistical Review of World Energy, 2019) [1]. As a result pressure on resources of fossil fuels has been increased. Moreover, the fossils fuels are likely to be exhausted within few decades. On the other hand with the increased awareness on the ill effects of use of fossil fuels on the environment, a trend has been noticed worldwide in the use of clean and renewable energy (Ingvar B. Fridleifsson, 2003) [2].

It is observed that energy consumption worldwide has grown by 2.3% in 2018, which is nearly double the average rate of growth since 2010, mostly driven by a use of heating, cooling and ventilation needs in some parts of the globe. The higher energy consumption has led to increased CO2 emissions which stands at 33.1 Gt CO2, higher by 1.7%. Thermal power based on Coal-fired power is the single largest emitter at 30% of total carbon dioxide emissions (Global Energy & CO2 Status Report, 2019) [3].

The pattern of energy consumption is usually classified into three main sectors: industry, domestic, agriculture and others, which include commercial, traction & railways etc. At present the residential and commercial sector is accounting for 30% of total electricity consumption and it is rising at a rate of 8% per annum.This sector include all commercial and public buildings, which also include schools, restaurants, hotels, hospitals, etc. with a wide variety of uses and energy services Heating Ventilation and Air Conditioning (HVAC), domestic hot water, lighting, refrigeration, food preparation, etc.. The increasing population has also resulted in increased demand for energy for buildings (Nagaraju Kaja, 2017) [4].

As per World Business Council for Sustainable Development, 2009; the buildings are responsible for 40 percent of primary energy use in most countries. According to International Energy Agency estimate (2008) the current trends in energy demandwill catalyse approximately half the energy supply investments by 2030 for buildings. The rise of energy consumption and emission of CO_2 in the building environment has forced us to made energy efficiency and energy saving a priority objective for energy policies in most countries (*Lombard et al 2008*) [5].

The Air Conditioners and electric fans consume about 20% of the total electricity consumed in buildings globally. The demand for energy supply is rising further for space cooling and is putting huge pressure in electricity systems resulting in increased emissions. The global demand for space cooling and hence the demand for energy would grow in the coming years (IEA, 2018) [6].

The passive properties of the mud/ earth mass provided warmth in winters, and coolness and shade in the hot summers. It was observed in many cases that the location of caves was chosen as per understanding of the Sun's movement. These were oriented to get maximum sunlight in winters and shading in summers. The cave dwellings of Mesa Verde are especially noteworthy and best examples in this respect. Another such example of the use of earthen insulation in extreme climates can be seen in the subterranean settlement of Honans in China. The settlements were deep dug into the ground up to 10-15 meters with proper arrangements for lighting and staircases. Both of these examples demonstrate the knowledge of indigenous people about the principle that the mass of earth below the surface has the characteristic to retain temperatures close to the yearly average, which provide relative warmth in winter and coolness in summer. This principle has been utilised by local traditional communities in designing and constructing their dwellings (Nayak J.K. et al, 1999) [7].

Traditional buildings have many built in features which are providing indoor thermal comfort with minimum dependence on auxiliary heating/ cooling. Such buildings are climate responsive and are designed to take optimum benefit of the surroundings. On the other hand the modern buildings do not respond to the climatic conditions and a lot of auxiliary energy is required to achieve a condition of indoor thermal comfort in such buildings. However, the modern buildings are aesthetic having a magnificent exterior and indoor thermal comfort is controlled through artificial devices. A huge amount of energy is consumed in such building. The present paper is providing an insight into energy efficient self sustainable building material.

2. Review of Literature

The Energy costs for producing and transportation of building materials have been minimized by using locally available construction materials. As explained above, these houses are perform better in terms of energy efficiency and thermal comfort to the inhabitants. Such traditional houses are vernacular and sustainable providing best components for sustainable built environment. Hence, vernacular settlements could be seen as an opportunity for sustainability and an inspiration to professional and designers (Halıcıoğlu F.H, 2012) [8].

The phase change thermal energy storage materials which have large latent heat and high thermal conductivity should be used for passive solar design (Cabeza L.F, 2011) [9]. It is a basic principle that the adequate use of thermal energy storage materials and systems in the building designs and industrial sectors have rich potential in terms of energy conservation. Such thermal energy storage systems in a building set up have the capability to increase the energy efficiency and reliability and at the same time it can lead to economic efficiency as well. As such buildings can payback the amount utilised in investment of thermal systems in the years to come. Besides, less carbon emissions, less pollution add to the advantages of such systems (Gracia and Cabeza, 2015) [10].

There are different types of architectural built forms on the laps of Himalaya in the city of Shimla, the capital of Himachal Pradesh, India. It was started from the Scottish Baronial style in the time of British rule – when Shimla was chosen as the summer capital of India, followed by the traditional vernacular styles, coming up with the New-Tudor style and in recent times with the Modern Architectural style. However, the raw building materials used for all of these styles are stones, timbers, batten boards and glass. Extensive use of stone and wood makes the built form to be sculpted out from the hills itself to balance the settlement of the built forms with the nature making it harmless for the hills. Use of locally available materials and adopting local construction techniques are more responsive to the climate and geographic conditions (Chatterjee Rajroshi et. al, 2017) [11].

The selection of building materials plays a very important role in the energy efficiency and thermal performance of a building. It is observed that in most of the buildings single glazed windows with poor air sealing have been used. These buildings also lack in insulating properties. The thickness of external walls is not as per climatic specifications. The conclusion is that choice in selection of building materials is very poor resulting in climatically non responsive buildings requiring a lot of artificial energy for maintain a level of indoor thermal comfort. The existing buildings are a copy of inadequate design pattern with single pane glasses, poor insulation and air leakages. However, the energy efficient sustainable buildings demand site specific appropriate building materials. Sustainable buildings have good thermal performance have features of energy efficiency, air quality, besides these have goods aesthetics. The important factors while selecting appropriate building materials are climatic considerations, eco friendly, strength, durability, availability and cost effectiveness. Use of recycled materials can also be exercised. While designing such sustainable designs innovation is required for products for building, and local communities. Economics of the construction materials is important is selection of the materials. One of the better options is to have Green roofs which can provide thermal insulation as well as reduce urban heating effect, at the same time it can provide ecologically important environmental features (Garg Neeti et al, 2018) [12].

3. Thermal Properties of Building Materials

U value (transmittance value of building materials) - Thermal transmittance, or U – value of the materials is the rate of heat transfer through these materials divided by the difference in temperature across that structure. The materials can be composite or uniform in nature. The U values are measured in W/ m^2K. The lower the U value is, better insulated the structure will be.

Materials with low U values are best suited in Passive Solar Housing. The traditional buildings are built using locally available materials like mud, wood, stone etc and are therefore thermally more stable.

Table: U values of building materials – In most of the buildings, walls and glazing are responsible for most of heat transfer [13].

Material (Wall)*	"U" Factor (W/m^2-K)
Burnt brick (230 mm)	1.84
Burnt brick (345 mm)	1.47
Concrete block wall (150 mm)	2.66
Sand-stone (300 mm)	2.29
Autoclaved Cellular Cement Concrete block e.g. Siporex (ACCB) (150 mm)	0.73
ACCB (200 mm)	0.58

Indicative U-value for 600 mm thick traditional stone walls is as follows;

Uninsulated walls finished with ‘plaster on laths’	1.1 ±0.2 W/m^2 K
Uninsulated walls dry lined with plasterboard	0.9 ±0.2 W/m^2 K

Generally, an increased wall thickness, and building materials of higher thermal resistance, results in a lower U-value. However, careful consideration needs to be given to establish the actual build-up of the building element as defective areas, building irregularities, ventilated cavities etc. can have a significant impact on the heat flux, at least locally [14]

Conclusion

Traditional buildings across the western Himalayan State of Himachal Pradesh have been constructed mostly using locally available building materials such as stone masonry, mud, wood etc. and are found to be more comfortable thermally in comparison to modern cement concrete buildings constructed at the same site. One such study has been carried out by the author for village Sapni, a remote village in district Kinnaur located at an altitude of 2650 meters above mean sea level. Both types of buildings i.e. traditional and modern buildings have been monitored at this village during winters of 2018. It was found that, at the same location and time period, a traditional building is consuming electric power of 33.4 Kw-h and modern cement concrete building is consuming 75.8 Kw-h of electric power for attaining a level of comfortable indoors [15]. Less energy consumption, for attaining a level of thermal comfort, by traditional building is evidently attributed to the locally available construction material having low U – value. Apart from consumption of more auxiliary energy, the construction materials for modern buildings, during their fabrication, contribute towards CO2 emissions and hence are not eco friendly. On the other hand the local construction materials like stone, mud, wood etc. are eco friendly and such houses with the blend of beauty of mountains look aesthetic.

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