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A Numerical Simulation to Select the Optimal Thermal Agents for Building Parts

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ABSTRACT

The use of thermal insulation is one of the most crucial solutions for reducing energy consumption when designing buildings. In this study, we investigate the use of various types of thermal insulation (air, cellulose, fiberglass, mineral wool, polystyrene, and polyurethane foam) to determine the best location when designing. The numerical study is done using ANSYS/FLUENT 16 software and an enthalpy-porosity formalism. According to the study's findings, all heat insulators investigated offer effective insulation, but some of them, like air, have characteristics that make them challenging to employ. The remaining insulators satisfy all requirements for usage as a thermal insulator. Given that it possesses all the necessary characteristics to be used as a thermal insulator, (polystyrene) is one of the most important insulators that are readily available locally. The use of thermal insulation in buildings reduces the need for refrigeration equipment to maintain comfortable conditions, which has a significant negative impact on the environment.

1. INTRODUCTION

Energy is an important component of daily life and plays a major role in developing all aspects of life [1]. And the depletion of traditional fossil energy resources, and the associated challenges represented in the stability of supply and the increase in prices and their impact on the environment [2], [3]. Currently, approximately 70% of the electricity produced in the world is generated using coal, natural gas, and petroleum products. Electricity generation is the largest contributor to global carbon emissions. In 2016, 39.5% of energy was used worldwide for heating and cooling buildings [4-6]. Thus, the focus is on the use of thermal insulation to reduce energy use [7, 8]. Energy use in the real estate sector accounts for a very large percentage of the total energy consumption in the world. As the annual energy consumption in the European Union and the United States increases, the construction sector represents 40% of the total amount of energy used in 2012 [9-13]. And energy consumption in China in the real estate sector in 2009 was about 33% of total energy consumption, and this percentage is expected to increase with the development of output in the construction sector [14]. Energy consumption will increase by an estimated 56% by 2040. Most of this energy demand is met from fossil fuels, which will cause serious problems with the depletion of energy resources and the high impact of global warming [15, 16]. Some estimates indicate that the construction sector consumes about 40% of energy, 25% of water, and 40% of the world's resources [17], [18]. That is why the focus has been on the insulation properties of building envelopes through the use of insulation materials, which play a major role in energy consumption because they can lead to significant improvements in energy consumption, which are evident during not much time [19], [20]. The researchers focused on developing several insulation materials for buildings to reduce energy consumption in the real estate sector [21]. It has been found that thermal insulation materials can effectively improve the thermal insulation performance of the real estate sector and reduce energy consumption [22, 23]. Thermal insulation in the building sector affects three areas: economic, environmental, and social [24]. The use of thermal insulation is one of the most effective means of energy conservation in the real estate sector. The thermal resistance provided by the thermal insulation increases with the increase in the thickness of the insulating layer and its thermal conductivity decreases. The decreasing factors, time delay, and peak transmission loads are only a few of the additional thermal properties that insulation materials have a significant impact on. Many types of insulation materials available differ in terms of thermal and many other properties, material properties as well as cost [25-28]. Materials used for thermal insulation have a big impact on how energy-efficient buildings [29]. An enormous amount of energy (up to 30%) is used to keep homes at a comfortable temperature [30]. Many insulating materials are available, including polyurethane foam (PUFs), expanded polystyrene foam (EPSFs), fiberglass, and mineral wool. PUFs are most likely because of their low cost, high mechanical strength, and apparent low heat conductivity (= 0.03-0.04 watts/(MK). PUFs can also be customized to fulfill individual needs, with applications like shock absorbers in vehicles, enclosures, and shoes. However, because of its great flammability, it is critical to improve fire safety. By trapping free radicals, halogen compounds enter the gaseous phase. Despite their effectiveness, they have been banned in large-scale regions and events because of major environmental concerns. Phosphorus and nitrogen-containing compounds, on the other hand, drew more attention due to their low toxicity [31-33]. To choose the appropriate insulation according to what is locally available, the most important of which is thermal conductivity, taking into account several things: Weak perforation, adaptation to the construction site, and durability; fire protection; smoke emission during a fire; mechanical strength; durability; freeze/thaw resistance; climatic ageing durability; water resistance cycles; and costs. and environmental impact [34, 35]. Heat losses from buildings occur through external walls, windows, ceilings, and floors, as well as by air leakage. Where are calculated the thermal conductivity resistance of the wall (R) and the thermal conductivity (k) so that the required thickness of the insulation (P) equals the thermal conductivity resistance of the wall multiplied by the thermal conductivity [36, 37]. In this research, the importance of using thermal insulation in buildings and its effect on energy consumption were studied, and several types of insulators were studied to choose the best in thermal insulation and the importance of this in reducing energy consumption. have been studied (air, cellulose, fiberglass, mineral wool, polystyrene, and polyurethane foam) to choose the most suitable for building insulation [38-40].

2. NUMERICAL PROCEDURE

2.1 Physics models

In Figure 1, the wall was studied using an insulating material installed in the middle of the wall, as the wall is made of bricks with a width of 10 cm, insulation of 5 cm, and bricks of 10 cm. From the outside, it is covered with cement with a width of 5 mm, and from the inside, it is covered with cement 5 mm and gypsum 5 mm.

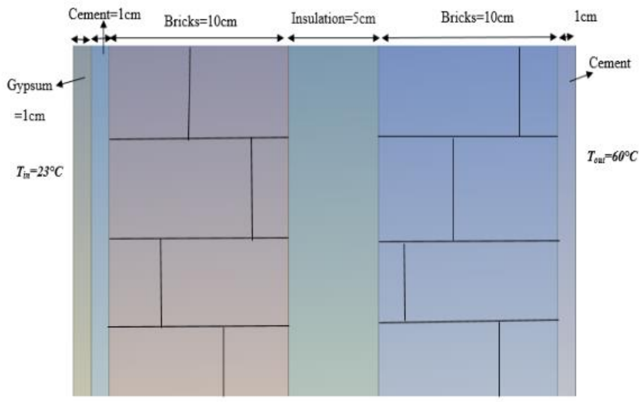

Figure 1. Schematic diagram of the wall with thermal insulation to the middle of the wall

2.2 Materials

The materials used in the wall are mainly bricks, and it is sheathed from the outside with cement and from the inside with cement and gypsum, in addition to the thermal insulation used in the study, which is Mineral wool, as well as the use of double-glassed deflated from the air. In Table 1 it shows the thermo physical proprieties for the materials used for the wall and the glass used in the windows in this numerical study.

Table 1. Thermophysical proprieties of the materials

Thermal properties	Bricks [41]	Cement [42]	Gypsum [43]	Mineral wool [44]	Air
Density [kg/m³], ρ	1466	1730	1200	100	1.225
Specific heat [J/kg K], C_P	800	920	950	840	1006
Thermal conductivity [W / m K], k	0.67	0.33	0.35	0.04	0.024
	Fibreglass [45]	**Polystyrene [46]**	**Polyurethane foam [47]**	**Cellulose [48]**	
	300	25	900	60	
	1000	1500	2076	1600	
	0.067	0.035	0.048	0.04	

2.3 Enthalpy–porosity method

The simulation of the heat transfer process of the wall was obtained by adopting the enthalpy–porosity method. The computational domain of the heat transfer divides the wall by the number of components of the wall. Where we notice that every part of the wall is clarified the heat transfer through it, which shows the temperatures inside the wall, which explains the importance of using insulation in buildings.

3. RESULTS AND DISCUSSION

In this paper, we study several types of insulators to choose the best, most appropriate, most useful, and least expensive, which will give better results and help reduce energy use and create comfortable conditions for building occupants. where it is the study (air, Cellulose, Fiberglass, Mineral wool, polystyrene, and Polyurethane foam) where it is will explain the study of each thermal insulator to demonstrate the transfer of heat through the insulator and to choose the best one that is available locally and has the required specifications when used in thermal insulation.

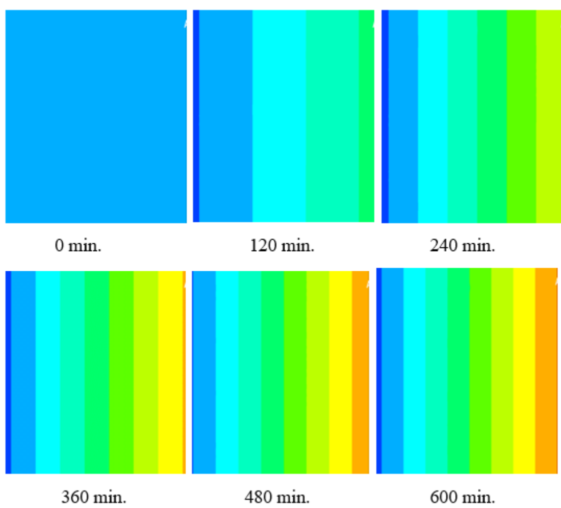

Figure 2. Heat transfer stages inside the thermal insulation (air)

3.1 Air

The study of the use of air in thermal insulation to clarify the importance of its use, but it cannot be applied due to the difficulty of fixing the wall, and therefore we are trying, through subsequent studies, to find a solution through which the air can be used as thermal insulation as it is in the double glass discharger from of the air. In Figure 2, noted the slow heat transfer through the thermal insulation, which has a great effect to maintain comfortable conditions in buildings with the lowest energy consumption.

3.2 Cellulose

The use of thermal insulation (Cellulose) is considered an environmentally friendly insulator, as it is made from paper waste and materials are added to prevent burning, but this type of insulator does not withstand strong shocks. In Figure 3, it is noted that the slow transfer of heat through thermal insulation, which has a great effect in maintaining comfortable temperatures inside buildings, has a great impact on the environment as a result of reducing energy consumption.

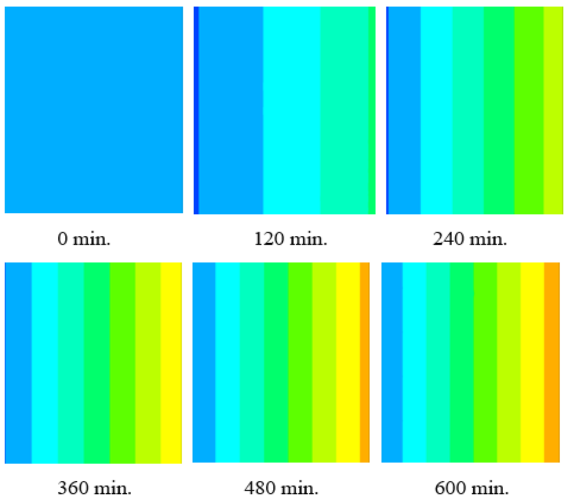

Figure 3. Heat transfer stages inside the thermal insulation (Cellulose)

3.3 Fibreglass

The use of thermal insulation (Fibreglass) When compared to other insulation solutions, this is usually the most cost-effective option. The fibreglass is able to limit heat transfer because of the way it is created, by effectively weaving thin strands of glass into an insulating substance. It is critical to wear the appropriate safety equipment when installing fibreglass, as powdered glass and fine shards of glass can cause damage to the eyes, lungs, and skin. It can be shaped easily using casting processes. In Figure 4, it is noted that the slow transfer of heat through thermal insulation, which has the effect of reducing energy consumption in addition to providing comfortable conditions for building occupants.

3.4 Mineral wool

Thermal insulation (Mineral wool) rock wool fibers are made from either natural volcanic rocks or those that have been melted in special furnaces at temperatures above 1500 degrees Celsius, after which the flexible and high-temperature fibers are woven. Then the fibers are collected and processed on production lines to create various shapes and products from rock wool, each product of different thicknesses and densities. Rockwool is a highly efficient insulation material used in most known applications that require thermal or acoustic insulation, thanks to its very low thermal conductivity and melting temperature. Very high-performance rock wool against fire and burning materials rock wool does not harm the skin of the body and does not cause irritation. This product is highly compatible with all materials used in construction and industry. In Figure 5, the heat transfer is observed through the thermal insulation, which has a great effect on the transfer of heat into the building and thus provides comfortable conditions and reduces energy consumption.

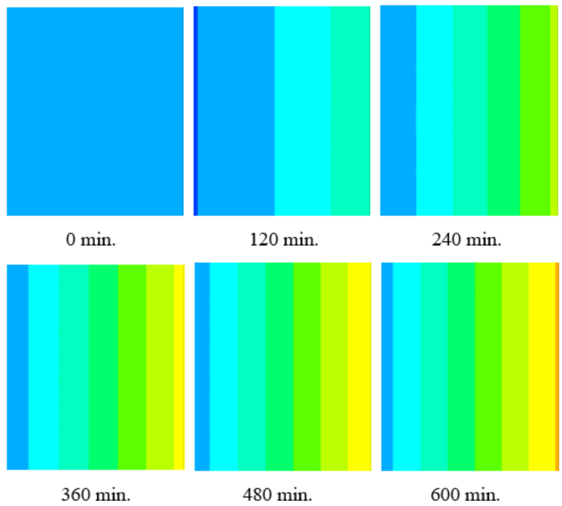

Figure 4. Heat transfer stages inside the thermal insulation (Fibreglass)

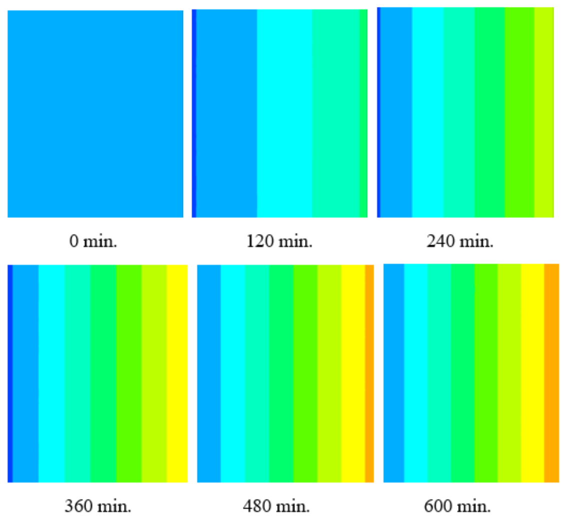

Figure 5. Heat transfer stages inside the thermal insulation (Mineral wool)

3.5 Polystyrene

Thermal insulation (polystyrene) is a water-resistant thermoplastic foam that is a good sound and heat insulator. Expanded (EPS) and extruded (XEPS), often known as Styrofoam, are the two forms. No other type of insulation has the same smooth surface as polystyrene insulation. It can be found in both residential and commercial structures. Insulation made of polystyrene is extremely durable. The foam is usually created or cut into blocks, which is ideal for wall insulation. In Figure 6, heat transfer is observed through thermal insulation, which has a significant impact on energy consumption and reduces the impact on the environment, which provides comfortable conditions inside buildings.

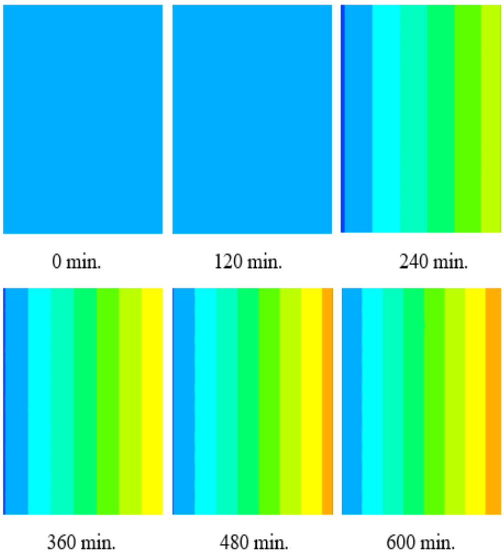

Figure 6. Heat transfer stages inside the thermal insulation (Polystyrene)

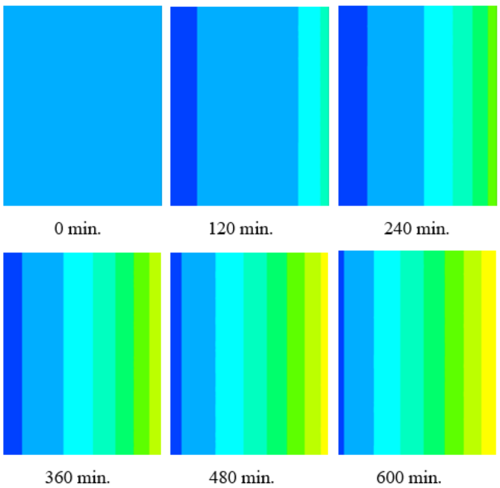

Figure 7. Heat transfer stages inside the thermal insulation (Polyurethane foam)

3.6 Polyurethane foam

Thermal insulation (Polyurethane foam) To make polyurethane foam, chemicals are mixed and reacted to create a foam. The ingredients that are being mixed and reacting react quickly, expanding on contact to form a foam that insulates and softens the air while also functioning as a moisture barrier. Properly deployed insulation material can be part of a system designed to protect against moisture, providing the advantage of reducing the chance of harmful mould, mildew and wood damage. Spray foam insulation is often used to reduce noise. Foam insulation acts as a barrier to airborne sounds, and reduces the transmission of airborne sound through the building's roof, floor and walls compared to a non-insulated structure. In Figure 7, it is noted that the slow transfer of heat through thermal insulation, which has the effect of reducing energy consumption in addition to providing comfortable conditions for building occupants.

4. CONCLUSIONS

In this paper, a numerical study of several types of thermal insulators was carried out to choose the best insulation, which has several factors, the most important of which are (low thermal conductivity and does not burn, expand, rust or fade, excellent resistance to high strong pressure, water resistance, moisture resistance, light weight, ease of use, excellent stability and corrosion resistance and good environmental performance as well as sound insulation). Note that all the insulators that have been studied provide good thermal insulation, but the difference in some properties of the insulators makes some better when used. For example, the air is a good insulator, but you do not use it due to the difficulty of installing the wall. One of the insulators available locally, which has all the properties insulation materials is polystyrene at reasonable prices. Therefore, it can be used, which will save a lot of energy as a result of reducing the use of high-capacity cooling devices and provides comfortable conditions for building occupants. It reduces the environmental impact and reduces the material costs due to high energy consumption.

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NOMENCLATURE

CP	specific heat, J. kg^{-1}. K^{-1}
k	thermal conductivity, W.m^{-1}. K^{-1}

Greek symbols

ρ	Density [kg/m_3]