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A simplified analysis method to predict the impact of thermal insulation on the heating and cooling loads in residential buildings in Syria

Rayan Azhari

MSc Sustainable Buildings performance and design, Oxford Brookes University, UK.
E-mail: rayanazhari@gmail.com

Abstract

This paper provides a simplified analysis method to reduce energy demand in residential buildings in Syria, focusing on minimizing heating loads, which accounts over than 55% of the total energy consumption, as well as reducing heat loss without causing summer overheating. The simplified analysis method is developed based on detailed simulation analyses utilizing several combinations of passive design strategies (construction materials, glazing types, and climate). A direct correlation would be established between the developed methods and the heating energy requirement as well as the total cooling loads, finally a recommended structural system will be introduced.

1. Introduction

The thermal insulation of the building has a major effect on both construction costs as well as energy costs of buildings. The Building Thermal Insulation Code was issued in 2007 in Syria by the Ministry of Electricity and the National Energy Research Centre (NERC), the recommended structural system is; u-values (0.8 $W/m^2/k$) for walls (Double blocks wall 20cm each & limestone external rendering) without the use of any insulating materials, and (3.5 $W/m^2/k$) double glazing for windows (Keshkeh, 2007). Neither studies have fairly investigated the impact of the building thermal insulation on its thermal performance for the climate in Syria, nor were conclusive and simple correlations established between the basic aspects associated with buildings' envelope insulation and their total annual heating/cooling loads.

Some limited investigations have focused on minimising the energy demand by applying different types of thermal insulation to the building's envelope. The reported studies used relatively simplified methods to classify and recommend the best solution. For instance, Fadi Ajjoub, in his research, which was titled: *Designing a low energy dwelling in Syria using Passive Design strategies to achieve thermal comfort*, Ajjoub recommended the Syrian code as the best thermal insulation type among all the other proposed types ignoring the financial aspect and the thickness of the wall (Ajjoub, 2010).

In this paper, a simplified analysis method is suggested to evaluate the impact of building's thermal insulation on total annual heating/cooling load in Syria. First, the exemplary residential building model is described. Then, the results of the parametric analysis are summarized. Finally, the simplified analysis method is developed.

2. Parametric analysis

A typical residential building was modelled using the IES (Integrated Environmental Design) software with typical Middle Eastern residential space occupancy patterns as following:

- Lighting power density = 7.8 W/m^2
- Equipment power density = 8.0 W/m^2
- Average occupancy density level of 25.5 m^2/person
- Cooling set-point is 25°C, and heating set-points are 19°C for living room and 18°C for bedrooms kitchen and Bathroom
- Window to wall ratio was fixed all the time

Several factors were varied to estimate the annual heating and cooling loads with different wall structures and glazing types. See tables 1, 2.

Table 1 different wall construction types with thicknesses and u-values

Wall type	**Wall thickness** cm	**U-value** $W/m^2/k$
Concrete Blocks 15cm & limestone (external rendering)	25	1.7
Concrete Blocks 20cm & limestone (external rendering)	30	1.5
Concrete Blocks 25cm & limestone (external rendering)	35	1.3
(2x 10cm) Double Concrete block & limestone (external rendering)	30	1.18
(2x 15cm) Double Concrete block & limestone (external rendering)	40	0.96
(2x 20cm) Double Concrete block & limestone (external rendering)	50	0.8
10cm Concrete block & 5cm insulation & limestone (external rendering)	25	0.4
10cm Concrete block & 10cm insulation & limestone (external rendering)	30	0.22
10cm Concrete block & 15cm insulation & limestone (external rendering)	35	0.15

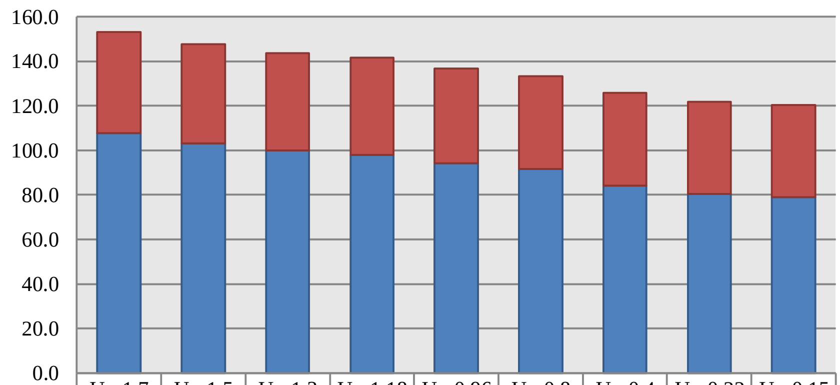
Table 2 Window types used in simulations

Window type	**U-value** $W/m^2/k$
Single glazed (Base-case)	5.6
Double glazed	1.9
Triple glazed	0.8

This experiment was divided into three parts; the first includes applying different wall constructions to the building and finding out the different effects on heating and cooling. Whereas the second and third parts include changing the glazing type from single into double then triple and run all the previous simulations again.

3. Discussion of results

3.1 <u>*Impact of wall construction and insulation*</u>: To determine the effect of the thermal insulation on the variation of total heating and cooling loads, an experiment was conducted for the building located in Damascus-Syria. The results of the simulation analysis are illustrated in Fig. 1 for both cooling and heating energy requirements, when the windows were fixed to single glazed with a u-value of (5.6 $W/m^2/k$). It is clear that the higher is the building envelope insulation, the lower are the heating and cooling loads.

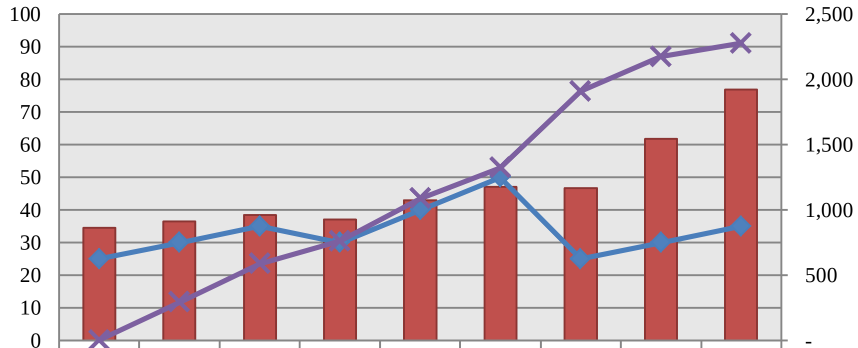


	U= 1.7	U= 1.5	U= 1.3	U= 1.18	U= 0.96	U= 0.8	U= 0.4	U= 0.22	U= 0.15
Cooling Load KWh/m2/year	45.3	44.6	43.6	43.7	42.5	41.9	41.8	41.4	41.2
Heating Load KWh/m2/year	107.8	103.3	100.1	97.9	94.2	91.5	84.0	80.5	79.1

Figure 1 shows heating and cooling loads as a result of changing wall insulation.

It can be noticed that the heating load can be reduced 26.58% by only improving the wall insulation. While only 9.04% of the cooling load could be reduced.

3.2 *Impact of installation cost*: Fig. 2 presents the impact of the wall cost per m^2 in relation to its thickness as well as its performance. As long as the wall thermal

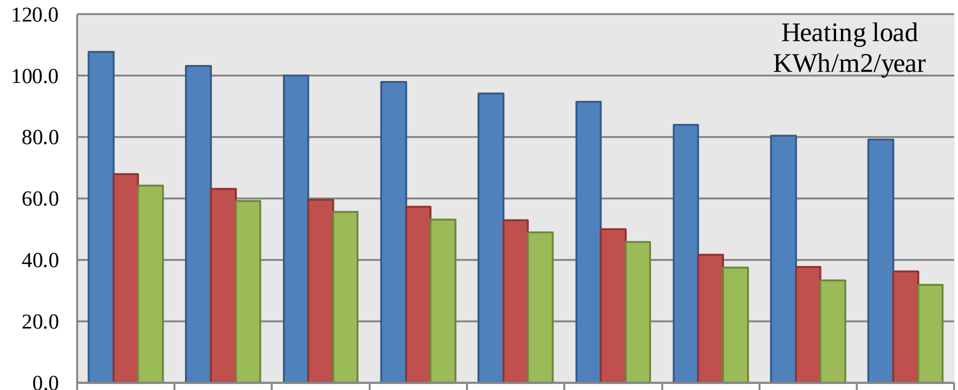


	Blocks 15cm & limestone	Blocks 20cm & limestone	Blocks 25cm & limestone	2x 10cm block	2x 15cm block	2x 20cm block	10cm block & 5cm insulation	10cm block & 10cm insulation	10cm block & 15cm insulation
Cost SP/m2	863	913	963	925	1,075	1,175	1,166	1,544	1,922
Wall thickness cm	25	30	35	30	40	50	25	30	35
Wall imporvment %	0	11.7	23.5	30.5	43.5	52.9	76.4	87	91.1

Figure 2 represents the cost of each structure against its thickness and performance

characteristic was improved its cost was increased as well as its thickness until a change in the structure occurred. Where the insulation material had been added to the structure, a 50% reduction of the wall thickness and 50% thermal improvement were achieved compared to the previous structure, which is the recommended structure by the Building thermal insulation code in Syria, with almost the same price.

3.3 *Impact of glazing type*: Fig. 3 illustrates the effects of both the glazing type and wall thermal insulation on the total building heating loads. A huge reduction in heating load had occurred by replacing the single glazed windows with double glazed ones. 36.92% reduction in heating load was achieved in the base-case by upgrading to double glazed windows, and a total reduction of 66.30% in heating load was reached by improving the wall insulation compared to the base-case. When upgrading from double to triple glazing, no major changes happened as less than 1% reduction could be measured.



	U= 1.7	U= 1.5	U= 1.3	U= 1.18	U= 0.96	U= 0.8	U= 0.4	U= 0.22	U= 0.15
Single Glazed	107.8	103.3	100.1	97.9	94.2	91.5	84.0	80.5	79.1
Double Glazed	68.0	63.1	59.6	57.2	53.1	50.0	41.8	37.8	36.3
Triple Glazed	64.2	59.3	55.7	53.2	49.0	45.9	37.5	33.4	31.9

Figure 3 illustrates the effects of both the glazing type and wall thermal insulation on the total building heating loads.

Improving the building envelope insulation, either walls or windows, did not have negative effects on cooling load and did not cause overheating in summer. Contrariwise, it has reduced around 10% of the total cooling load.

3.4 *Developing a simplified analysis scheme*: Based on the simulation results presented previously, it is clear that there is a stronger link between various wall structures and glazing types with the annual heating loads than with the cooling loads, as the heat gain in summer is not vastly affected by the conduction as much as by solar and ventilation gains.

To form a correlation between the annual heating and cooling loads with the insulation levels, a scatter plot of the different wall u-values and both heating and cooling loads in three different case (Single, double and triple glazing) are shown in Fig. 4, 5.

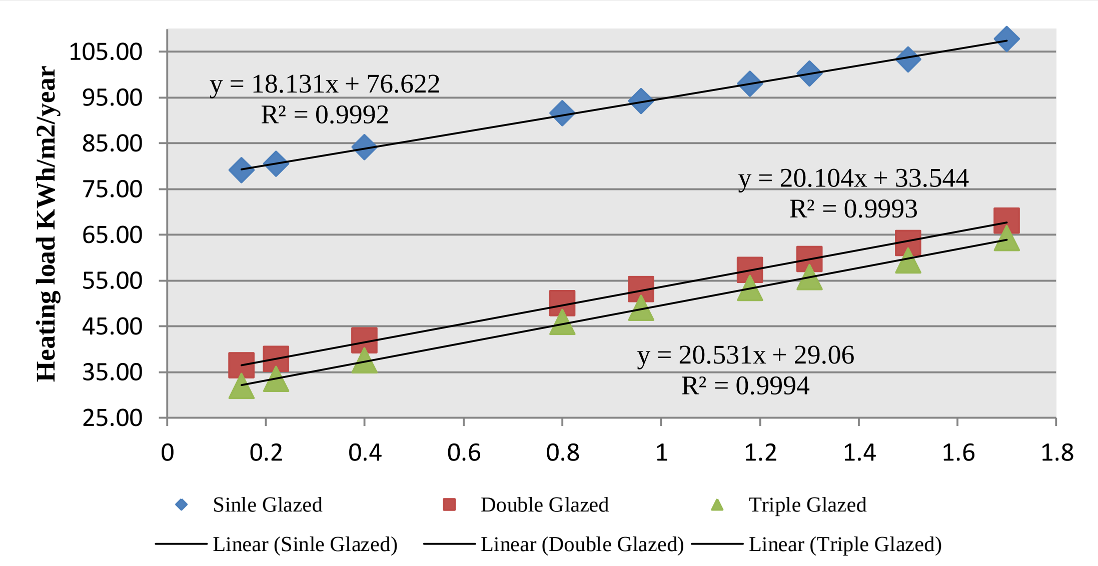


Figure 4 illustrates the scatter plot of the heating load against the wall u-values

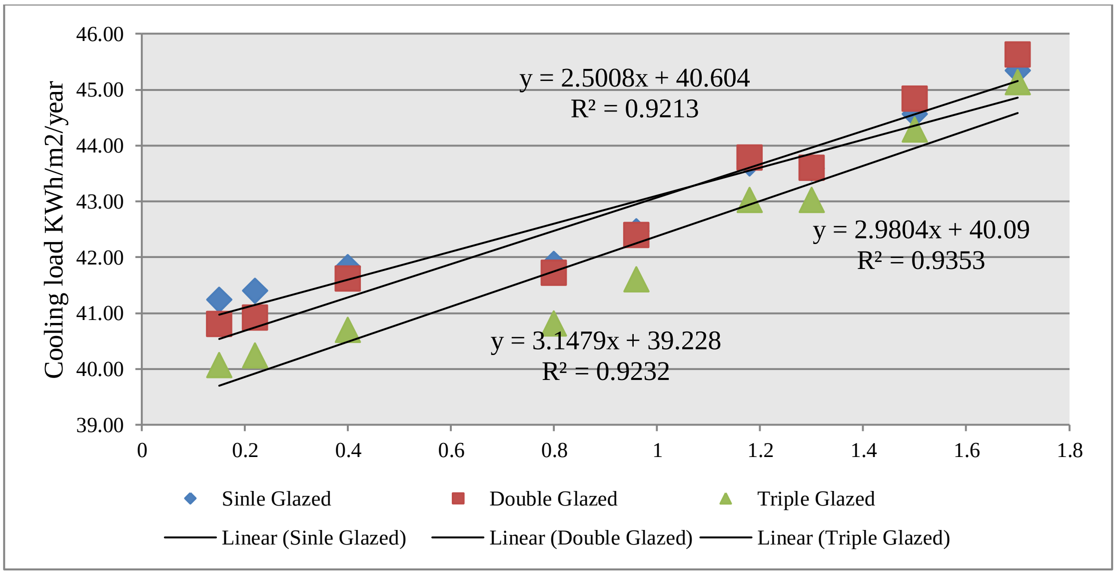


Figure 5 illustrates the scatter plot of the cooling load against the wall u-values

From Fig.4, the strong correlation between the heat load reduction and wall insulation improvement is clear in the three cases (single, double and triple glazing) with R^2=0.99, therefor the heating loads can be predicted using the trend line equations.

The different effects which various glazing types create can be calculated by finding the difference between (y) values by replacing the x (which represents the wall u-value) with (1).

y_1 = 94.753 *KWh/m²/year* - y_2 = 53.648 *KWh/m²/year* - y_3 = 49.591 *KWh/m²/year*

Almost 43.4% of the heating load can be reduced by changing from single to double glazed windows. 4.3% more can be reduced by upgrading from double to triple glazing with a total reduction of 47.7%, regardless the wall structure and u-values.

On the other hand, Fig.5 illustrates the correlation between the cooling load and wall insulation improvement which is relatively weaker than with heating loads with R^2=0.92. A similar calculation can be made to predict the cooling load reduction in relation to the window glazing types.

y_1 = 43.126 *KWh/m²/year* - y_2 = 43.07 *KWh/m²/year* - y_3 = 42.375 *KWh/m²/year*

It can be noticed that the cooling load is barely affected by applying the three different glazing types with less than 0.12% difference between single, double and triple glazed windows.

4. Conclusion

The analysis indicates that there is a strong correlation between the building envelope thermal insulation and its heating loads but not cooling loads. In addition, the type of the glazing is found to have a major effect on the total heating loads in the building. A simplified analysis scheme was developed to estimate the total annual heating and cooling loads as a function of the wall u-value and glazing type. The main recommendation that could be drawn from this paper is using a structural system that provides the best reduction in heating and cooling loads with reasonable cost which is:

Walls: a single block (10cm) with insulation (Polyurethane board 5cm) and limestone external rendering with a total thickness of 25cm. U-value=0.4 W/m2/k

Windows: Double glazed window. U-value=1.9 W/m2/k

This system is predicted to save 61.24% of the heating load compared to 49.98% by the Syrian code with the same cost. And the walls are lighter as well as thinner than the Syrian code recommendations.

5. Bibliography

Ajjoub, F. (2010). *Designing a low energy dwelling in Syria using Passive Design strategies to achieve thermal comfort.* Oxford: Oxford Brookes University.

Keshkeh, H. (2007). *Building Thermal insulation Code in Syria.* Damascus: The Ministry of Energy and Electricity .