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RESEARCH ARTICLE

ENERGY EFFICIENT BUILDING DESIGN: TIMBER FRAME CONSTRUCTION BASED IN HEMP FIBER INSULATION

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ABSTRACT

Energy efficient building concerns to the structure and using the process that is environmental liable and material efficient all around a building lifecycle. The basic principle of this building to minimize the energy consumption for heating and cooling system. The paper investigates the thermal behavior of hemp fiber insulation in timber framed wall panels for which timber framed structures will be experimented. Steps to enhance the energy performance were applied to building structure, window area, window glazing, lightning, heating ventilation and air conditioning (HVAC) system. We were measured the U-values of timber walls, hemp fiber insulation and window glazing. Results showed that energy efficient building enjoy the benefits of saving 40-50% energy by reducing greenhouse gases emissions into atmosphere. We have discussed about the rating system of energy efficient building or green building. In this paper, information pertaining to building life cycle and detailed explanation regarding fundamentals of building energy will be provided.

KEYWORDS

Timber Frame Structure, Hemp Fiber Insulation, U-Value, HVAC, Building Energy Consumption.

1. INTRODUCTION

Buildings considered to be a key contributor of energy at all levels. Population growth has impacted the energy consumption immensely. Since conventional buildings are consumed more than 40% of world total primary and 24% carbon dioxide emission every year (Yuksek and Karadayi, 2017). Approximately, 30 to 60% of energy is utilized in providing different forms of energy. The National Energy Conservation Center (ENERCON) of Pakistan has initiated certain standards to lessen the energy consumption of households nearly to 30%. (National Energy Conservation Center of Pakistan, 2001). The energy efficient strategy has a potential to create a greener economy as buildings used to live for the period of over fifty years. Energy efficient buildings are cost effective in overall life cycle, more comfortable to live in, and more environmentally friendly (Oldewurtel et al., 2012). Energy efficient buildings also reduce the greenhouse gasses emission in both local and global. As well, the reliance on non-renewable fuel is not suitable for energy efficient building.

There are number of ways to improve the energy efficiency in the building and many different parts of building that improve the value of building. Better the insulation, energy efficient windows, daylighting, as well as air conditioning or ventilation system can all contribute to improve the energy efficiency in building by keeping comfortable environment both summer and winter session (Chou and Bui, 2014). HVAC increase the energy efficiency in the building, i.e. minimize the energy use and feasibility cost of the building, while comfortable indoor environment. Moreover, energy efficiency can be enhanced by orienting building to south so that the solar energy can be extracted during cool temperature seasons, whereas it breaks the entrance of solar energy at high temperature seasons (Chou and Bui, 2014). Construction of structures using timber frame is one of the most advantageous methods to attain energy efficient buildings.

It helps in reducing the negative impact on environment. Materials industries such as bricks and cement contribute to around 10% of carbon emissions, however, timber helps in reducing the carbon emissions. It is due to this, that timber is regarded as a highly energy efficient material in building sector. Also, timber proves to be a good heat resistant material in comparison to other building materials (Leskovar and Premrov, 2012). Hemp fiber has been used as thermal insulation in cavity walls of timber structure which reduces the consumption of energy in the building. Hemp fiber is better heat resistant material as compared to other insulating material (Martinez, 2017). Polyurethane are used as binder material with natural fiber such as hemp fiber, cellulose, jute, sisal and kenaf. Hemp fiber is a most vital natural fiber used in industrial area and building construction as thermal insulation. In addition to, hemp characterized by a tensile strength up to 1110 MPa. It is one of the sturdy fibers among all bast fibers (Sair et al., 2018).

The hemp fiber carries 10-40 single elementary fibers which consists of layers and lumen inside the cells. The penetrable structure of hemp fibers makes them ideal for thermal insulation (Harputlugil et al., 2017). Day lightening in building is a significant part of energy efficiency which enhance the visual comfort and reduce the energy consumption or artificial light use. In addition to, the windows are designed in such a way that to avoid the access of direct sun light on task surface or occupant's eyes (Kischkoweit-Lopin, 2002). The Residential Energy services Network (RESNET) is a national organization that built standards and certificates in energy rating system of homes (Dutta et al., 2017). A RESNET rating uses a scoring system called HERS index, which involves the numbers from 0-100 (Stein and Meier, 2000). The commercial energy network (COMNET) is also a rating system for assessing the energy efficiency of commercial buildings in the United States (Stein and Meier, 2000).

Leadership in Energy and Environmental Design (LEED) is a set of rating system for the examination of building parameters such as building design, construction of a facility, operation and maintenance of sustainable buildings in following six areas: sustainable site development, energy and

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atmosphere, water efficiency, material and resources, indoor environmental quality and design process. The level of LEED certification include platinum (52- 69 points); Gold (39-51 points); silver (35-38 points); certified (26-32 points) (Azhar et al., 2011). VOC paints can cause health problems and may create syndrome like "sick building syndrome". European standards based on the chamber test of Voc emission from materials used in buildings are currently being developed to enable certification of products to satisfy the EC CPD's essential requirement to control VOC emission from the building (Yu and Crump, 1998).

2. MATERIAL AND METHODS

2.1 Description 0f The Model

The project considers 2.5ft × 2.5ft for overall building footprint. The total heated area of the building is 4.41ft2 and the total heated volume of the building is 11. 47ft3.The shape factor (f=A/V) of the model is 0.38 ft.-1

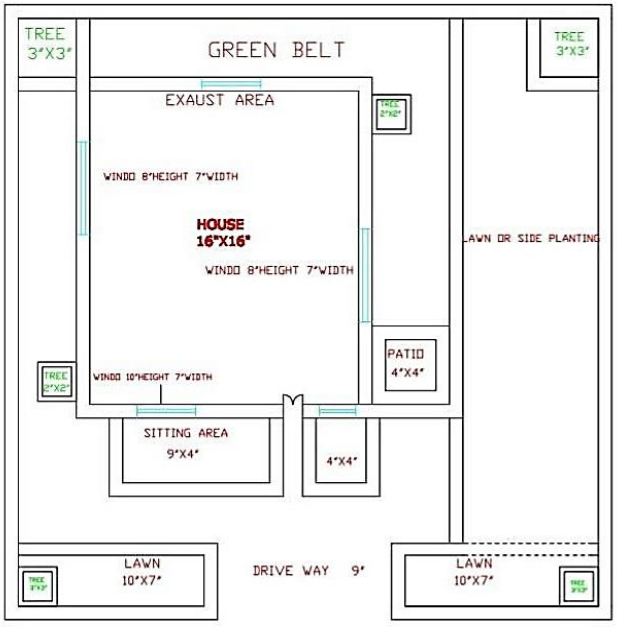

Figure 1: Scheme of the test building

2.2 Timber Frame Construction

Timber is associated with lighter weight and ecofriendly construction although it is used as building material. The cavity walls are constructed using timber frame system. The distance between two walls is kept 1 inch for thermal insulation in all sides of the building. The cavity wall thickness is 2 inches, and the U-value of exterior cavity walls are 0.271 W/m2 k. Different external construction elements bear different U values, for instance, floor slab have U value as 0.270 W/m2 k, flat roof has 0.270 W/m2 k value and overhang south directed construction above the ground level has value of 0.268 W/m2 k.

2.3 Glazed Windows

Double glaze windows were installed in building for thermal insulation. Single room with three double glass windows was considered. Thermal mass having 1 inch thickness of double glass windows was also part of a model. The room bears a width of 1.3ft, a length 1.3ft, and a height of 1.3ft. The argon gas was inserted between two glass panes (cavity). Each cavity being 12mm thick, with 4mm thick glass panes, was installed. The window glazing configuration with U-value (Ug) of 0.52W/m2k consider a high level of heated insulation and light transmission. The impact of heat on lighting has two distinct phenomena, first the major part of energy needed to lighten the room is being transferred into heat directly, whereas, the second part deals with heat emitted in form of radiation from light.

2.4 Hemp Fiber Insulation

Polyurethane-Hemp fiber (PU-HF has used as thermal insulation in cavity walls of timber structure. The Polyurethane-Hemp fiber composite insulation selected in this study contain 90% hemp fiber and 10% polyurethane. The U-value of PU-HF insulation is 0.3675W/m2k and R-value is 2.721 m2k/w for thickness of 1 inch or 25.5mm. The U-value are inversely proportional to the R-value. The thermal conductivity of PU-HF insulation is 0.039w/mk. Low thermal conductivity makes the hemp excellent insulator. RT is the thermal conductivity.

Where,

RT = Rsi + R1 + R2+……+ Rn + Rse Rsi is the internal surface thermal resistance,

R1, R2 … Rn are the design thermal resistances of each layer, and

Rse is the external surface thermal resistance.

2.5 Climate and Orientation

The house model was designed for Lahore, since, Pakistan has a wide area of glazing in south direction. Lahore is located at an altitude of 217m, latitude 31.5°N and longitude 74.3° E (Dutta et al., 2017). The Average external temperature is 24.7 °c and annual rainfall is 605mm (Dutta et al., 2017). Average solar radiation intensity ranging from 1500 W/m 2 /day to 2750 W/m 2 /day (Dutta et al., 2017). Orientation of the building effects the solar radiation gains of building sides, consequently the total solar radiation gain of the building Good orientation increase the efficiency of the building and reduce the operational cost over the life cycle of building (Farhadi et al., 2019). Building is designed in south oriented which increase the daylighting inside the building. Daylighting improves the energy efficacy and provide the healthy indoor environment (Morrissey et al., 2011).

2.6 Shading

The house model was constructed in south oriented and extended overhang above the ground. The walls shaded with external shading above the windows, which blocks the direct sun radiation and admit the diffuse light from entering the ground floor windows during the summer session, while lets it enter during the winter session when angle or incident of sun is low and increase the use of day light in building. External shading device such as eaves, awning and verandas play an important role in reducing the unwanted solar heat gain, especially during summer season in temperature climate. Shading work firstly by restricting unwanted direct solar radiation through windows in building (Chan, 2012).

2.7 Internal Gain and HVAC

The house model was equipped with Heat recovery ventilation system. To prevent the overheating in summer session and make healthy indoor environment, night ventilation with cooling through manual window system was planned. The indoor temperature of house model was designed to a Tmin of 20 °C and Tmax of 25°C. DHW and other additional requirement for space heating pump (Jouhara and Yang, 2018). Solar collectors were not installed. More efficient HVAC system in building leads to a significant reduction in power consumption, which is significantly bearing in mind that building consume overall 40% of the total power consumption in many developing countries. To achieve efficient HVAC system in building it is essential to enhance the design of various integrated mechanical and electrical components and to control and operate the plant (Haniff et al., 2013).

2.8 Low or Zero VOC Paint

Low or zero VOC paint was used in building outside and inside. I applied two coats and time duration between two coats were 2 to 8 hours, depending upon temperature and relative humidity. Low voc paint contains less than 50 gram per litter of volatile compounds (Chang et al., 1999). Low voc paint Zero or low voc paint are free of chemicals and not toxic for human health. It makes the healthy indoor environment of the building. Low voc paint reduce the heat island effect by reflecting the radiation comes from the sun. Voc can cause adverse health effects to the building occupants, and many contribute to symptoms like "sick building syndrome" (Schieweck and Bock, 2015).

3. CONCLUSION

In this study, Energy efficient building is made to reduce the operational energy cost for heating and cooling system of building through timber frame construction, thermal insulation, glazing and eco-friendly materials. Energy efficiency measures are needed in all the sectors as conventional buildings consume major part of the country's energy resources. Timber frame structures are more efficient as compare to concrete and bricks. Timber frame structures are eco-friendly and very low U-value than concrete and bricks. It was measured that hemp fiber is a good insulator and very low U-value than other insulating materials like cellulose, jute

fiber, and cotton etc. The ventilation system plays an important role to prevent the overheating and make the healthy indoor environment in the building. Energy efficient buildings consume 21% less energy than conventional buildings. It is also a carbon savings and cost savings. Thermostat set point and large window areas can help to reduce energy consumption in the building.

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