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ANALYSIS OF MINERAL WOOL INSULATION ON RESIDENTIAL BUILDING

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Abstract – Cooling and heating systems consume the major portion of total energy production to meet the thermal comfort needs of the masses. Providing resistance to the heat flow is one of the efficient and environmentally friendly methods to reduce the consumption of energy. For this purpose, thermal insulation is widely used. Material with high thermal resistivity is used to reduce heat loss and heat gain. This results in the reduction of energy consumption that is used for heating and cooling purposes hence cutting energy costs. This study is aimed to investigate the effects of insulation material on energy cost and energy performance on a house. A house is modelled using BIM technology. BIM can evaluate the building's energy performance and energy cost savings. Autodesk Revit 2021 is used for modeling the house. A comparison of the energy cost of the house is done before and after the installation of insulation material in the exterior walls and roof of the house. Mineral wool is used as an insulation material for the house. Mineral wool has two variants known as rock wool and glass wool. It contains 70% recycled material that makes it a greener material. It can be a costly product but it has less health risk during installation. It is easy to install. Mineral wool products are manufactured in different shapes and properties depending on the requirement. It covers a temperature range from -250 to 800+ degrees acting as a good physical barrier to heat transfer. It also performs well for soundproofing and fire protection.

Keywords- Building Information Modelling (BIM), energy-efficient buildings, insulation material, mineral wool

1 Introduction

The global energy demand will continue to increase as the world grows according to the IEA's annual projections. The global population was 7.7 billion in 2019 according to the IEA [1]. The IEA in its 2020 report predicts that the global population is expected to increase an additional 1.3 billion; from 7.7 billion in 2019, 9 billion population in 2040. Increased energy demand is predicted with developing economies and emerging markets. There is a forecast of a 19% increase in world energy demand. It means that the world would need twice as much energy as it produces today [1]. The energy demand is increasing day by day. It is expected to be more severe, especially in developing countries. The reason is the rapid growth of new buildings while the use of energy-efficient technologies is not having sufficient attention [2].

As a result of the rising energy demand, environmental issues are becoming more and more evident. The energy is converted from one form to another with the help of energy. It means energy is required to get energy. The gathering, processing, and delivery of fossil fuels are responsible for 8 percent of carbon emissions [3]. Approximately 40% of global CO_2 emissions are emitted from electricity generation through the combustion of fossil fuels to generate the heat needed to power steam turbines. Burning these fuels results in the production of carbon dioxide (CO_2)—the primary heat-trapping, "greenhouse gas" responsible for global warming [4]. Carbon

dioxide (CO_2), an example of a pollutant, is widely known as a harmful substance to human health [5]. Greenhouse gases are gases in Earth's atmosphere that traps heat. Greenhouse gases allow the sunlight to pass through the atmosphere but they stop the heat that sunlight brings in to escape from the atmosphere. The cooling systems used in the summer season run on power generated by fossil fuels. Air conditioners emit air pollutants like chlorofluorocarbon that go into the environment and deplete the ozone layer. CO_2 and chlorofluorocarbon are an example of greenhouse gases. Carbon dioxide plays a strong contribution to the greenhouse gas effect. If no necessary steps are taken to reduce the emissions of CO_2 and other greenhouse gases, the Earth's average surface temperature is predicted to rise about 1.1– 6.4 °C by the end of 2100 [6].

Generally, when house construction takes place, walls are constructed using conventional materials i.e., solid bricks. The heat can be easily conducted through these walls in the summer season which makes it unbearable to live in that house. Then air conditioners are used to cool the house but that ends up causing huge electricity consumption. As explained above large consumption of electricity and air conditioners cause emissions of harmful pollutants i.e.CO_2 and other greenhouse gases. There is another way that can be used in the construction or renovation of the house. That is to insulate the exterior walls of the house with special materials that resist the transfer of heat to and from the house. Roof insulation can also be done. The most important advantage of insulation is the reduction in energy consumption of the house. Also, the use of air conditioners will be reduced to a huge extent. In this way, emission of harmful pollutants will be avoided and hence cost-saving due to less energy consumption.

Nowadays, energy efficiency in the building is the main objective in energy policy at regional, national, and international levels [7]. Based on the literature review using the famous database (ScienceDirect and researchgate.net) gave the idea of using the properties of insulation material and doing energy analysis using BIM technology. Building information modeling (BIM) is a technology that can help designers in predicting the energy efficiency of the structure, based on the model created by 3D visualization of data on the software.

In Pakistan, a large sum of resources is annually consumed within the building sector. Due to the large share of energy consumption in this sector, an analysis as accurate as possible of the heating and cooling loads of a building should be done. Energy performance analysis using BIM can save a lot of time and money. Building Information Modeling technology indicates optimization, design identification, comparison, and reduction of energy consumption in the initial phases of design as well as in retrofitting. This study includes a case study of a residential house. Its building information modeling is done in Autodesk Revit 2021. Energy performance analysis is done using Autodesk Insight.

2 Research methodology

2.1 Selection of software

AUTODESK Revit 2021 is selected to create a model for building information modeling. This software is used because of its wide range of tools for different designs and modeling available in it. Revit 2021 has all the required options to design a house from top to bottom. Another reason for the selection was the built-in plugin of Autodesk that allows performing energy simulation in this software. Autodesk insight is an energy-related tool used to get results for energy analysis. The results are obtained after running an energy simulation on a model in Autodesk Rivet 2021. It gives real-time feedback. It allows to visualize and interact with key performance factors and helps to make better and informative design decisions. It is a cloud-based service. It allows for simulation of building performance to optimize energy efficiency by using minimum hardware resources of the system and providing high-speed energy analysis.

2.2 Site selection

A five Marla house is modelled for the case study. The location for taking the weather into account is set as Sialkot, Punjab Province, Pakistan. It is a mild climate region. The area of the house is about 135.26 m^2. It is a single-story house of 4.2m (14 ft) height above ground level. The interior and exterior walls are made of 9-inch thickness. The front side of the house is south facing. Initially, there is no insulation material provided in the walls

and roof of the house. The walls of the house are finished with cement plaster and paint. The roof is a 6-inch thick RCC slab finished with ceramic tiles. The purpose of the study is to observe the thermal response with and without insulation material to make a comparison. The comparison of energy performance and energy cost.

2.3 Mineral wool – An insulation material

Mineral wool is an inorganic product manufactured from a mix of raw materials, which mainly consist of stone or silica. Stone or silica are heated to a high temperature until liquified by heat. The material prevents the process of conduction, convection, and radiation. Convection is prevented by trapping air in the open cell of the material, the wool matrix. Conduction is a process that requires pathways so it is reduced in mineral wool because there is very little solid material to provide pathways for the process. Heat transfer reduces because the material act as a physical barrier to radiations. With its good thermal properties, it also provides fire protection. Mineral wool has two main variants i.e., rock or stone wool and glass wool. Glass wool is made from spinning the strand of melted glass. It is usually made as rolls, slabs, and applied in-place or sprayed. Rock or stone wool is made from molten rock materials. Their final product of rock or stone wool is compressed into boards, mineral wool batts, or other forms. Mineral wool is used for insulation of cavity walls and exterior walls, flat roofs, thermal and acoustic insulation of partitioning walls and floors. Minera wool can withstand a temperature range of -250 to 800+ degrees. Its thickness is usually 30 to 120 mm (4-inch). Density is up to 120 kg/m^3. Its packaging is polyethylene bags. This material is used in the BIM of the house [8].

3 Results

The model is created (Fig 1) to examine the design in Autodesk Revit 2021. Then the type of materials, floors, and energy setting are defined for the model. Then the results were received after generating the energy model and sending it to the Autodesk cloud service.

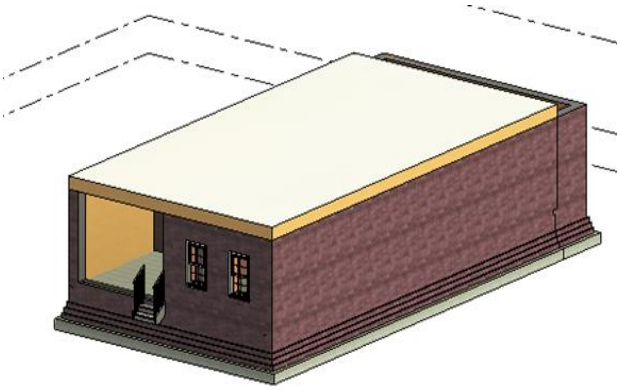


Figure 1: The 3D view of the Residential house simulation in Autodesk Revit 2021

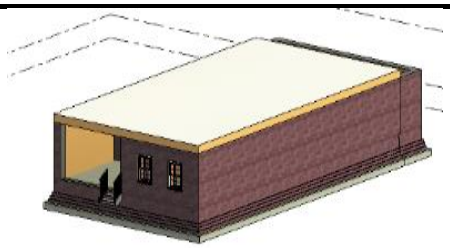
The Autodesk insight gives mean energy cost and energy consumption using different parameters. The parameters are building orientation which is between 270 and 315 degrees, window to wall ratio i.e., 19% for southern walls, 15% for northern walls, 4% for western walls, and 0% for eastern walls, wall construction, and roof construction shown as BIM modelled, infiltration, lighting efficiency (no lighting efficiency in modelled house), no daylighting and occupancy control, no plug load efficiency, no HVAC, and no photovoltaic solar panels. The structure of the walls used in the model is high mass construction (construction with concrete) with no insulation, and the roof structure is dark with no insulation. Dark means the surface of the roof is dark-coloured or finished with dark-coloured material and absorbs the heat of the sun. This is a modelled scenario. The cost of energy consumption based on these parameters is 20.7 USD/m^2/y. Accordingly, the energy consumption is equal to 207 kWh/m^2/y.

In the energy performance settings in the edit type of the building element, there is a thermal resistance factor that is the important number R underneath analytical properties. The R-Value is known as imperial units of measurement ($ft^2 \cdot °F \cdot h/BTU$). High R-value means a slow rate of heat transfer through the insulation material. This number is determined based on the material's properties (in our case material is mineral wool). Going further into edit type the wall structure is enhanced by adding a layer of mineral wool as insulation/thermal resistant material. The same process goes for roofs. The software will add all of the layers added for thermal resistance and gives the final number called R. The 4-inch-thick layer of mineral wool as an insulation material is added inside for all the exterior walls (9 inches thick) and under roof slab (6 inches thick) of the house.

Initially, before installing insulation material the R-value of exterior walls and roof was zero. The 4-inch-thick layer of mineral wool with a plywood finish gives an R-value of 20.39 ($h.ft^2.F^o$)/BTU for exterior walls and 19.05 ($h.ft^2.F^o$)/BTU for the roof slab. So, the parameters i.e., roof and wall construction are adjusted by adding thermal resistance keeping all other parameters of Autodesk insight result the same. By adjusting the roof and wall construction parameter with an increase R number as mentioned above, the cost of energy consumption would be 18.4 USD/m2/y. Correspondingly, the energy use intensity would be equal to 166 $kWh/m^2/y$.

The consequences of this analysis show that the use of building information modeling technology for changing the parameters affecting energy consumption in the designed model is helpful. The changing of parameters can save up to 11.11% energy cost and 19.81% of energy use intensity. The adjusted parameters are roof and wall construction. The adjustment is the increased R-value.

Table 1 Comparison of results before and after optimizing parameters



Building form		Energy cost	Saving	Energy use intensity	Saving
		$USD/m^2/y$	Percent	$kWh/m^2/y$	Percent
5 Marla House	BIM parameters Before optimization	20.7	0	207	0
	BIM parameters After optimization	18.4	11.11	166	19.81

Figure 2: Autodesk Insight results for wall and roof construction

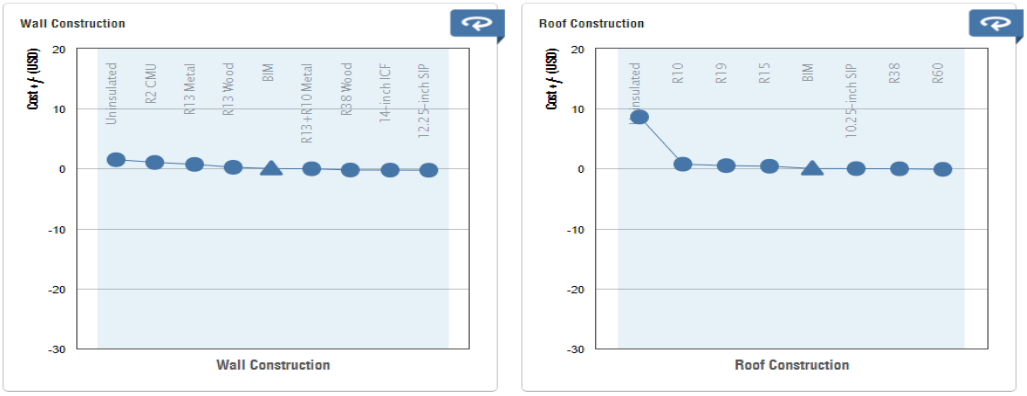


Figure 3: Zoom in results of Autodesk insight for wall and roof construction

The options are shown (Fig 2) as circles in the graph. The current setting (insulated one) is shown as a triangle from the model. It is named BIM. When the arrow is brought on any option, a small pop-up appears. The pop-up shows either the energy cost or energy consumption. It depends on whether we are showing the results in terms of energy cost or energy consumption. The BIM option means it is taken from the model in Revit. It is a baseline so it will be zero. The options other than BIM will have a positive or negative effect on energy consumption and energy cost. Each option represents a change. The change from the BIM option. The circular options with positive values show an increase of that amount in energy cost or energy consumption. The circular options with negative

values show a decrease of that amount in energy cost or consumption. The saving difference compared with the BIM option can be observed with the negative values. Moving left from the current setting will cause an increase in energy cost and moving right will cause a decrease in energy settings. Almost all types of insulation materials would exist between this range. The R-value for the exterior wall is 20.39 ($h.ft^2.F^o$)/BTU and as can be seen in the wall construction graph it exists somewhere between R-13 wood and R-10 + R-13 metal.

Mean energy cost before insulation of wall and roof with mineral wool = 20.7 USD/m^2/y
Mean energy cost after insulation of wall and roof with mineral wool = 18.4 USD/m^2/y
Saving cost in 1 year = 2.27 USD/m^2/y
Mean energy consumption before insulation = 207 kWh/m^2/y
Mean energy consumption before insulation = 166 kWh/m^2/y

4 Conclusion

Following conclusions can be drawn from the conducted study:

- Using insulation material (Mineral wool) as a form of thermal resistance is effective. Effective in terms of reducing energy cost and energy consumption.
- The saving percent of energy cost due to mineral wool insulation is 11.11%.
- The saving percent in energy consumption is 19.81%.

Less energy consumption will lead to less emission of atmospheric damaging pollutants. It can be observed that mineral wool acted as a physical barrier in the transfer of heat. BIM helped in conducting energy analysis on the house. The Autodesk Insight's results and parameters helped in explaining the effects of insulation material on the house.

Acknowledgment

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References

[1] CAPP, "CAPP." https://www.capp.ca/energy/world-energy-needs/.

[2] L. Aditya, T. M. I. Mahlia, B. Rismanchi, H. M. Ng, M. H. Hasan, and H. S. C. Metselaar, "A review on insulation materials for energy conservation in buildings," no. June, 2017, doi: 10.1016/j.rser.2017.02.034.

[3] "Climate Communication." https://www.climatecommunication.org/change/energy-use/.

[4] "Reducing Carbon Dioxide Emissions from Electricity Sector Using Smart Electric Grid Applications," doi: https://doi.org/10.1155/2013/845051.

[5] T. H. Oh and S. C. Chua, "Energy efficiency and carbon trading potential in Malaysia," *Renew. Sustain. Energy Rev.*, vol. 14, no. 7, pp. 2095–2103, 2010, doi: 10.1016/j.rser.2010.03.029.

[6] S. Guendahou, "ipcc." https://www.ipcc.ch/people/sabin-guendehou/.

[7] L. Pérez-Lombard, J. Ortiz, and C. Pout, "A review on buildings energy consumption information," *Energy Build.*, vol. 40, no. 3, pp. 394–398, 2008, doi: 10.1016/j.enbuild.2007.03.007.

[8] "ROCKWOOL," [Online]. Available: https://www.rockwool.com/north-america/products-and-applications/products/toprock-dd/?selectedCat=toprock downloads#Overview.