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[Abstract:0030][Energy Efficient Buildings]

STUDY OF DIFFERENT SCENARIOS OF BUILDING EXTERIOR INSULATION SYSTEM USING EQUEST

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SUMMARY

In this paper, a study of the effect of varying the insulation type and thickness on heat space energy consumption. Different thicknesses of polystyrene, polyurethane and polyisocynurate has been used in three scenarios for each type of insulation material, small, medium and large. The simulation was performed by using the eQUEST software. This software which has been found by previous work to be the most close to the real recorded values for energy consumption. A comparison between the thickness variation with the same insulation and the heat space energy consumption , as well as the comparison between different types of insulation with the same thicknes and heating energy are investigated. Results of the simulation show that when increasing the thickness of insulation results in a decrease of energy consumed,, butut doubling the thickness of insulation does not result in the doubling the savings of energy.

INTRODUCTION

Jinghua Yu et al [1] use eQUEST software to analyse the effects of envelope factors on energy saving of AC, which included five single strategies of exterior wall thermal insulation absorbance of exterior wall, ratio of window to wall, categories of glazing and kinds of shading system, and two combined strategies. The effect of heat insulating on heating and cooling energy consumption of residential building in hot summer and cold winter zone have been studied by [2]. The influence of residential air conditioning load on the exterior wall heat insulation in hot summer and cold winter zone was studied by [3]. The impact of structure and environment on global energy consumption was developed by [4]. C. Filippin, S. Flores Larsen, [5] analysed the energy consumption patterns in multi-family housing in a moderate cold climate, he found that the winter energy consumption of the multifamily dwellings is lower that of single-family dwelling. Turki and Zaki [6] investigated the effect of insulation and energy storing layers upon the cooling load. Bolatturk [7] calculated the optimum insulation thicknesses, energy savings and payback periods. He used the heating degree-days concept to obtain the annual heating and cooling requirements of building in different climates zones. Durmayaz et al [8] estimated the heating energy requirement in building based on degree hour method on human comfort level. Some researchers used the life cycle cost analysis to optimize the insulation thickness Hasan [9]. The effects of insulation materials on energy saving in Iranian building are studied by Farhanieh and Sattari [10]. Bokos [11] study the comparison in energy savings before and after application of thermal insulation in the exterior envelope. The natural gas consumed by residential heating systems in terms of degree-days is studied by Sarak and Satman [12]. A mathematical model was developed by Sofrata and Salmeen [13] to find the optimal insulation thickness. Mohammed and Khawaja [14] determined the optimum thickness of insulation for some insulating materials used in order to reduce the rate of heat flow to the building in hot countries, and he mentioned that the solar radiation has the most important factor. The effect of climatic zones on the choice of the insulation type and thickness has been studied by Sallal[15] using the life cycle model. The life cycle cost analysis using the degree day was also used by Comakli and Yuksel [16] to investigate the optimum thickness of insulation for coldest cities in Turkey. Daous et all [17], used also life cycle cost analysis in order to determine the optimal insulation thickness under steady periodic conditions. Sisman et al [18] determine the optimum insulation thickness for different degree day region in Turkey for a lifecycle number of years by taking in consideration the thermal conductivity and the price of insulation material, average temperature in the region, fuel price for the heating and the present worth factor PWF. Dombayaci [19] studied the environmental impact of optimum insulation thickness; he used coal as a fuel source, and expanded polystyrene as insulation material. The effect of average electricity tariff on the optimum insulation thickness in building walls by using a dynamic heat transfer model and an economic model based on the present worth method was investigated by Al-Sanea et all [20]. Mahlia et al [21] developed correlation between thermal conductivity and the thickness of selected insulation material s for building wall. Significant economic advantage in energy consumption can be seen by using insulation to achieve high performance building envelope was demonstrated by Lollint [22]. Ozel and Pihtili [23] used an implicit finite difference method for multi-layer wall during winter and summer to obtain the optimum location and distribution of insulation for all wall orientations. S.Ali Hussain [24] Jafri make a review of soon optimum insulation thickness for building envelope, he summarized previous references, the place, the insulation material and thermal conductivity, and components of building envelope. Alexander Gorshkov, et al used the life cycle analysis to assess energy savings delivered by building insulation.

METHODS.

The building envelope construction is composed of three mean parts, roof surfaces, above grade walls, and ground floor, the roof surfaces and above grade walls characteristics are divided into five parts, construction, external finish and colour, exterior insulation, additional insulation and interior insulation. For construction, different scenarios can be fitted from eQUEST library such as wood frame standard, wood frame, wood frame 24 in, wood frame > 24in, metal frame 24 in and, metal frame > 24in, or it can be costumed layer by layer.

For external finish we can choose any material from the following: Aluminium, asphalt pavement, clay tile, concrete, felt, bituminous, film, Mylar aluminized, glass spandrel, gravel, marble, roof built up, roofing shingle, steel galvanized bright or weathered, vapour deposited low-e coating, and wood/plywood. For the colour we can choose any colour from dark to white, gloss or flat, or lacquer, we can also choose the colour according to the absorption coefficient.

Exterior insulation, polystyrene with standard thickness from 1, 1.5, 2,3,4,5,and 6in may be used in our variables scenarios, then polyurethane with the thicknesses from 1,1.5,2,3,4,5,6in, polyisocyanurate may also be used in our examples with the same standard thickness. Thermal values of polystyrene are ranged from R-4, for a thickness of 1in, to R-30 for a thickness of 6in, values for polyurethane range from R-6 for a thickness of 1in, to a value of 36 for a thickness of 6in, values of thermal resistance of insulation with polyisocyanurate varies from R-9 for a thickness of 1in, to a value of 42 for a thickness of 6in.

Additional insulation are expressed in thermal values, and the eQUEST software give standard values of R-7, R-11, R-13, R-15, R-19,, R-21, R-26, R-30, R-38,R-49,and R-60.

Ground floor is defined by its exposure, on earth contact, over conditioned space (adiabatic), crawl space, unconditioned space, parking garage, or exposed to ambient conditions, the type of construction of the ground floor can be 2, 4, 6, or 8in concrete, or 1in to 2in plywood underlayment. Exterior cavity insulation can be from ploystyrene , polyurethane, polyisosyanurate, with different thickness ranging from 1,1.5.2,3,4,5in, or with batt insulation with different R values ranging from R-3to R-38. Interior insulation could be from polystyrene, polyurethane, or polyisosyanurate, with different thicknesses and R-values from R-4 to R-2. Light concrete with thickness ranging from 1.25 to 4in can be used as internal finish, different kind of carpet with pad or without pad, fibre or rubber pad, tile from vinyl, ceramic or stones may be used as finish. When the slab penetrates the wall plan, the type of slab insulation could be the same as the insulation materials used before, and the slab edge finish can be aluminium, asphalt, brick, concrete, film, glass, marble, steel, stucco, vapour deposit, or wood/plywood.

Building interior construction. Building interior construction is divided in four main parts, the top floor ceiling (above attic), other floor ceiling, vertical walls, and floors. The top floor ceiling is composed of interior finish, framing, Batt insulation, and rigid insulation. Interior finish may be made of lay-In acoustic tile, drywall finish, or plaster finish. Batt insulation, canFramimg is made of wood standard framing, wood advanced framing, or metal stud 24in o.c. The batt insulation that could be added to the top floor ceiling have a standard R values ranging from R-3 to R-60. The rigid insulations that may be fixed on the top floor ceiling are polystyrene, polyurethane, or polyisocyanurate with a thickness of 1in or 1.5in. For other floor ceiling, between each level, interior finish could the same as in the top floor ceiling, lay-In acoustic tile, dry wall finish or plaster finish. The batt insulation R values for other floor ceiling have values of R-11, R-13, R-19, R21, and R-30. Floors are characterized by their internal finish, construction, concrete cab, and their rigid insulation. Internal finish may be made of carpet, carpet with rubber pad, carpet with fibre pad, vinyl tile or ceramic/stone tile. Construction may be made of 2 to 8in concrete, or 1 to 2in plywood underlayment. Concrete cap may be made of 1.25in of light weight concrete to 4in LW concrete. Rigid insulation is made of polystyrene, polyurethane, ployisocyanurate, with thickness ranging from 1in to 3in.

Different scenarios.

The building chosen to be considered in the following is a multifamily mid rise, and is situated at Ledrugas street, number 7, Riga, Latvia, the weather data file for Latvia is used, the building area is measured in feet (2230.3.76 ft), the number of levels is 5, and as a heating equipment a heating coil, the year 2010 is chosen for the simulation. The roof is not pitched roof, but it is 6in attic above last floor.

The roof surfaces construction chosen is metal frame 24 in,o,c. as external finish we choose asphalt pavement weathered, and medium colour of 0.6 abs.

For above grade walls, we choose for construction HW concrete of width 4inches, and with no external finish, with a medium absorption of 0.6, and 2 in polystyrene as external insulation.

For floor, the exposure over crawl space was chosen, the construction chosen is 4 in concrete, the external insulation 2 in polystyrene R-8, interior insulation used 1 in polystyrene and as a finish 1.25 of LW concrete and vinyl tile, and there was no board insulation or finish selected for slab edge penetring wall plane.

The simulation results for electrical energy consumption are given in MWh, but for space heating and domestic hot water, the simulation results are given in gas consumption by one million Btu, or Mbthu.

Strategies
Three mean strategies were adopted for the analysis of the effects of varying insulation type, and thickness on annual heating space energy consumption. The first strategy is to act upon the external building envelope insulation, by changing the thickness and the type, while keeping all the others, interior building insulation and windows type and categories constant. The external building envelope is divided in three parts, exterior insulation for roof, above grade wall (vertical wall), and ground floor. The second strategy is to act upon interior construction, by changing the thickness of batt insulation while keeping all the others as constant. The interior construction is divided in three parts as well, top floor ceiling (under attic), other ceiling, vertical walls, and floors, but vertical walls, other ceiling and floors are kept constant without variation during these scenarios. The third strategy is to act upon exterior windows type and glazing on space heating energy consumption.

The external building envelope. For the external building envelope insulation three type of insulation were used, the polystyrene, the polyurethane, and the polisoycynurate with different thicknesses, we choose small, medium and large insulation thicknesses. The following table 1 summarizes the different insulation scenarios.

Table 1 sumarizes the differents insulation scenarios.

Scenarios	Insulation type	Thickness in inches	Roof insulation	Above grade wall	Ground floor
1	Polystyrene	thickness	2	2	2
2	Polystyrene	thickness	4	3	4
3	Polystyrene	thickness	6	3	5
4	Polyurethane	thickness	2	2	2
5	Polyurethane	thickness	4	3	4
6	Polyurethane	thickness	6	3	5
7	polyisocynurate	thickness	2	2	2
8	polyisocynurate	thickness	4	3	4
9	polyisocynurate	thickness	6	3	5

RESULTS.

Polystyrene thicknesses effects on space heating energy consumption
The results of the comparaison of the space heating annual energy consumption, when acting upon building exterior envelope insolation by changing the thickness of the insolation material while maintaning the other factors constant, to eveluate only the effect of adding more insolation using the same type (polystyrene in Scenarios 1,2, and 3), In the first scenario, the polystyrene thickness are 2 inches for roof, wall, and floor. In the second scenario, the polystyrene thickness are 4 in for the roof, 3 inshes for the wall, and 4 in for the floor, and in the third scenario 6in insolation for the roof, 3 in for the wall, and 5 in for the floor. The results are given in million Btu and are summarized in Figure 1.

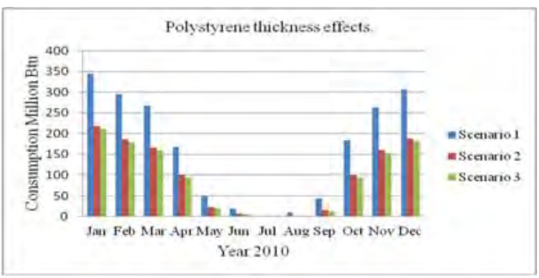

Figure 1. Polystyrene thickness effects on energy consumption

Polyurethane thicknesses effects on space heating energy consumption
The results of the variation of the thickness of the polyurethane used as insolation material for the building envelope(roof, wall, and floors), on the space heating annual energy consumption when keeping the other factors constant, ,are given in Figure 2. The insolation material thickness used in scenario 4,5, and 6. In the 4 scenario, the polyurethane thickness are 2 inches for roof, 2 inches for the wall, and 2 inches for the floor. In the fifth scenario, the polyurethane thickness are 4 in for the roof, 3 inshes for the wall, and 4 in for the floor, and in the sixth scenario 6in insolation for the roof, 3 in for the wall, and 5 in for the floor. The results are illustrated in Figure 2.

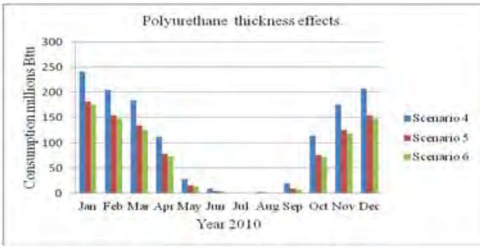

Figure 2. Polyurethane thickness effects on energy consumption

Polyisocyanurate thicknesses effects on space heating energy consumption

The results of the variation of the thickness of the polyisocynurate used as insolation material for the building envelope(roof, wall, and floors), on the space heating annual energy consumption when keeping the other factors constant, ,are given in Figure 3. The insolation material thickness used in scenario 7,8, and 9. In the 7th scenario, the polyisocyanurate thickness are 2 inches for roof, 2 inches for the wall, and 2 inches for the floor. In the 8th scenario, the polyisocynurate thickness are 4 in for the roof, 3 inshes for the wall, and 4 in for the floor, and in the 9th scenario 6in insolation for the roof, 3 in for the wall, and 5 in for the floor. The results are illustrated in Figure 3.

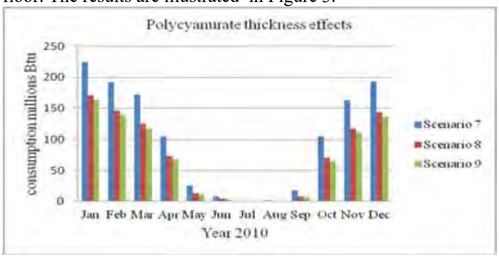

Figure 3. Polyisocyanurate thickness effects on energy consumption

Comparison of energy consumption for small thickness of different insulations types.

The comparison between different insulation materials with the same thickness are shown in the figure 4, the scenario 1 refers to the polystyrene material with 2 inches thickness used for roof, 2 inches for wall, and 2 inches for floor, the scenario 4 refers to the polyurethane insulation material with the same thickness as for the polystyrene. And scenario 7 refers to the insulation material polyisocyanurate of 2 in thickness for roof, wall and floor. The results are illustrated in Figure 4.

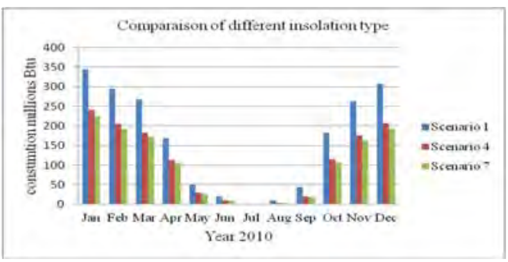

Figure 4. Comparison of different insulation type small thickness.

Comparison of energy consumption for medium thickness of different insulations types.

The comparison between different insulation materials with medium thickness are shown in the figure 5, the scenario 2 refers to the polystyrene material with 4 inches thickness used for roof, 3 inches for wall, and 4 inches for floor, the scenario 5 refers to the polyurethane insulation material with the same thickness as for the polystyrene. And scenario 8 refers to the insulation material (polyisocyanurate) of 4 in thickness for roof, 3 inches for wall, and 4 in for floor. The results are illustrated in Figure 5.

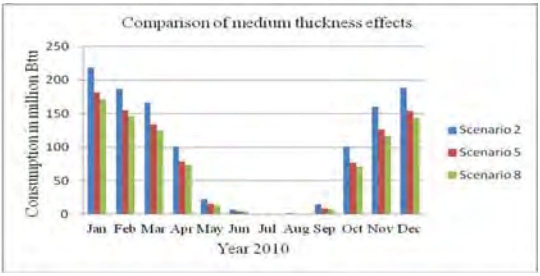

Figure 5. Comparison of different insulation type medium thickness.

Comparison of energy consumption for large thickness of different insulations types.

The comparison between different insulation materials with large thickness are shown in the figure 6, the scenario 3 refers to the polystyrene material with 6 inches thickness used for roof, 3 inches for wall, and 5 inches for floor, the scenario 6 refers to the polyurethane insulation material with the same thickness as for the polystyrene. And scenario 9 refers to the insulation material (polyisocyanurate) of 6 in thickness for roof, 3 inches for wall, and 5 in for floor. The results are illustrated in Figure 6.

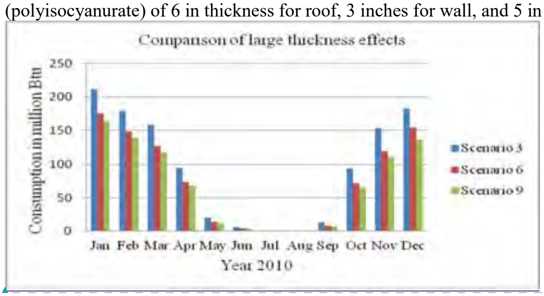

Figure 6. Comparison of different insulation type medium thickness.

DISCUSSION

As a conclusion the use of scenario 2 (4in for roof, 3 in for wall, and 4 in for floor) as insulation for external envelope is more convinient than scenario 3 (6 in roof, 3in wall, 5 in floor). The mean different percentage of gain is only 2.52%. while the percentage of added thickness of insulation is is 33.33% for the roof insulation and 20% for the floor insulation, the wall insulation remains with the same thickness 3 inches.

The use of scenario 5 (4in for roof, 3 in for wall, and 4 in for floor) as insulation for external envelope is more convinient than scenario 6 (6 in roof, 3in wall, 5 in floor). The mean different percentage of gain is only 3.66%. while the percentage of added thickness of insulation is is 33.33% for the roof insulation and 20% for the floor insulation, the wall insulation remains with the same thickness 3 inches.

The use of scenario 8 (4in for roof, 3 in for wall, and 4 in for floor) as insulation for external envelope is more convinient than scenario 9 (6 in roof, 3in wall, 5 in floor). The mean different percentage of gain is only 3.99%. while the percentage of added thickness of insulation remains with the same thickness as in previous scenario.

As a conclusion the use of polyurethane and polyisocyanurate as insulation for external envelope seems to be more efficient than using polystyrene, with the same thickness of 2 inches each. The mean percentage of energy saved in space heating when using polyurethane is 32.57%, and when using the polyisocynurate is 37.18% with a difference of 4.62% between polyurethane and polyisocynurate. If the cost difference is large between polyurethane and polyisocynurate, then the most efficient insulation to be used is the polyurethane.

The conclusion of the use of polyurethane and polyisocyanurate as insulation for external envelope seems to be more efficient than using polystyrene, with the same thickness. The mean percentage of energy saved in space heating when using polyurethane is 19.45%, and when using the polyisocynurate is 25.02% with a difference of 5.57% between polyurethane and polyisocynurate. If the cost difference is large between polyurethane and poliisocynurate, then the most efficient insulation to be used is the polyurethane.

The conclusion of the use of polyurethane and polyisocyanurate as insulation for external envelope seems to be more efficient than using polystyrene, with the same thickness. The mean percentage of energy saved in space heating when using polyurethane is 19.52%, and when using the polyisocynurate is 25.97% with a difference of 6.45% between polyurethane and polyisocynurate. The most efficient insulation to be used is the polyurethane.

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