

Investigation of Thermal Behavior and Comparison of the weight of Constituent materials in the Convectional Outer Shell of Buildings in Iran

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Abstract

Nowadays, with regards to the rapid growth of technology and the production of new materials in the construction industry and move towards industrialization in this sector, paying attention to the active and inactive methods in terms of optimizing in the construction sector, has been of particular importance and imprecision and mismanagement in the selection of consuming materials are of the main problems existing in the building industry [1]. The influence of thermal resistance of surrounding walls is one of the most important parameters of the wall insulation and barriers to waste of energy in buildings. The surrounding walls as the exterior shell of the building play an essential role to reduce cooling and heating loads between the internal and external areas, hence, the use of such material with less weight for thermal insulation of buildings that is energy saving and capable to prevent waste of energy, is of particular importance. Therefore, in the selection of materials for construction, it is necessary that the thermal properties of them and their constituent elements be assessed, especially in the outer shell and surrounding walls. In the present paper, the thermal behavior and the weight of these materials as constituent materials of the outer shell of building are investigated according to existing rules and regulations, in addition, their behavior with each other is taken into consideration.

Key Words: Outer Shell, Building, thermal resistance, Thermal conductivity coefficient, weight of materials

Introduction

In the recent years, urban construction in the country has stepped up towards apartment building and development of cities in the height and not on area. So that in most metropolises, less trace of single story buildings or villas has been remained. The experience of industrial countries obviously reveals the necessity of developing regulations complying with the conditions in each country. In

this regard, the first edition of section 19 of national building regulations entitled saving in energy consumption developed, which the majority of it was about design criteria for thermal insulation of building exterior shell. Energy consumption in the buildings of the country as a non-productive sector has allocated the largest contribution among all sectors of consumption. According to the country's energy balance, more than 40 % of energy consumption is directly used to meet the needs of this section, annually. Perhaps because of the inexpensive price of energy, industry owners and private consumers have not respected energy saving and rational use of it. Whilst, much of the performed researches show that more than half of this amount of energy consumption is wasted due to various reasons. In fact, if the building condition is handled, by the implementation of energy optimizing solutions, enhancing efficiency, and modifying the exploitation pattern, the intended comfort in buildings could be provided with using less than half of this amount of consuming energy. Therefore, it is required to pay attention in order to reduce fuel consumption, save energy and to optimize buildings especially in the case of using appropriate and new materials in design and construction of buildings.
Keywords: thermal resistance, thermal conductivity coefficient, weight, exterior shell, thermal insulation.

Management actions and identification method of the sources of energy loss in buildings

In order to identify the sources of energy loss in residential and commercial buildings, it is required to specify the sources of energy loss and necessary measures be taken to solve it. For this purpose, developing and better understanding of the mechanical, chemical, and thermodynamic properties of materials, light properties as well as familiarity with newly invented materials, and analytical models for studying heating and cooling properties of the materials used, could be useful. Generally, in order to obtain the general information of building, some parameters including building coverages (roof, walls, and floor in terms of type and material), building area, windows and walls area, building form and orientation, specifications, energy consumption system from the viewpoint of climate heating and cooling (temperature and humidity),

size and location of skylights (to optimal use of solar energy), building life, and building lighting should be taken into consideration [2].

The more heat transfer from exterior shell of the building, the faster consumed energy for providing comfort will be lost. In this condition, heating or cooling power is required to provide the lost energy, hence, in order to avoid this wasting, necessary provisions are required to be considered for reducing heat transfer in the outer shell. From the strategies of consumption control in different parts of the final consumer is developing energy consumption criteria. These criteria are defined in three forms in the sector of construction and housing, which include building shell, facilities and lighting system, and household appliances [3].

Outer Shell

The outer shell of building has a significant impact on energy consumption. In this subject, the variety of thermal insulation methods of building exterior shell and adequate selection of methods for existing buildings are investigated. The exterior shell of building consists of all the surrounding surfaces of the building including roofs, openings, light-passing surfaces and so on, which are in connection with outer or uncontrolled space from one side, and are connected to controlled space inside the building, from the other side. The outer shell of a building is not necessarily the same physical shell of building, because the physical shell can also contain uncontrolled spaces, since the physical shell is the entire surrounding surfaces of building including walls, roofs, floors, openings, and so on, which is in connection with outer space from one side, and with inside space, from the other side [4].

The constituent materials of outer shell

Mainly, regarding the use of frame bearing system in the construction of buildings, drywalls are referred as separator panels that are not load bearing and only carry their weight. In the case of placing these drywalls between the building outside and inside and be used in the surrounding places, they are called external drywall or outer shell. Considering that the constituent materials of the outer shell are exposed to sunlight, wind, rain, and snow, they should be specially paid attention in terms of thermal and moisture conductivity, insulation, etc.

In terms of materials, the constituent drywalls of building can be divided into the following types:

- Traditional drywalls made from brick and baked clay such as compressive or ceramic bricks,
- Drywalls made from concrete with expanded clay granules such as Lika,
- Drywalls made of silica sand and lime, cement and aluminum powder such as Siporex,

- Gypsum boards including Perforated gypsum panels,
- Drywalls consist of yonolit insulation with two layers of reinforced sand cement mortar such as walls of Puma system, and
- The variety of walls made of PVC, wood, etc. [5].

Thermal conductivity coefficient and thermal resistance

Restricting heat transfer is one of the most effective ways for saving energy. For this purpose, the entire constituent components of outer shell (which are in connection with controlled spaces from one side, and are connected to outer or uncontrolled spaces, from the other side) should have thermal insulation. Thermal insulation is performed by different methods. According to environmental condition as well as material type and manufacturing method, it can be implemented from inside, outside, or as layers between building elements or the constituent materials of the building element has low thermal conductivity coefficient and acts like thermal insulation.

Generally, the thermal conductivity coefficient is expressed as the amount of heat that flows per unit time (1 sec) through a unit area (1 m²) of a homogenous element with 1 m of thickness in the steady state and creates a temperature variation equal to 1°K between the two surfaces of the element sides. It is shown with λ and is measured in watts per meter kelvin ($W/m^{\circ}K$). Thermal resistance of a layer is the ratio of its thickness (m) to its thermal conductivity coefficient [4]. Moreover, the thermal resistance specifies the insulation capability of one or several layers of the shell or the entire shell and is defined as:

$$R = \frac{d}{\lambda} \quad (1)$$

Where d is measured in m^2k/w . Thus, the lower conductivity coefficient and more thermal resistance of a material, the better insulation will be achieved. In the following table the thermal conductivity coefficient of various materials is summarized. In addition, thermal resistance of an outer multi-layer shell is calculated as follows [6]:

$$R=R_1+R_2+R_3+....R_n=d_1/\lambda_1 + d_2/\lambda_2 + d_3/\lambda_3 + \dots + d_n/\lambda_n$$

Investigation of thermal resistance of various constituent materials of outer shell

Of the most important parameters affecting energy loss in buildings is the type of constituent materials of the buildings, in order to prevent thermal waste in the building coverages, most important parameters must be assessed, which include the design heat transfer coefficient, surface heat transfer coefficient, thermal conductivity coefficient, etc. The less these

heat transfer coefficients will lead to less thermal wasting from the building and more favorite results are obtained. Due to the mechanical strength of the material used in buildings coverages, we may not be able to change thermal resistance of them, largely. However, thermal insulation could be used in these covers in order to fix this issue. The consistent layer of surrounding walls have been only investigated in the present study and it is attempted to compare the thermal resistance of commonly used materials in the building of surrounding walls. The air inside material is neglected and also according to the criteria of section 19 of national building regulations, the application type of the building is considered identically as residential, moderate energy requirements and high thermal requirements are considered. in addition, the building is considered to be located in the region of large cities and the category of moderate energy consumption from the aspects of energy saving provisions. The type of consuming energy is non-electrical and the thermal characteristics of the entire outer shell of the building is considered invariable. The walls are assumed to be made from compressive brick, ceramic brick, Lika brick, hebelex brick, Delijan gypsiferous brick, 3D-Wall, and wall with gypsum insulation of Knauf with plaster on both sides.

Table 1. Thermal conductivity coefficient

Material Type	Gypsum plaster	Cement plaster	Compressive brick	Lika brick	Hebelex brick	Delijan gypsiferous brick	Ceramic brick	Polystyrene
thermal conductivity coefficient	0.35	1.15	1	0.1	0.17	0.35	0.51	0.38

Table 2. Comparison of thermal resistance of constituent materials of outer shell

Material Type	Thickness, d (cm)	Thermal conductivity coefficient, λ	Thermal resistance, R	Total thermal resistance
Compressive brick				
Gypsum plaster	0.3	0.35	0.085	0.311
Cement plaster	0.3	1.15	0.026	
Compressive brick	0.2	1	0.2	
Lika brick				
Gypsum plaster	0.3	0.35	0.085	1.861

Cement plaster	0.3	1.15	0.026	
Lika brick	0.2	1	0.2	
Hebelex brick				
Gypsum plaster	0.3	0.35	0.085	1.287
Cement plaster	0.3	1.15	0.026	
Hebelex brick	0.175	0.1	1.75	
Delijan gypsiferous brick				
Gypsum plaster	0.3	0.35	0.085	0.682
Cement plaster	0.3	1.15	0.026	
Delijan gypsiferous brick	0.2	0.17	1.176	
Ceramic brick				
Gypsum plaster	0.3	0.35	0.085	0.501
Cement plaster	0.3	1.15	0.026	
Ceramic brick	0.2	0.35	0.571	
3D-wall				
Gypsum plaster	0.3	0.35	0.085	2.271
Cement plaster	0.3	1.15	0.086	
Polystyrene insulation	0.08	0.038	2.10	
Knauf				
Gypsum plaster	0.3	0.35	0.071	2.713
Cement plaster	0.3	1.15	0.0108	
Polystyrene layer	0.1	0.38	2.63	

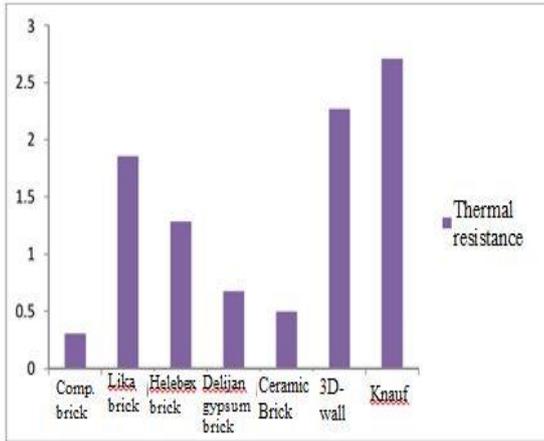


Chart 1. Thermal resistance of constituent materials of outer shell

Table 3. Weight of a square meter of wall with constituent materials of surrounding walls

Wall material	Compressive brick	Lika brick	Helelex brick	Delijan gypsum brick	Ceramic brick	3D-wall	Knauf
Weight (kg/m ²)	480	267.5	230	202	280	257	90

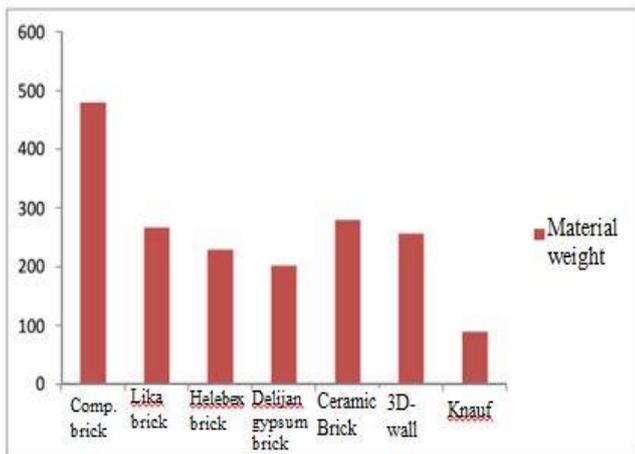


Chart 2. Comparison of the weight of a square meter of wall with constituent materials of surrounding walls

Conclusion

Considering the low cost of energy in the country and non-compliance with laws and regulations and the growth of consumption and intensity of energy in this sector, which is much more than global standards, the necessity of reducing energy in the

buildings requires planning and programming to control the energy consumption. One of these methods is the use of materials with appropriate thermal behavior and lightweight. In the present paper, the steps of investigating thermal resistance of conventional materials used in the outer shell of buildings have been studied according to section 19 of national building regulations, and the comparison of their weight according to available standards. Based on the obtained results, it was observed that the thermal behavior of the walls made from Knauf are more suitable insulation as compared with the other materials and could be an appropriate replacement rather than other materials, especially traditional ones, moreover, the use of these materials could be effective in the weight reduction of buildings. In addition, compressive brick has the less thermal insulation and greater weight than other studied materials. Therefore, the use of Knauf materials is recommended to prevent wasting energy in the building of surrounding walls.

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