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INVESTIGATION OF PERFORMANCE DIFFERENCE BETWEEN TRADITIONAL AND RECOMMENDED THERMAL INSULATION MODEL

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ABSTRACT

Insulation is the name given to processes and systems that prevent unwanted physical effects or events from passing from one side to the other. Within this scope, preventing heat energy from entering or escaping can be considered as one of these operations. This paper aims to evaluate the traditional types of thermal insulation used for walls in Jordan and recommend an effective new wall type. For this reason, the characteristics of the three types of thermal insulation walls were checked. For example, the thermal transmittance and thermal resistance for each type were determined. The obtained results were compared with the result of the recommended model. The results showed that the thermal transmittance of the recommended model has decreased by 65% with respect to the traditional types. Finally, these results would help for developing the Green Building Guide in Jordan through adopting a specific arrangement of insulation layers, which ensures less energy consumption and thus less harm to the environment.

Keywords: thermal conductivity, thermal resistance, wall insulation.

1. INTRODUCTION

Heat is a type of energy and according to the second Law of Thermodynamics, heat; transfers from high temperature to low-temperature environment. Therefore, in buildings; heavy losses of energy occur in winter and unwanted energy gains occur in summer. In order to provide the desired comfortable environment in the building, the heat lost in winter must be met with a heating system. Likewise, the heat gained in summer must be removed from the interior with a cooling system. Energy is spent on both heating and cooling processes.

Space air conditioners can consume a lot of energy to operate buildings. In a typical American house, for instance, space warming and cooling represent 50-70% of its energy consumption [1]. So too, in Europe, buildings account for 40% of total energy use and 36% of total CO2 emission [2]. Likewise, according to the planning studies, Turkey's final consumption of primary energy is estimated to be 130 million tons of oil equivalents (mtoe) in 2005, 171 mtoe in 2010 and 298 mtoe in 2020 [3]. The energy consumption is dispersed among four primary areas: industrial, building (private), transportation and farming. Clearly the building area is the biggest energy customer following the industrial area [4]. The impact of ceiling and walls insulation on the average energy consumption was determined by [5]. The study showed that in case of using both wall and ceiling insulated, the average consumed energy could be reduced by 40%. In 2015, the sector with the largest share of final energy consumption was the transport sector, which consumed 33.1 % of the total amount of final energy consumption. Residential sector follows with 25.4%. Industry was the third and the contribution of the service sector was the fourth [6]. The main key property of a thermal building insulation material or solution is the thermal conductivity, where the normal strategy or goal is to achieve as low thermal conductivity as possible. A low thermal conductivity (W/(mK)) enables the application of relatively thin building envelopes with a high thermal resistance (m^2K/W) and a low thermal transmittance U-value ($W/(m^2K)$) [7]. To save consumed energy, green roof strategy in its simplest application gives total energy savings up to 17% which could reach higher percentages in more advanced green roof types [8]. Energy efficiency in the residential sector can be improved by upgrading the energy characteristics of buildings or changes in energy-consuming behavior [9]. The average consumed energy by sector in the EU is presented in Figure-1.

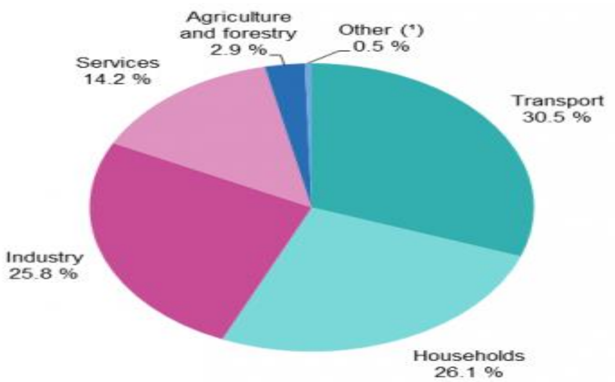

Figure-1. Energy consumption by sector, EU-27, 2018 [10].

The construction sector in Jordan is one of the most basic sectors in the economy, as the population is increasing significantly due to immigration reasons, which depend on the political situation of Jordan's neighboring countries. Also, due to climate changes resulting from the

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worldwide global warming, which makes thermal comfort in spaces more difficult to be achieved. Consequently, energy consumption in Jordan rapidly grows up in recent years. If we analyze this sector, we find that the construction method in Jordan is a traditional method based on the use of local materials. For instance, the outer walls are built with multiple layers, and in most cases, no heat-insulating materials or a low insulation layer are used. Unfortunately, no attention is paid to arranging the building layers in order to obtain thermal conductivities as low as possible. Moreover, in the building regulations and legislation in Jordan, only building models are listed in an unclear manner without mentioning the thermal properties of them [11]. While 95% of the energy used in Jordan is imported, the residential buildings sector is only one of the sectors that consume 21.5% of the total energy consumption; heating consumes 53% of the total energy and 4% for cooling [12]. In this research, three traditions of the used walls cross sections will be inspected and compared with each other and with a developed model developed by researchers. The comparison is based on terms of access to a model that guarantees the best thermal performance with techniques that ensure ease of implementation, possibility of maintenance and reasonable costs.

2. METHODOLOGY

In this research, thermal resistance (R) and thermal transmittance (U) were used to evaluate the used types of wall insulation in Jordan. Thermal resistance is a measure of the resistance (opposition) of heat flow as a result of suppressing conduction, convection and radiation. It is a function of material thermal conductivity, thickness and density [7]. U-Value of building element is given by equation 1 below:

$$U = 1 / (R_{so} + R_{si} + R_1 + R_2 \ldots) \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

R_{so} is the external resistance
R_{si} is the internal resistance
R_1, R_2 etc. are resistivity of all elements within the application.

Thermal resistance value (R) is given by the equation2:

$$R = \frac{\Delta x}{A * K} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

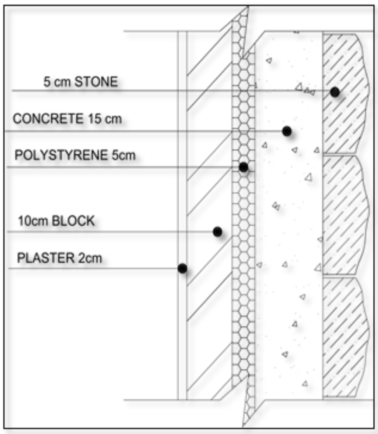
R = absolute thermal resistance (K/W) across the thickness of the sample
Δ_x = thickness (m) of the sample (measured on a path parallel to the heat flow
K = thermal conductivity (W/ (K·m)) of the sample.
A = cross-sectional area (m^2) perpendicular to the path of heat flow

Three different insulation types for walls were investigated; the thermal characteristics of these types were calculated and compared with those for the recommended developed model. The results are presented in the next results analysis paragraph.

3. ANALYSIS AND RESULTS

The types of thermal insulation of traditional walls in Jordan are shown in Figure-2 through Figure-4. The scaled thicknesses of each layer are also presented. The characteristics of the proposed thermal insulation wall are presented in Figure-5. Top view and three-dimensional view of the proposed model are presented in the appendix.

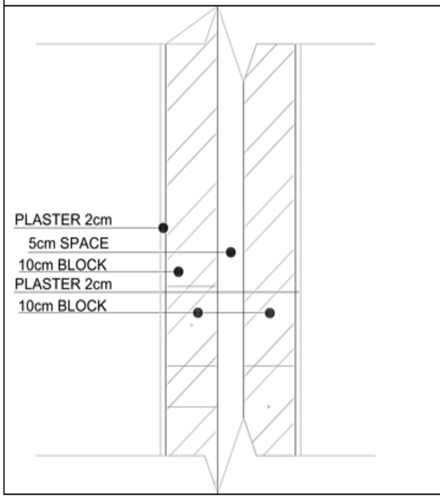
Type 1



Layers
1- Stone 5 cm
2- Concrete 15 cm
3- Polystyrene 5 cm
4- Block 10 cm
5- Plaster 2 cm
Total Thickness: 37 cm

Figure-2. Traditional heat insulation type1 for walls.

Type 2



Layers
1- Plaster 2 cm
2- Block 10 cm
3- Air space 5 cm
4- Block 10 cm
5- Plaster 2 cm
Total Thickness: 30 cm

Figure-3. Traditional heat insulation type 2 for walls.

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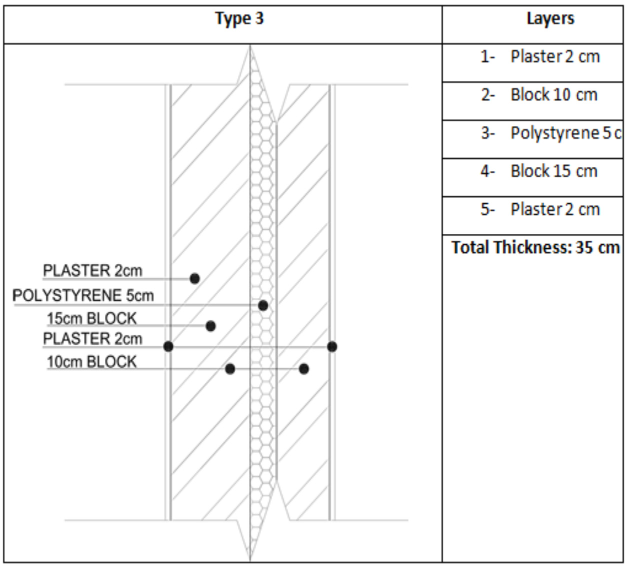

Figure-4. Traditional heat insulation type 3 for walls.

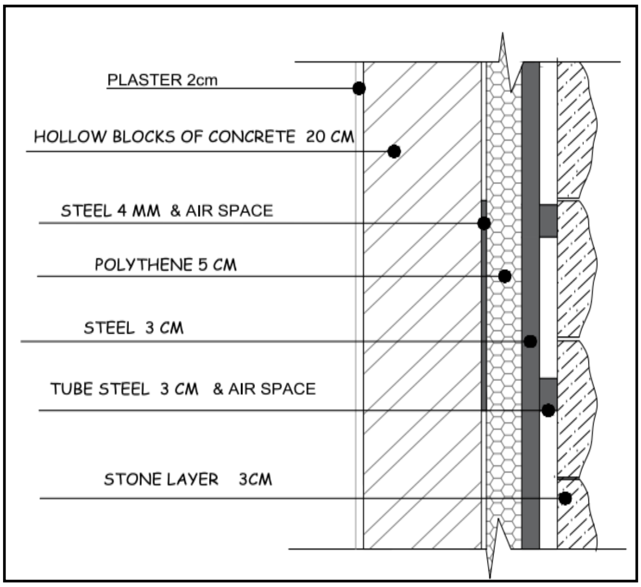

Figure-5. Proposed heat insulation type4 for walls.

Calculation of thermal characteristics like Thermal conductivity, R- value and U- value for all types are presented in Table-1 through Table-4. The analysis showed that the resistance value between the four types is changing from 1.39 (type1) to 5.16 (proposed type). In other meaning, the proposed type has an increase in resistance value by 272% with respect to the most common type in Jordan. These increases have accompanied by a reduction in U-value from 0.71 to 0.19 (-73%). On the other hand, the thickness of the proposed type was 44 cm. Despite the thickness of the wall of the proposed insulation type which was slightly thicker than the traditional types but its effectiveness over a long time gives it an advantage to be used by the related authorities in Jordan.

Table-1. Thermal characteristics of wall type1.

Type$_1$ (most common)	**Thickness (d)**	**Thermal conductivity (k)**	**R value (d/k)**	**U value (1/R)**
			0.10	
Layer 1 (stone)	0.06	1.60	0.04	
Layer 2 (concrete)	0.06	0.87	0.07	
Layer 3(polystyrene)	0.03	0.04	0.83	
Layer 4 (block)	0.10	0.40	0.25	
Layer 5 (plaster)	0.02	0.50	0.04	
			0.04	
Total	0.27	3.41	1.37	0.72

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Table-2. Thermal characteristics of wall type2.

Type2	Thickness (d)	Thermal conductivity (k)	R value (d/k)	U value (1/R)
Layer 1(concrete block)	0.10	0.40	0.25	
Layer 2 (space)	0.06	0.02	2.50	
Layer 3 (concrete block)	0.15	0.40	0.38	
Layer 4 (plaster)	0.02	0.50	0.04	
Layer 5 plaster)	0.02	0.50	0.04	
Total	0.35	1.82	3.21	0.30

Table-3. Thermal characteristics of wall type3.

Type3	Thickness (d)	Thermal conductivity (k)	R value (d/k)	U value (1/R)
Layer 1 (concrete block)	0.15	0.40	0.38	
Layer 2 (polystyrene)	0.06	0.04	1.66	
Layer 3(concrete block)	0.15	0.40	0.38	
Layer 4 (plaster)	0.02	0.50	0.04	
Layer 5(plaster)	0.02	0.50	0.04	
Total	0.40	1.84	2.49	0.38

Table-4. Thermal characteristics of wall type4.

Type 4	Thickness (d)	Thermal conductivity (k)	R value (d/k)	U value (1/R)
Layer 1 (stone)	0.03	1.60	0.02	
Layer 2 (air space)	0.06	0.02	2.50	
Layer 3 (polythyrene)	0.05	0.03	1.92	
Layer 4 (block)	0.20	0.40	0.50	
Layer 5 (plaster)	0.03	0.50	0.06	
Layer 6 (steel)	0.01	14.00	0.00	
rso			0.13	
rsi			0.04	
Total	0.37	16.55	5.17	0.19

Table-5. Thermal comparison of the four-types.

U value (1/R)	R-value (d/k)	Insulation type
Type1	1.39	0.71
Type2	3.33	0.3
Type3	2.66	0.37
Proposed type	5.16	0.19

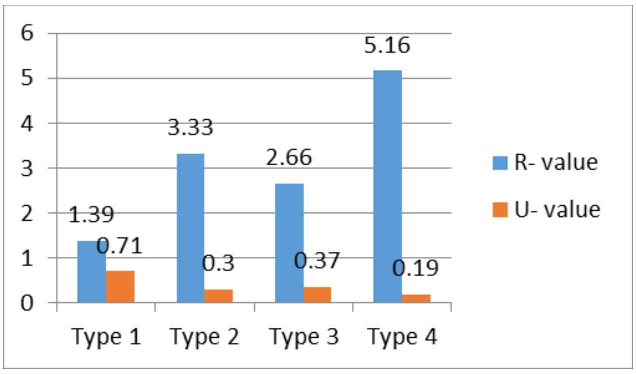

Figure-6. Thermal comparison chart of the four-types.

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APPINDIX1:

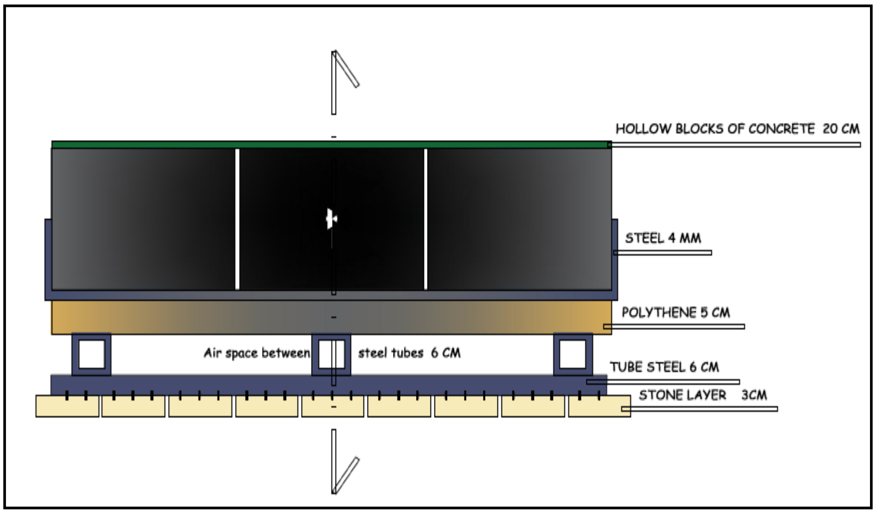

Figure-7. Top view of the proposed model (type4).

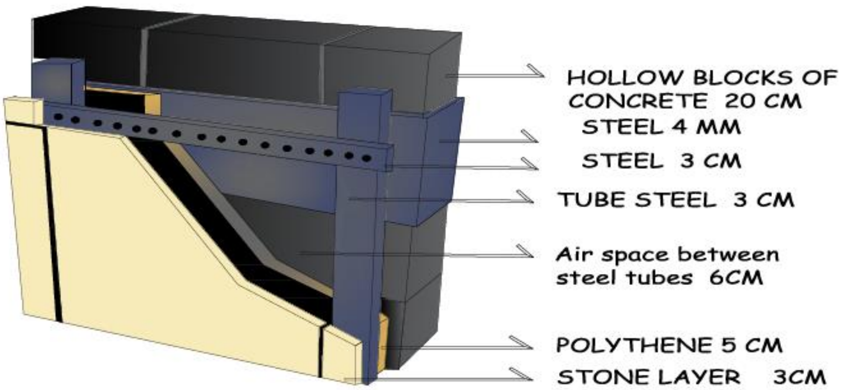

Figure-8. Proposed model (type4) as 3D.

4. CONCLUSIONS

Wall insulation is one of the effective technological ways that could be available for energy conservation. The main objective of this research was to find a new type of wall design of construction applicable for the residential buildings in Jordan which has been applied on the proposed type in figure no. (4) to reduce the energy consumption that comes from heating or cooling of buildings' envelopes by increasing the thermal resistance of the wall. The new materials that have been added will reduce the U- value of the wall by increasing the R-value which makes this technology of building construction a good energy conserver, the evaluation that is shown on the calculations for the modified proposed type on the wall design section materials and their thicknesses will have a great impact on the building wall insulation and make the building envelope more sustainable and stronger facing the weather changes.

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