CRITERIA FOR CONSTRUCTING A SUSTAINABLE GREEN BUILDING

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ABSTRACT:

Development of Zero Energy Building (ZEB) is an important issue in the sustainable development planning. The improvement in building thermal comfort passively helps in reducing energy utilization in the building, throughout the year. Different criteria are directly associated in reducing cooling and heating load of building when implement at the time of construction. In this paper the authors have analyzed the available literature on energy efficiency of building and presents detailed study about six important parameters which can be very helpful to construct energy efficient Green Building system.

Keywords: *Green building, insulated materials, thermal conductivity.*

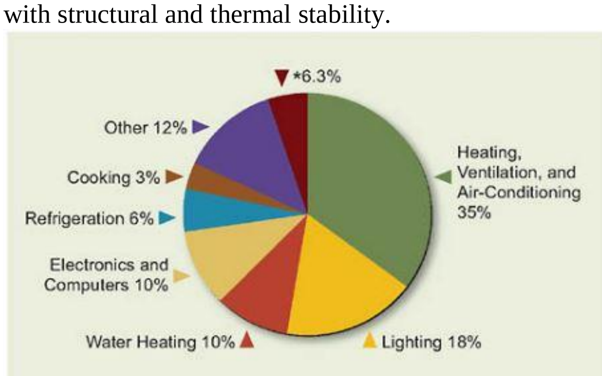
1. INTRODUCTION

Energy consumption in residential and office building has been increased at significant rate. The energy-saving technology in buildings has become one of the focusing points all over the world. Researchers had pen down several solutions, one of the best ways to reconnoiter this problem is to introduce insulated materials into building envelope which will enhance the thermal performance of walls, roof and other parts of building. Thermal insulation materials have low thermal conductivities which can effectively reduce the heat flow through the building envelope and consequently result in the indoor temperature balance.

NOMENCLATURE			
XPS	Extruded Polystyrene	CSIR	Center Building Research Institute
PUR	Polyurethanes	ECBC	Energy Conservation Building Code panels
EPS	Expanded Polystyrene	AAR	autoclave aerated concrete

Both developing and developed countries like India and USA spend a lot of money for thermal comfort of buildings every year, it can be seen from Fig1 that maximum amount of energy is used by both residential and commercial buildings for heating and cooling purposes alone. It is driven by the heat transferred through building walls which is the largest component of energy load for cooling the spaces in building. Any reduction in this cooling load results in reducing the electricity consumption by air conditioner. Therefore, the determination of best insulation material with the objective of achieving acceptable comfort for building occupants with reduced cooling load is imperative. The insulation material also indirectly reduces the release of harmful emissions due to the electricity generation through power plant. A proper insulation of building walls and roof with optimal insulation thickness is an easy solution to reduced cooling/heating load over the lifetime of the building. The cost of insulation installation will increase with thickness, while the cost related to energy consumption in cooling will decrease. Thus the optimal thickness of insulation material should be determined.

There are several kinds of insulation materials commercially available in India, such as fiber glass–urethane, polyurethane-rigid panels, Rice hulls, expanded perlite, cork, foam. Nonetheless, it is a matter of research to choose the best one, in terms of economy with structural and thermal stability.



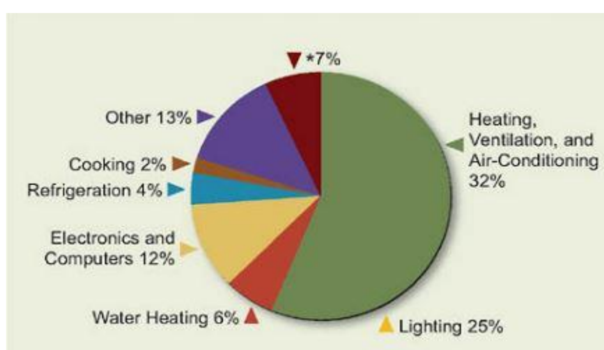


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FIG1: (1) Energy use in U.S. residential buildings by end-use, 2006. (2) Energy use in U.S. commercial buildings by end-use, 2006[1].

2. LITERATURE REVIEW

Protection from extreme cold and heat conditions is one of the basic needs of human being all over the world. Energy and insulations are two major factors for overcoming this problem. Energy has emerged as a critical economic issue and top priority for policymakers. Unsustainable energy supply and demand have serious implications on everything from household budgets to international relations. Buildings are on the front line of this issue because of their high consumption of energy. It is a need to find the parameters for each building during the time of its construction which may reduce its energy consumption rate. One of the techniques to overcome this problem is the incorporation of insulation material in building walls and roof.
In this direction first building was insulated with mineral wool in 1880 in United States of America and from 1970s onwards more effective insulations materials have been discovered and analyzed which are used in building construction in the world[2].
Following 6 factors are directly associated with the thermal comfort of the building.

2.1 Insulation Thickness

The most important factor which is linked with the thermal comfort of building is the insertion of insulated layer thickness in between walls of different material. In this aspect when one hundred and twelve combinations of wall and roof sections have been computed and compared with different thicknesses of insulating materials for determining U-factor and R-value to satisfy ECBC requirements. To validate the results, two prototype buildings are constructed at CSIR shanti nagar campus; one with conventional burnt clay brick wall, reinforced cement concrete roof and 50 mm thick outside thermal insulation and the other without insulation. The results of the winter and summer season for six months are presented. The results show that the wall with 50 mm elasto-spray insulation satisfies the ECBC requirements and for other insulation materials like PUF, EPS, Fiber glass and foam concrete, the required thicknesses is 60 mm, 70 mm, 80 mm and 150 mm, respectively, to satisfy the ECBC requirements. Similarly, in the conventional roof, 50 mm elasto-spray insulation satisfies the ECBC requirements, whereas other insulation PUF, EPS, Fiber glass and foam concrete require thicknesses of 55 mm, 70 mm, 80 mm and 140 mm respectively to satisfy the recommended values[3].
Another mathematical study was carried out by on the thermal performance of insulation thickness using XPS and EPS) insulation on south wall made of concrete, brick, briquette, blokbims and AAC in climatic condition of Elazig, Turkey. In this study, the optimum insulation thicknesses of building walls constructed of five different structure materials and two different insulation materials are investigated by using an economic model under dynamic thermal conditions. The optimum insulation thicknesses of walls constructed of concrete, briquette, brick, blokbims and AAC are obtained as 5.6, 5.3, 5, 3.4 and 2 cm for XPS insulation, and as 8.2, 7.8, 7.4, 5.4 and 3.6 cm for EPS insulation, respectively. Similarly energy saving in $/m² is 98, 67, 48,11,2.7 for XPS and 102, 70, 51,13,4 for EPS[4].
While performing the feasibility study on silica aerogel as insulation for buildings, it is found that Measured values for conductivities (W/mK) of EPS,XPS, acoustic form, Silica aerogol are 0.0258,0.0264,0.0325,0.0145 for 24,24,20,10 mm thickness receptively. The results show the energy efficiency of buildings will be greatly improved and the annual heating costs will also be reduced about 50% when compared with other insulation materials. But, due to such good thermal characteristics of silica aerogel, it has corresponding much higher selling prices than the other insulation materials, and then a much longer payback time has to be taken for silica aerogel[5].
Finally to obtain a optimum value of thickness for different conductivity materials, a study was performed using mathematical formulation, it was found that the optimal thickness of building insulation material, The total resistance of un-insulated wall (R_{wall}) is equal to the summation of the surface resistances of convective heat transfer inside and outside surfaces of the wall and the total internal resistances of all layers of the wall .The study has found that a relationship between the thermal conductivity (k) and optimum thickness (X_{opt}) of insulation material is non-linear which obeys a polynomial function of $X_{opt} = a + bk + ck2$, where a = 0.0818, b = 2.973, and c = 64.6. The results show that the insulation cost would increase while cooling cost decreases, as the thermal resistance of insulation material increases, beyond a certain level, incremental cost will exceed the savings, which means additional thickness of insulation material is not cost effective anymore. they also conclude that using fibre glass– urethane as an insulation material for air conditioner system will save up to $71,773 which is the highest savings among the others materials with almost similar to the thickness of Fiberglass (rigid), Urethane (rigid) and Urethane[6].
Four (3mx3mx3m) cubicles in *RAK Research & Innovation Center*,UAE was constructed in order to perform an open air outdoor test for energy savings obtained with solar insulating materials. The design is aimed to determine the heat flux reduction and the energy savings achieved with and without different solar insulating materials, mounted at the south wall of solar calorimeters with similar indoor and ambient conditions. Experimental results will be discussed to evaluate the thermal performance during summer's peak season when cooling demand of the building is at peak. Duration of the test is from 2012 to 2014. The steady state experimental study shows that if standard building material i.e. concrete is replaced with energy efficient solar insulation materials (like Polyisocyanurate and Exterior insulation finishing system) and reflective coatings, energy saving by coated cubical (ά=0.16) is 7.6%, while with PIR=23% and for EIFS(gypsum+mineral board+EPS)=25.3% due to reduction of heat flux by an average 22-75% at south wall during summer's steady state analysis[2].

2.2 Depth of Air Space

While analyzing the Effect of Air Space Thickness within the External Walls, five building materials studied, among them the cellular homogeneous building materials are the best materials from lowest decrement factor (0.497 at 0.2 m) and highest time lag (5.31 h at 0.2m) perspective. This result shows that while we create vacuum or provide airspace in between building walls and roof, it is possible to reduce the temperature flow in between outer and inner elements of building[7]. From Fig2 it can be seen clearly how cooling load is differ for concrete and AAC blocks in the month of July from $2.7MJ/m^2$ to $0.67MJ/m^2$ respectively. It shows the effect of air space on thermal stability of building.

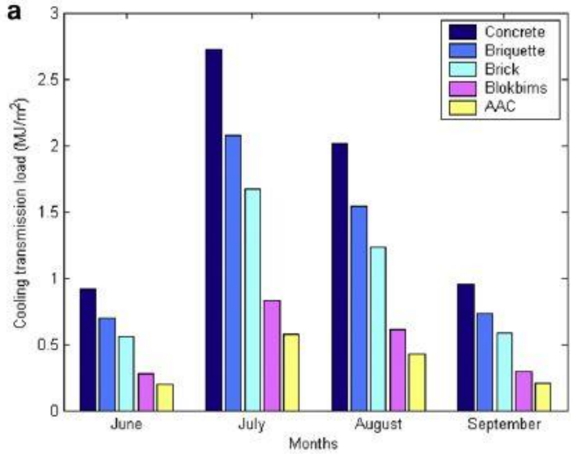


Fig2: Cooling transmission loads for different building materials during the period from July to September[4].

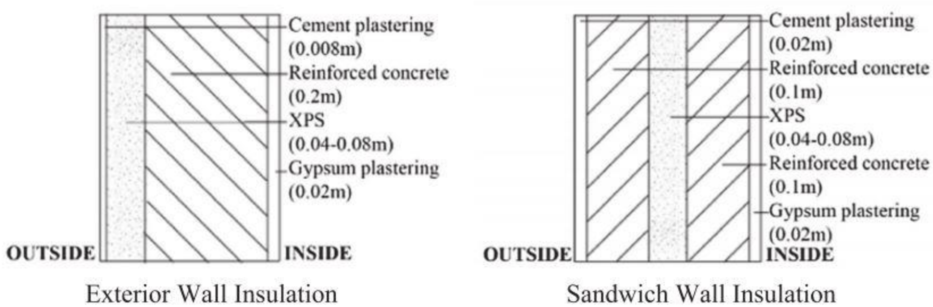
While comparing both the effect of insulation layer with hollow and perforated brick having some air space, an experimental study was carried out on insulation materials in Mediterranean ambient conditions, a reference building(2.4m x 2.4m x 2.4m) made of hollow and perforated bricks walls was compared with the thermal performance of same buildings made of perforated and hollow bricks, added with either polyurethane cubicle (PUR), mineral wool and XPS insulation materials respectively. It was identified that up to 64%energy use can be reduced in summers by using PUR[8].

2.3 Reflective Coating

When an experimental study conducted to investigate the effect of reflective coatings on lowering surface temperatures of buildings and other surfaces of the urban environment to investigate the thermal performance of the reflective coatings using surface temperature sensors and a data logging system as well as infrared thermography procedures. It was demonstrated that the use of reflective coatings can reduce a white concrete tiles surface temperature under hot summer conditions by 4 degree Centigrade[9].

2.4 Position of Insulation layer:

On the thermal performance of a building envelope, a masonry wall has been investigated by theoretical investigation under steady periodic conditions. A numerical model based on the implicit Finite Difference Method (FDM) has been developed for the computation of thermal transmittance. Six different wall Configurations have been identified based on those typically used in commercial and residential buildings in India. They found that different wall configurations have a strong effect on time lag and decrement factor. The inside surface heat flux in a building wall also depends on the wall configuration, its corresponding thermal transmittance and heat storage capacity. It is seen the wall having EPS layer at outer side has 0.009 DF and time lag of 12.27hrs while the wall having EPS insulation inside having 0.016 and 8.37hrs DF and time lag respectively[10].



(1) (2)

Fig3: two different types of wall insulation based on position (1) exterior (2) sandwich

Similarly a numerical study on XPS insulation analyzed that insulation models of opaque walls with different orientations like external, internal and sandwich materials, the sandwich wall insulation produced more convenient heat loss and heat gain for each climate and direction[11].

2.5 Building orientation:

It is well recognized that the amount of heat gained in a building from solar energy will depend on the aspect of the building design and construction, such as location, orientation and layout. In order to improve the thermal behavior of buildings, all relevant factors should be evaluated and analyzed.

In warm climates, solar heat gain should be reduced whenever possible or preferably controlled. He reported that the best orientation for warm climates is true north-south orientation with the longer axis of the building running east-west.In New Delhi (composite climate) it found that there can be a difference of as much as 2.7 K in air temperature in a building on summer afternoons between the worst and best orientation[12]. The importance of orientation on indoor climate is also emphasized by many researchers[13], [14]. When the four buildings of the same floor area but different aspect ratio was analyzed, the results shows that east-west orientation is significantly better for air-conditioned buildings results from the location of the windows in these buildings in the south wall, which is useful for direct gain in cold climates[12].

2.6 Glass window/door:

As glass windows and doors are also play an important role in the temperature conditions of building. In this aspect K. Kumar [15]studied the effect of different types of glass such as bronze, green, grey, bronze-reflective, green-reflective and grey-reflective glasses using MATLAB program, the study reveals that as far as the daylight factor is concerned, the green-reflective glass placed in south orientation is the best due to its adequate daylight factor (2.05% to 2.06%) in summer season and bronze glass window placed in north orientation is observed to be the best due to its sufficient daylight factor (2.2% to2.8%) in winter among six studied window glass materials.

3. CONCLUSION:

From the above discussion, it can be concluded that, there are 6 major factors to which thermal comfort of building depends. The most important is a layer of insulation which can be used as a barrier for heat flow in the building, but the thickness required for different insulation materials to put together with wall for attain adequate energy efficiency is inversely proportional to those of their thermal conductivities, in this point of view Polyurethane is the most appropriate form of thermal insulation in building as it has very high in R value and also good from the point of structural stability. To determine the insulation thickness for different materials to achieve required amount of energy efficiency, the formula, $X_{opt} = a + bk + ck^2$, where a = 0.0818, b = 2.973, and c = 64.6 can be used effectively. Similarly air space in between building elements like wall and roof or in between building materials such as brick or concrete plays a major role in reducing heat flow from outer to inner part of building and hence leading to a difference in temperature from 2-4 C°. In addition to this some paint like elastomeric paint also help to lower the temperature of roof surface upto 4-5 C° in hot summer days. The 4thparameter which is considered by author is the positioning of insulation layer which is best suited when it was sandwich between two facing of walls and roof. The projection and building orientation is also plays a crucial role to construct thermal proof building, hence it is also recommended that the best orientation for warm climates is true north-south orientation with the longer axis of the building running east-west. The last important part of the building is ventilation which is totally based on window and doors opening, hence for windows, as far as the daylight factor is concerned, the green-reflective glass placed in south orientation and bronze glass window placed in north orientation is suggested.

4. REFERENCES:

[1] "Energy Efficiency in Residential and Commercial Buildings." [Online]. Available: https://www.nap.edu/read/12621/chapter/4#42.

[2] H. U. Rehman, "Steady State Experimental Analysis of Various Solar Insulation Materials and Techniques for Buildings in Climatic Condition of Ras Al Khaimah, ARE," *Energy Procedia*, vol. 75, pp. 1419–1424, 2015.

[3] A. Kumar and B. M. Suman, "Experimental evaluation of insulation materials for walls and roofs and their impact on indoor thermal comfort under composite climate," *Build. Environ.*, vol. 59, pp. 635–643, 2013.

[4] M. Ozel, "Thermal performance and optimum insulation thickness of building walls with different structure materials," *Appl. Therm. Eng.*, vol. 31, no. 17–18, pp. 3854–3863, 2011.

[5] B. Palm, "FEASIBILITY STUDY OF USING SILICA AEROGEL AS INSULATION FOR BUILDINGS," pp. 1–92, 2012.

[6] T. M. I. Mahlia, B. N. Taufiq, Ismail, and H. H. Masjuki, "Correlation between thermal conductivity and the thickness of selected insulation materials for building wall," *Energy Build.*, vol. 39, no. 2, pp. 182–187, 2007.

[7] S. Saboor and T. P. Ashok Babu, *Effect of Air Space Thickness within the External Walls on the Dynamic Thermal Behaviour of Building Envelopes for Energy Efficient Building Construction*, vol. 79. Elsevier B.V., 2015.

[8] A. De Gracia and L. F. Cabeza, "Ac ce pt e t," *Energy Build.*, 2015.

[9] A. Synnefa, M. Santamouris, and I. Livada, "A study of the thermal performance of reflective coatings for the urban environment," vol. 80, pp. 968–981, 2006.

[10] B. N. C. Indian, "Thermal performance of the building walls," pp. 151–160, 1998.

[11] T. Pekdogan and T. Basaran, "Thermal performance of different exterior wall structures based on wall orientation," *Appl. Therm. Eng.*, vol. 112, pp. 15–24, 2017.

[12] E. O. F. Orientation and O. N. Thermal, "Effect o f orientation on thermal performance," vol. 16, no. October 1991, pp. 709–715, 1992.

[13] E. Mazria, "Passive solar energy book," 1979.

[14] S. A. R. Saeed, "Indoor climate as a function of building orientation," *Int. J. Ambient energy*, vol. 8, no. 1, pp. 41–47, 1987.

[15] K. K. G and A. B. T. P, "Study of Various Glass Materials to Provide Adequate Day Lighting in Office Buildings of Warm and Humid Climatic Zone in India," *Energy Procedia*, vol. 109, no. November 2016, pp. 181–189, 2017.