Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 5, Issue 2; January-March, 2018, pp. 49-53

http://www.krishisanskriti.org/Publication.html

Comparative Study of different Parameters to Reduce the Energy Use Intensity in a Building Envelope

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Abstract—*Building envelope is entirely responsible for gains and loss in the energy through various parts of the building such as wall, windows, roofs etc. In recent trends, Agenda 2030 for sustainable development is highlighted everywhere which promotes reducing the energy use intensity of any unit. Role of thermal properties of different parameters of building envelope is discussed that how we can reduce energy use intensity by varying the R-value and U-value of different materials in wall and roof construction. Importance of fenestration in any building has been discussed for optimum solar heat gain and heat transfer into the building. Also optimum percentage of wall window ratio has been found by selecting any particular type of glazing unit in different directions. Then it has been discussed that how we can alter the window shades to reduce the energy use intensity by varying the size of window shades. This paper deals with the modeling of a dwelling based in cold climatic conditions and study of different types of insulation with different thermal properties for efficient design of the dwelling in order to minimize the energy use intensity using Autodesk Revit 2018 and Autodesk Insight 360 and Autodesk Green Building Studio. At the end the overall energy use intensity has been compared with the ASHRAE 90.1 standards and the Architecture 2030 standards. This study would help in selecting the suitable material for constructing more energy efficient dwelling.*

1. INTRODUCTION

India comes under the category of developing country and its requirement for everything is increasing day by day. The energy requirement of the country has gone up from 450 million tons of oil equivalent in 2000 to 770 million tons of oil equivalents in 2012 [1]. As day by day the country is growing its energy requirement is also growing so there is a great requirement to develop certain sustainable construction practices in order to reduce the energy consumption. Recent trends have shown that there is a huge concern with fast changes in weather and depletion of resources everywhere. The sector which is held responsible for the excessive use of energy which lead to global environment impact is the residential and office building sector. [2]. However research these days has several methods for the development of a sustainable building [3]. We can divide the different parts of a building for evaluating performance into various categories. such as, (i) building envelope, (ii) air conditioning and ventilation, (iii) water heating system, (iv) illumination and dynamic equipment [4] and among all these parts it is known that building envelope has been considered the most important part. If we can alter the properties of a building envelope by designing a suitable energy efficient dwelling then we will be able to develop such a unit which will consume less energy and thereby reducing the overall energy us intensity. There are various parameters of a building envelope which can affect the efficiency of a building are as exterior wall or the exterior temperature of the site. [5] Building envelope works as a barrier to heat, light and air as previously stated and it revolves around the internal and external environment [7]. This paper aims at the study of various parameters of a building envelope such as walls, roofs and fenestration and selecting the most appropriate parameter as per the requirement of a building and local climatic conditions in the given location. This paper shows that how we can work in reducing the Energy Use Intensity by considering the local climatic scenario by making the suitable model of the given project and then running energy analysis in Revit 2018 and Autodesk Insight 360 by making appropriate choices. This approach of sustainable design of a dwelling will help the designers to develop such types of dwellings which will have low or economical operating cost, meanwhile it will lead to improvement in the comfort levels of the occupants in a building and thus it would help in creating a sustainable environment [6]. The prime concern of this study is that how and up to what extent we are able to reduce the EUI by proper design of building envelope.

2. RESEARCH METHODOLOGY

2.1 Site Description

The given project is located in mountainous climatic zone. Latitude and Longitude of Kanatal is 30.4137 N and 78.3458 E. The main objective of giving the site description in this paper is to understand the local climatic condition of the proposed site as it is the most important part for developing the efficient building envelope. The place is cool in winter and warm in summers. The temperature ranges from 1o C in winter to 38o C in summer. Hence suitable insulation should be adopted as per the climatic conditions.

2.2 Modeling of the proposed project

A single floor individual dwelling with the floor area of 2743 square feet with a swimming pool and an adequate lawn was planned and prepared in Revit 2018. The type of wall with proper insulation, roof and types of windows and including window wall ratio was considered and modeling of the proposed site was done by taking into account all these things together. The final render was done using ENSCAPE compatible with Revit.

Fig. 1: 3D rendered model

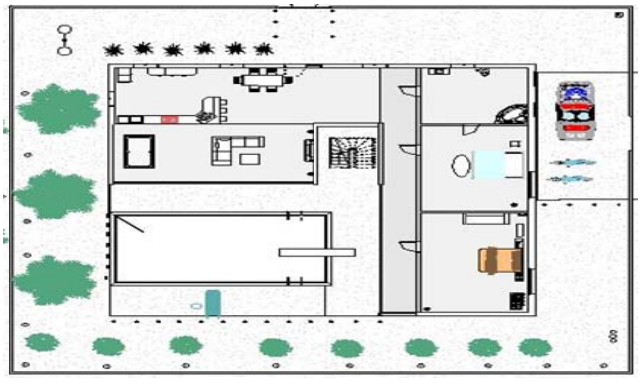

Fig. 2: 2D plan

2.3 Understanding the importance of selecting suitable systems of a building envelope.

For developing energy efficient model it is very important to understand the climatic condition of any area. Everything related to energy is dependent on the weather in any area [9]. We can say building envelope is nothing but the skin of the building which is then supported by the different parts of the structure. This building envelope is responsible for keeping a thermal barrier between the inside and outside space through which thermal energy is transferred [8]. Moreover, In order to achieve high performance building design proper insulation has to be selected as per the climatic condition of the given area. The insulation of a building is highly dependent on the R-value of the building. The high R-value (thermal resistance) of any building helps in keeping the excess heat out in a building envelope. So we will be taking into account R-values of each and every layer in the insulation. Thermal conductance also plays an important role in any building. The product is better in keeping the heat inside in any building if the value of U- factor is less. Another important component which comes into play is SHGC (Solar heat gain coefficient) which is responsible for blocking the unwanted heat gain. Although it is good for the winter season but lower SHGC is important and preferred in summer cooling season. In areas having hot summers, the shading strategies (it could be in the form of movable insulation) proves to be of extreme importance in order to control the daytime temperature in the room. [10]. ECBC recommendation wall window ratio has to be considered and appropriate U- value, R-value or SHGC has to be taken into account in any fenestration provided in any building [11].

2.4 BIM Simulation of the proposed model.

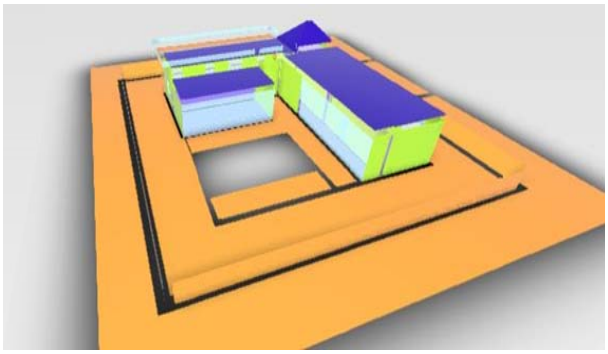

Fig. 3: Computational Energy model

The analysis for different systems involved in changing the energy use intensity was done Autodesk Revit 2018 and Autodesk Insight 360. Insight is reliable tool whole building performance analysis in Revit. The energy model of a building is an abstraction of overall form and layout into a computational network. This network captures all the key paths and processes of heat transfer throughout the building. Critical decisions have to be taken regarding the building

orientation, its impact and geometry including the internal loads and the climatic condition of the proposed area. The analysis includes several loads such as heat gains from occupants, solar heat gains, loss and gain of heat through infiltration, electrical consumption or by conduction through the fenestration or wall. Several options are available such as using single, double or triple panel windows or different types of wall with different R-values and all these values led to different energy use intensity. Energy efficient mechanical appliances are of immense importance. It has to be kept in mind that for energy analysis, the shades and operation of windows is highly important than the shape of the aperture. The energy analysis requires details about the material used in the building which could affect the thermal mass of the building. Hence, choice between concrete and wood has to be made in the earlier design phase. Moreover, energy model is influenced by the choice of color and finishes which influence the internal reflectance, while solar gains influences the exterior performances [12]

3. RESULTS AND DISCUSSIONS

Insight tool in Revit helps in selecting appropriate material of building envelope and even it is helpful in selecting the proper mechanical system and it explains that up to what extent that unit is able to reduce the EUI. Furthermore, there is a list of systems which is important from energy point of view and orientation is one of them and it proves to be helpful in improving the solar absorption ability and it is selected at the stage of preliminary design. Solar energy absorption capability is best utilized in any building if proper orientation is selected. [13] This section will cover the simulation of different component in the above mentioned tool which will prove to be productive in building a more efficient dwelling. These simulation results are given below as step by step:

3.1 Wall Characteristics

Wall characteristics are one of the most important units of the building envelope as it covers the majority part of the envelope. There is plethora of options available for wall construction and each material has different R-value. A 12.25-inch SIP (Structural insulated panel) has been used as per the given climatic conditions. Insulated panels are considered to be worthwhile in blocking the heating energy flow through the building envelope. 12.25-inch SIP has an R-value of 48 and it is known that higher R-value has more effective insulating abilities. This material helps in reducing the EUI up to 59.97kWh/sqm/year as recorded from the software. While alternate options which can be used are shown in the above graph.

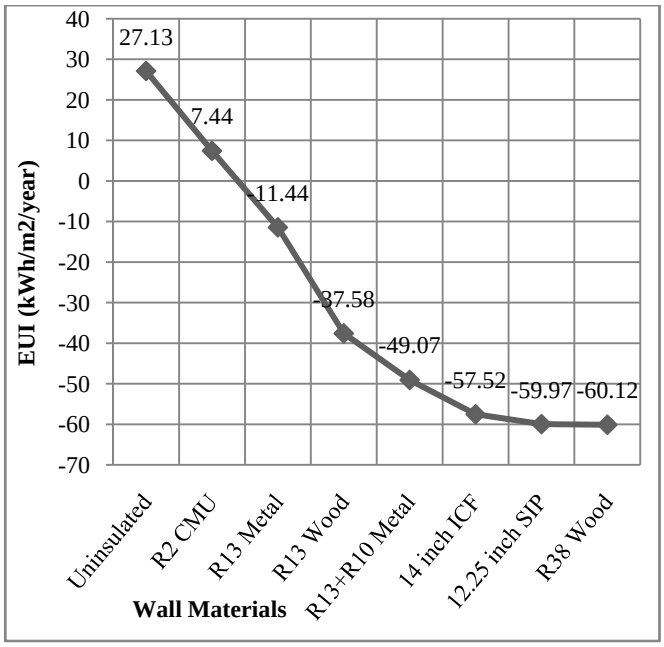

Fig. 5: Wall analysis

3.2 Roof Characteristics

Roof characteristics deals with exchange in loss and gain of heat through roof. So as per the requirement of roof construction for developing a better product proper insulation should be adopted. 10.25-inch SIP with R-value of 40 has been used in the roof construction and it reduces the EUI up to 267.64 kWh/sqm/year. The high R-value increases the thermal resistance and it is a better insulator and more efficient as it obstructs the heat exchange between interior and exterior environment. Different type of insulation can be sandwiched at the time of constructing any roof.

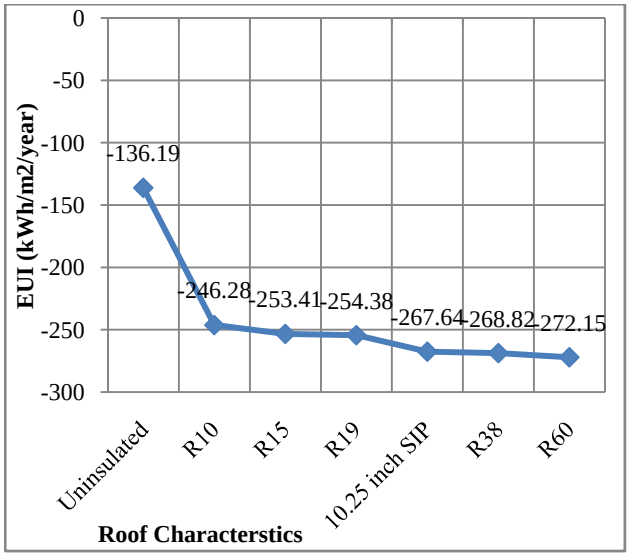

Fig. 7: Roof analysis

3.3 Window Glass

The fenestration in any building is of immense importance and it is responsible for solar heat gain and heat transfer into any building. In spite of improving the fenestration, the glazing has still the lowest R- value and high U-value among all the components of the envelope. After finalizing the wall characteristics it is important to discuss different types of glass panel. The performance of the windows can be improved by decreasing U-value by lowering the convection in the glazing unit. This is achieved by adding more panes and by replacing the air between the panes with denser gases like krypton or argon. Furthermore, addition of low emissivity (low-E) coating on the window improves the U-factor by minimizing the overall heat flow through the windows.

We can improve the Wall Window Ratio by selecting the most optimum glass panel as per the required conditions. In cold climatic conditions, low U-value is favorable.

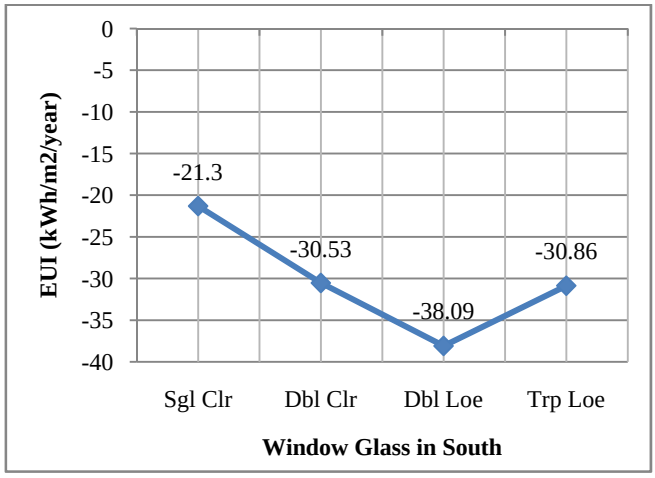

Fig. 8: Window glass analysis-South

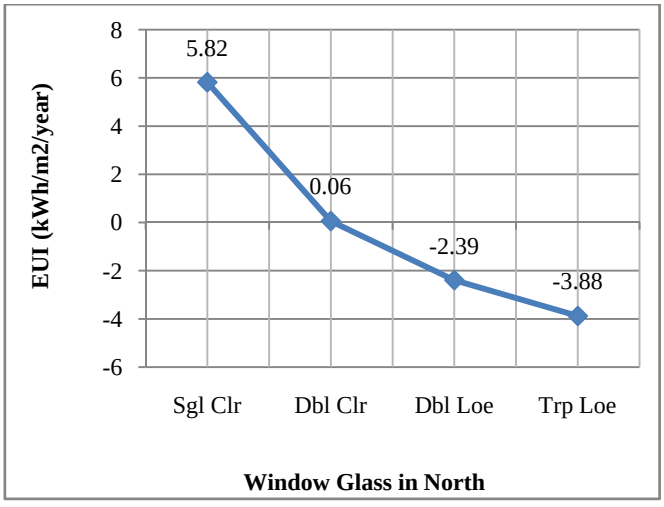

Fig. 9: Window glass analysis-North

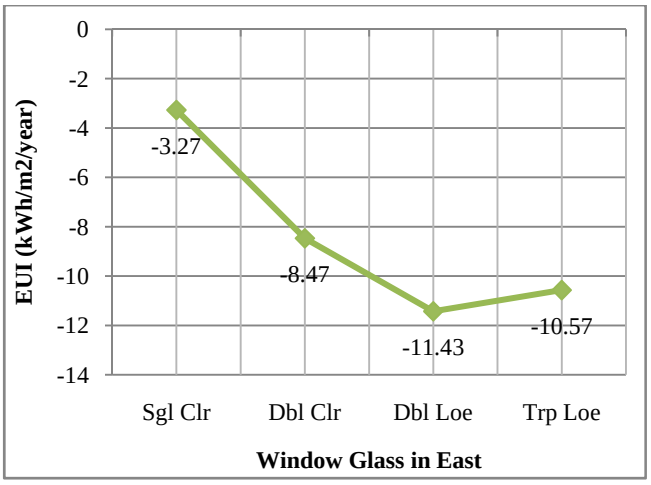

Fig. 11: Window glass analysis- West

It is known that in cold climatic conditions insulation will prove to be more effective on that side of the building which is not facing in the direction of sun's path as it would help in keeping the heat in while reverse is the case for hot climatic conditions. The efficiency of the glass panel depends on the size of the window and the direction of sun. There are different U-value and R-value for different materials and it has to be selected properly.

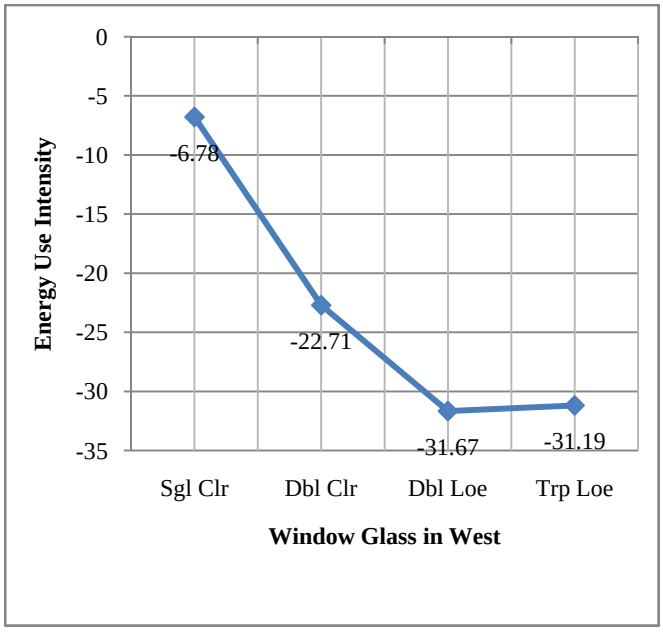

Fig. 11: Window glass analysis- West

3.4 Window Wall Ratio

WWR is glazing area per gross area wall. Window wall ratio alters the energy performance in a building. The glass has higher U-value then the wall and hence it is better in heat exchange between the exterior and interior environment in the

building. It impacts the heating or cooling units and day lighting. After selecting the optimum glass panel WWR analysis has been done. As suggested by ECBC it should not be more than 60%. But WWR ratio can be improved by choosing the optimum glass panel as per the required climatic conditions. Selecting different glass panel would lead to different WWR in different directions. It is shown that how we can increase the WWR by choosing the optimum glass panel.

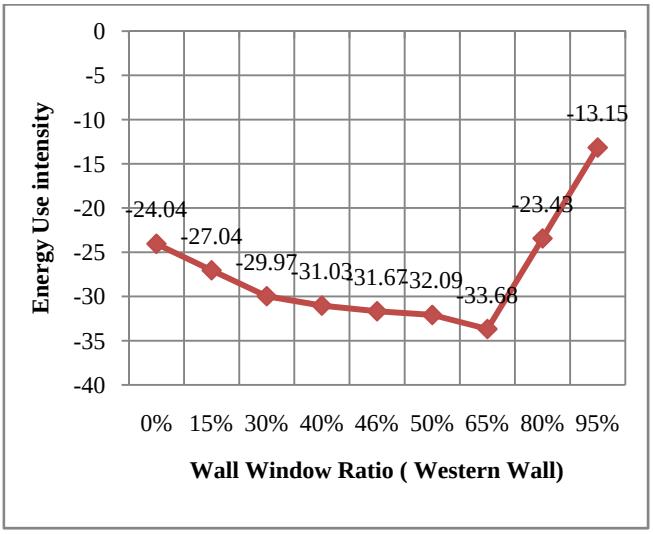

Fig. 16: WWR western walls

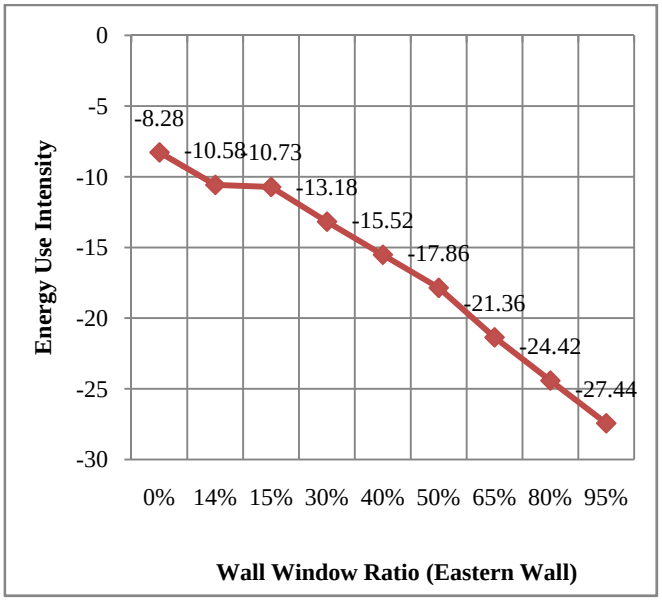

Fig. 17: WWR Eastern walls

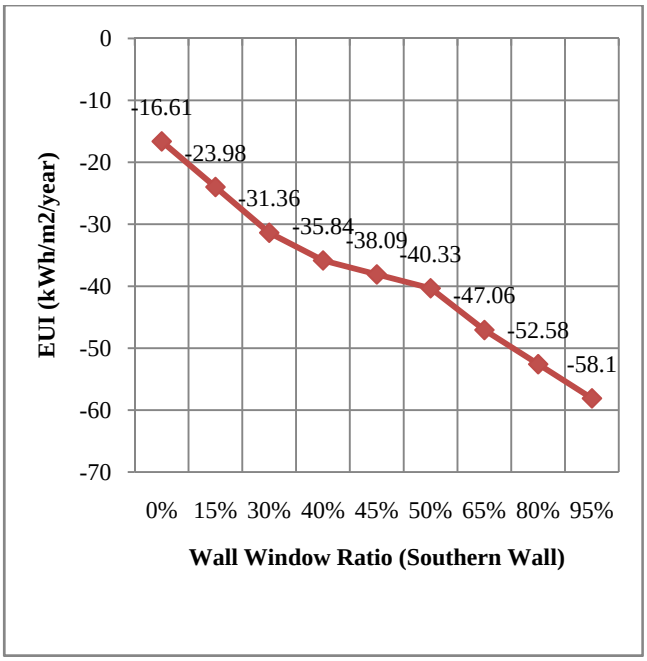

Fig. 18: WWR Southern walls

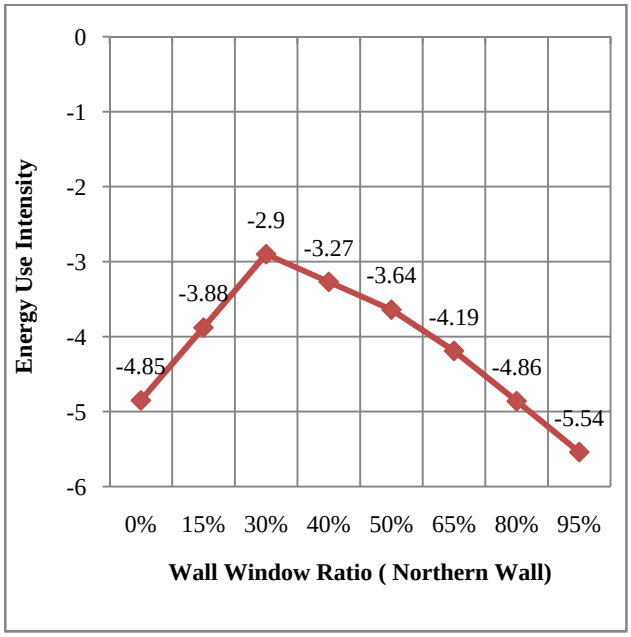

Fig. 19: WWR Northern walls

3.5 Window Shades

The SHGC (Solar heat gain coefficient) also plays an important role and this thermal property is based on the number of panes, glass type and tinting or any reflecting coats. In cold climatic conditions, the SHGC value should be high in order to minimize the heating loads by improving the passive

solar heating. Alternate window shades option analysis is shown below.

Window Shades depend on several factors such as SHGC and window size. HVAC energy loads can be minimized by using proper shades. This appropriate shading setting is important for thermal and visual comfort. Different shading strategies lead to different Energy Use intensity and based on that analysis we select the most optimum window shading option.

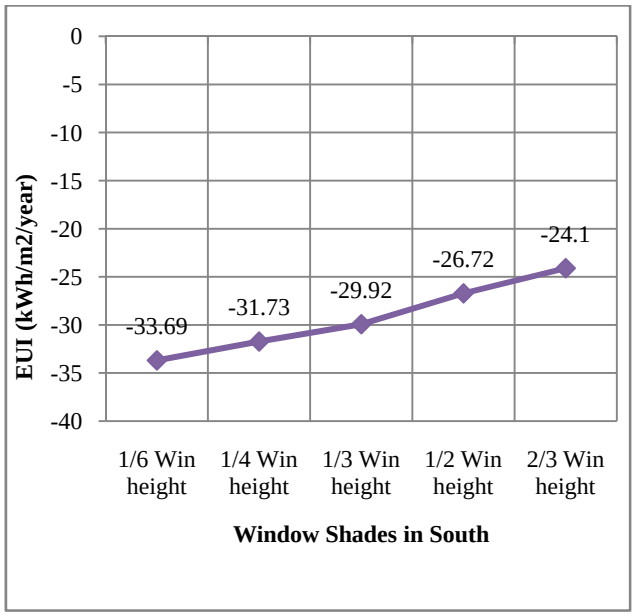

Fig. 12: Window shades- South

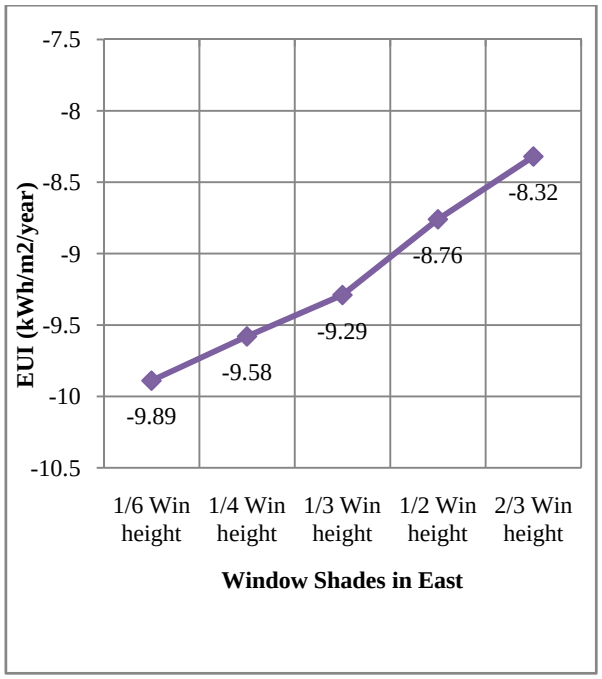

Fig. 13: Window shades-East

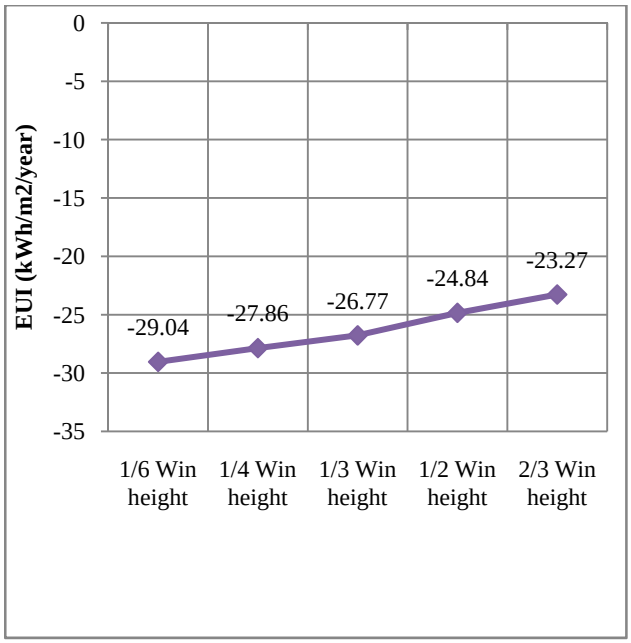

Fig. 14: Window Shades- West

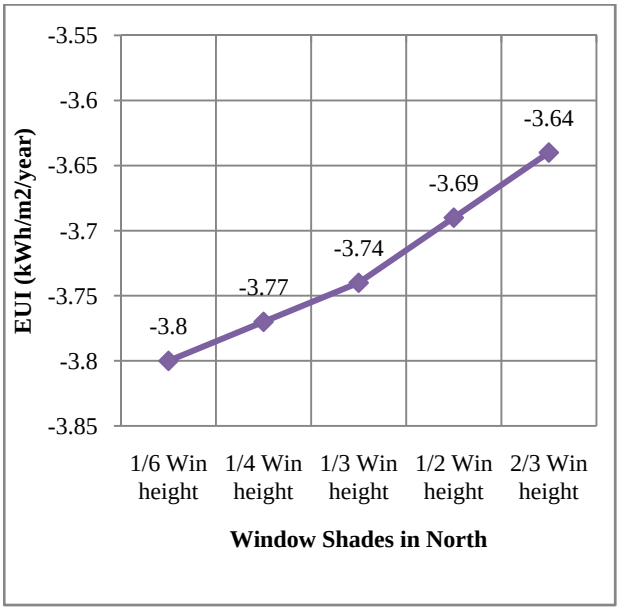

Fig. 15: Window Shades- North

At the end of the analysis, the whole building energy simulation was done and the result was compared with the two energy results as given by the ASHRAE 90.1 and ARCH 2030 results. After selecting the optimum parameters of the building envelope the overall EUI consumption by the given model is shown below.

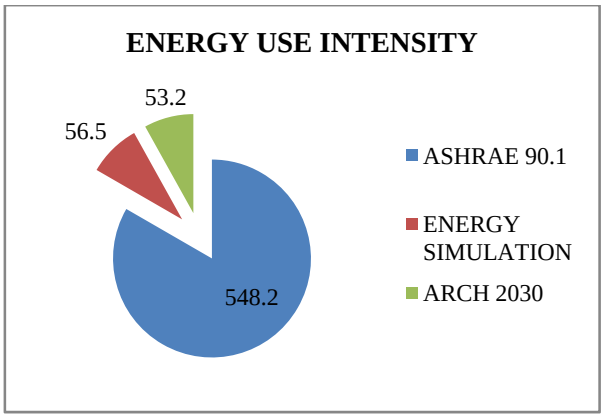

Fig. 20: Energy Analysis comparison between Ashrae 90.1 and Arch 2030

4. CONCLUSION

This paper highlights the importance of BIM by linking a BIM model with the energy analysis tool and not only it has highlighted its importance but it also proved to be effective in providing more accurate building performance analysis. From the analysis done by linking the BIM model with the energy analysis tool it explains that what type of material should be used in the building envelope and up to what extent it helps in reducing EUI by using that material. Importance of R values and U-values of different materials has been considered within a building envelope and appropriate materials have been selected step by step on the basis of these values which proved to be effective in reducing EUI using the Autodesk Insight 360 and Autodesk Green Building Studio. Variation of EUI by different parameters of the building envelope is shown by plotting the graph. It has been shown that how we can increase the Wall Window Ratio by selecting the optimum glass panel as per required climatic conditions and the direction of the sun. The use of these simulation tools and exploring the performance of the building using the virtually designed computational model in preconstruction stage will help the Engineers, decision makers and Architects to choose the materials of the building envelope with less deleterious impression to the environment. There is an immense need to adopt these techniques in order provide projects as per requirement of industry as well as environment.

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