Enhancing Residential Building Operation through its Envelope

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ABSTRACT

In this study heat loss is evaluated with the modeling software of Iranian Construction Engineering Organization, for both with and without insulation in the building. Of course the evaluation is in accordance with the laws of this organization, which support environmental and constructional matters. Also the amounts of energy consumption for these two states are compared and a substantial economy of energy consumption is presented. Eventually, results represent that 32% in heat load and 25% in cooling load of the building can be economized. And also most energy loss is related to the windows and the roof of the building.

1- INTRODUCTION

Energy is an essential input to the operation of the global economy. Not only is energy required by all production processes, it is also used in significant amounts directly by final consumers for household services [1]. Actually, with the growth of technology and production of new building staffs the thickness of outer parts of the building (e.g. walls and roof) decreased to the minimum amount; for they have more resistance in comparison with the older versions. As a result of this diminution, the building resistance to energy loss decreases. In industrial countries the production of heat and energy costs more than other countries; as an example China is not only the second largest energy producer in the world, but also the second largest energy consumer[2-3]. So they will pay attention to energy saving. Therefore, with proper insulation, energy loss can be avoided as much as possible. Adding wall insulation in buildings reduces annual energy utilization. It is also admitted in other researches [4-10]. Consequently the use of thermal insulation and special types of building materials has increased significantly in recent years in both hot and cold climate [11]. A proper insulation material also indirectly reduces emission from power plant.[12]. A proper insulation is an optimal insulation thickness where the total investment cost for the insulation can be minimized over the lifetime of the building [13]. As we know the reemergence of concerns about security of the energy supply reflects another significant uncertainty affecting the future energy system [14].

The international standards on calculation of space heating requirements for residential buildings are ISO 9164 and EN 832 [15-17].Here the main aim is the execution of the rules of part 19 of the Iranian Construction Engineering Organization which relates to the national regulation of buildings in Iran. This set of rules which relates to energy economy in buildings is now compulsory for buildings that are more than 1000m^2 and also for zones 1, 2, 3, 4, 5 and 22 of Tehran. As it is programmed to the end of 2013 it will be such an obligation in whole country. For this purpose, energy survey programming, support of companies that produce standard building staff such as two layer glasses, PVC cases and also production of specialized laboratories devoted to building construction, should be considered.

In this study the loss of heat and cooling load is investigated for a three story building in Mashhad (which is a north-east city in Iran) for two cases with and without insulation. Results show that with sufficient insulation, energy consumption can be decreased for about 30-40%. However, in regard to some factors like lack of energy sources in the world or environmental pollution this amount is somehow substantial.

2 INTRODUCTION OF THE SOFTWARE

Various methods with different levels of simplification exist for building energy calculation such as the transfer function, the degree day and bin methods [18]. But in this study a modeling software is used. Aforesaid software which is a modeling one is capable of computation of heat and cooling load in regard to heat transfer from a building to the outer space. So we can organize these loads according to the rules of part 19. Also this software is validated by Iranian Construction Engineering Organization [19]. And because of its good availability and efficiency and for it was in complete agreement with the rules of part 19, and by observing the results driven from this standard in comparison with others in other investigations, this software is chosen. [20]

2-1: Building Analysis With The Software

In this part we need some information which is described as follow:

2-1-1: Information about local climate.

The remarked city is Mashhad and the information needed in this part is available from weather data sources.

Table 1. Geographical Specifications

City name	Mashhad
Location	I.R. of Iran
latitude	36.19°N
longitude	59.37°E
Height form sea level	969.264 m
Dry bulb temperature in summer	38.388°C
Wet bulb temperature in summer	20.72 °C
Range of temperature in a day	28 °
Dry bulb temperature in winter	-9.388°C
Wet bulb temperature in winter	-12.222°C
Atmospheric Pressure	1
Mean reflection coefficient for the earth	0.25
Conduction coefficient of the earth	7.8844 W/m°C
Local time	-3.5+GMT
Beginning of hot days	20th March
Ending of hot days	21th September
Cold days period	October to April

2-2-1: Information on light system and affiliated instrument .

Each floor of the building has its own light system. 1900w is devoted to this system. The instruments used in each floor are:

Iron, oven, cloth washer machine, computer, fan small sonant equipment, TV, vacuum cleaner and refrigerator.

2-1-2: Overall Specifications of the building.

This building has three residential floors and it is located in Mashhad. Four people are living on each floor.

The main volume of the building is like a cube with the following dimensions:

Length: 20.5m

Width: 7m

Height: 9.5m

The north and the south faces of the building are free while the other faces are attached to the adjacent building. The building on the right side is in the same level but the one on the left is somehow lower than the test building. It is assumed that the aisles are ventilated, so the doors of the second floor have no heat transfer.

Also no heat transfer is assumed for inner walls, the roof of the first floor and the floor and the roof of the second floor. Some parts of the floor of the third floor have heat transfer and it is mentioned in calculations.

Now according to the defined specifications, the so called software can compute heat and cooling load. The results of these calculations are categorized. Table 2 includes the results of heat load and table 3 shows the results of cooling load for the building.

Table 2. Heat Load of the Whole Building Before Insulation

	Heat load (MJ in year)	Percentage of whole load
Load due to air ventilation	97356	34.7
Conduction load from the window	131061	46.7
Conduction and radiation load from the door	8489	3
Conduction and radiation load from the roof	21027	7.5
Conduction and radiation load from the walls	11491	4.1
Conduction load from the floor	10870	3.9
Total load	280294	-

Table 3. Cooling Load of the Whole Building Before Insulation

	Cooling load (MJ in year)	Percentage of whole load
Load due to lights	5079	2.4
Conduction load from the windows	10764	5.2
Conduction and radiation load from the door	1031	0.05
Load due to living people in the building	9399	4.5
Load from the floor	184	0.008
Conduction and radiation load from the walls	2820	1.4
Load due to sunshine	154500	74.8
Load due to equipments	11487	5.6
Load from the roof	4300	2
Load due to air ventilation	7053	3.4
Total load	206617	-

As it is shown in the tables, all amounts of heat and cooling load are computed with negligence of the rules of part 19.

Figures demonstrate that there is great amount of energy loss in the building and this is not proper to our environment. Also it is in great confliction with energy economy. So it would be better to think about proper insulation system.

3- INSULATION

Insulation has e great deal in keeping the buildings warm in winter and cool in summer. With this system, the building can be kept for about 5°C warmer in winter and 10°C cooler in summer. Assessment shows that 9cm of woolly insulation is equal to 3m cement, in decreasing fuel utilization and troublous noises and avoiding energy loss.

If we spend 2% more expenses for woolly insulation, 40% energy economy is possible and also it avoids outside noises to get into the building.

Statistics show that insulation costs about 1.8% of the whole expenses for a building. But its privileges are valuable. In one year the habitants of the building can pay the expenditure of insulation with the amount which remains from fuel and electricity economy. It is obvious that a well-insulated building as a higher insulation costs if compared with a purely-insulated one, this costs affect the financial performances of the building during its life cycle in a way that it is seldom taken into account .[21]

According to the rules of part 19, following statements should be kept under consideration:

- Insulation of outer walls.
- Insulation of duplex windows with wooden, standard PVC or thermal break metal cases.
- Insulation of local controller systems like thermostat valves or radiators.
- Insulation of sagacious central control system equipped to ambient air temperature sensor.

A remarkable fact is that humidity reduces the quality of insulation materials. So sweating of warm surfaces should not be neglected. To avoid sweating chiefly for the roof, a special insulation layer which resists vapor can be used to prevent humidity from entering the building.

With respect to the rules of part 19 the least requirements that are needed for the license of the building are:

- Efficiency testimony of the engineer or the designer company.
- Energy checklist.
- Control checklist for outer parts of the building.
- Building plots.
- Characteristics of used materials and insulation system in outer parts of the building.
- Technical specifications of heating, cooling, ventilation and light system, and also the way warm water is provided for whole building utilization.

A list of materials used to have proper insulation is mentioned in Table 4. These materials are surely chosen according to their properties that one important example of that, can be thermal conductivity. Availability and expenses are taken into consideration too.

Table 4.a. Materials Utilized for roofs & Floors

Roof 1	Precast specimen including carton cover with thickness of 1.5cm-glass wool with thickness of 5cm-cement block with thickness of 25cm -light weight concrete with thickness of 5cm -sand cement mortar with thickness of 3cm - granite with thickness of 3cm.
Roof 2	Precast specimen including carton cover with thickness of 1.5cm-glass wool with thickness of 5cm -cement block with thickness of 25cm -light weight concrete with thickness of 5cm -sand cement mortar with thickness of 3cm - granite with thickness of 3cm.
Floor 1	sand cement mortar with thickness of 3cm - marble stone with thickness of 3cm - rock wool with thickness of 5cm - light weight concrete with thickness of 10cm - granite with thickness of 3cm on free surface.
Floor 2	Baked clay with thickness of 25cm - marble stone with thickness of 5cm on uncontrolled surface.

Table 4.b. Materials Utilized for Doors,Walls & windows

Wall 1	Rock wool with density of 25 to 35 with thickness of 10cm- Rock wool with density of 35 to 80 with thickness of 20cm- cellulosic cement with density of 1400 to 1800 with thickness of 5cm in south direction.
Wall 2	Rock wool with density of 25 to 35 with thickness of 10cm- Rock wool with density of 35 to 80 with thickness of 20cm- cellulosic cement with density of 1400 to 1800 with thickness of 5cm in north direction.
Wall 3	Rock wool with density of 25 to 35 with thickness of 10cm- Rock wool with density of 35 to 80 with thickness of 20cm- cellulosic cement with density of 1400 to 1800 with thickness of 5cm in west direction.
Wall 4	Rock wool with density of 25 to 35 with thickness of 10cm- Rock wool with density of 35 to 80 with thickness of 20cm- cellulosic cement with density of 1400 to 1800 with thickness of 5cm in north direction.
Door 1	Wooden door with high quality material with thickness of 2.5 in north direction
Door 2	Oak tree, Ash tree and other fruitful trees with density of 650 to 800 with thickness of 3cm in south direction.
Window 1	Double window with clearance of 12 mm, PVC frame, inner curtain in south direction
Window 2	Double window with clearance of 12 mm, PVC frame, inner curtain in north direction
Window 3	Double window with clearance of 12 mm, PVC frame, inner curtain in south direction

Actually here, one of important physical properties of these used materials, thermal conductivity is shown in Table 5:

Table 5. Thermal Conductivity of used material

Material	Thermal Conductivity (w/m°k)
Glass wool	0.04
Rock wool	0.045
Concrete, light	0.42
cellulose	0.039
PVC	0.19
cement	1.01
Cement mortar	1.73
Granite	1.7 - 4
Oak tree	0.17
Marble stone	2.08 - 2.94

Here, table 6 and table 7 show the results for heat and cooling load respectively after insulation.

Table 6. Heat Load of the Whole Building after Insulation

	Heat load (MJ in year)	Percentage of whole load
Load due to air ventilation	97356	50.7
Conduction load from the window	54234	28.2
Conduction and radiation load from the door	7068	3.7
Conduction and radiation load from the roof	11868	6.2
Conduction and radiation load from the walls	11491	6
Conduction load from the floor	10016	5.2
Total load	192033	-

Table 7. Cooling Load of the Whole Building after Insulation

	Cooling load (MJ in year)	Percentage of whole load
Load due to lights	5079	3.2
Conduction load from the windows	4454	2.9
Conduction and radiation load from the door	950	0.6
Load due to living people in the building	9399	6
Load from the floor	135	0.08
Conduction and radiation load from the walls	2820	1.8
Load due to sunshine	112784	72
Load due to equipments	11487	7.3
Load from the roof	2110	1.3
Load due to air ventilation	7053	4.5
Total load	156271	-

As it is shown, the building obeys the rules of part 19 and so as a result there is tangible diminution in energy loss.

4- RESULTS & DISCUSSION

In figure 1 there are two cases. In the first case, the condition with no proper insulation is represented for both heating and cooling load. And in the second one the results of using efficient insulation is shown.

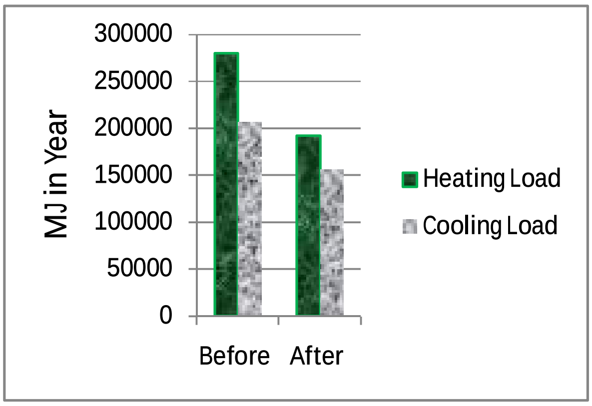

Figure 1. Comparison of Heating & Cooling Load Before insulation and After that, in Whole Building

As it was expected sensible economy is occurred and the percentage of this economy is shown in table 8.

Table 8. Economy Percentage for Whole Building

	Heat load	Cooling load
Before insulation	280294	206617
After insulation	192033	156271
Percentage saving	32%	25%

In previous parts the figures and tables demonstrated total load for the building. Now to have a better viewpoint of the amount of economy, investigation is done for the window, door, roof, floor and sunshine separately.

In this way it can be concluded which parts of the building are more critical and more attention should be paid to them. Also it can be clear that how effective was the insulation for different parts in their heat transfer. Table 9 shows so-called information.

Table9. Economy Percentage for Special parts of the Building

	Heating	Cooling
Window	58%	57%
Door	18%	9%
Roof	45%	51%
Floor	9%	27%
Sunshine	-	28%

After all these figures and tables, a good result can be obtained. As it is obvious the most economy took place in windows and roofs. The reason goes back to kind of materials used in this parts and their positions for instance hot air goes up to the roof and so the roof is in more contact of these hot air. Therefore using a good insulation system is mandatory. The result of this process is 50% diminish in fuel consumption and this is remarkable. So if there are limitations to have proper insulation, at least enough attention should be paid to these critical parts.

Sometimes in some countries the importance of proper insulation was downplayed. So there was no urge on building constituents to think about insulation materials. Therewith the notability of insulation did not improve. As an example it can be mentioned that the best insulation for a building costs 3.9% of total cost of the building and if the government offers cheap fuel to people, they have no propensity to pay for insulation, whereas in optimization perspective, in order to diminish the costs of repelling environmental pollutants, it is worthy to use proper insulation. Thereupon a good balance of the real price of fuel and the total price can have good effect on optimization.

Economically with analyzing the maximum and minimum amount of expenses that is due to insulation it will be about 3.7% of total expenses of the building. With respect to energy economy the minimum amount which is needed for insulation is 0.11% of total expenses whereas people's unawareness toward these subjects, results the state of not using insulation. So with permanent supervision on the execution of the so called rules, energy economy will improve.

Application of insulation for decreasing green house gases is not just devoted to developed countries and all changes to the environment or climate, affect the whole world.

5- CONCLUDING REMARKS

In this investigation, computation is done by using Iranian Construction Engineering Organization modeling software for two scenarios. First the condition with no insulation and then the case with proper insulation is verified. Considering mentioned results, below remarks can be taken into consideration:

1- Compulsory regulation should be put for regions that experience hot summer or cold winter to have expedient insulation in order to economize energy and prevent the environment from being polluted.

2- Mediums should try to improve people's knowledge of the advantages of insulation and energy economy.

3- Building constructors should regard this fact that if they spend more on a building to have convenient insulation it will soon be compensated with energy economy.

4- It should be taken into consideration that to have optimized heat transfer coefficient, the expenses of insulation which include preparation and installation should be in appropriate balance with other expenses.

5- The designer of insulation should try to set the heat transfer coefficient of the walls and the roof in the same range.

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