BIM and Thermal Performance Modeling Integration: A Case Study of Cyprus Highly Glazed Dwellings

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Abstract. In Cyprus 80% of buildings do not use thermal insulation materials. Besides, there is a rising tendency to live in highly glazed residences. The aim of this study is to provide an analytical proof of the effectiveness of applying insulation to building envelopes in minimizing annual energy consumption under the influence of enlarging fenestration area. The impact of increasing glazing area from 20 to 60% in conventional construction of Cyprus from thermal insulation point of view, by integrating Building Information Modeling and Thermal Performance Modeling was investigated, taking single-family dwellings as case study. Autodesk REVIT for Building Information Modeling and Autodesk Ecotect 2011 for Thermal Performance Modeling were employed in this research and the assignment of thermal comfort factors was based on ASHRAE Handbook of Fundamentals.

Total load demand for uninsulated 20%-glazed case calculated near triple the amount for insulated 60%-glazed case (34028 kWh compared to 11814 kWh annually). Furthermore, Insulated cases demonstrated better thermal comfort characteristics. A contrasting result as a decrease in load demand, in consequence of increasing fenestration area in uninsulated cases was also observed.

Keywords: BIM, Thermal Insulation, Building Thermal Performance, Cypriot Highly Glazed Residences

1. Introduction

Building Information Modeling (BIM) is a precious tool by which it is possible to simulate different stages of a project during its lifespan preceding construction initiation. Building thermal performance simulation on the other hand, attained the attention of a wide range of engineers since thermal performance contributes to inhabitant’s thermal comfort, environmental issues related to the project and, economic issues of the project in the operational phase, which according to a study by [1] accounts for 94% of the whole energy consumption in residential sector. Indeed, the integration of BIM and building thermal performance modeling provides us with the most comprehensive and rich computer simulation, by which it is possible to evaluate more aspects of a facility in different periods of its lifetime.

According to a statistical analysis by [2], there is no insulation applied to 80% of Cypriot buildings. Besides, residential construction characteristics have altered in different architectural periods due to people's preferences. The glazing area for instance, is increased from 9.15% in Ottoman period to an average of 19.25% in the modern period of Cypriot construction in urban areas [3]. The trend seems to be the same afterwards, as a result of the influence of modern architectural on the conventional construction. Although there are some studies on the design, construction and operation phase of conventional dwellings in Cyprus, there has been little investigation done on the thermal performance of aforementioned facilities, taking into account the transformation of these dwellings to highly glazed houses. As the tendency is grown to live in houses with more fenestration areas, the importance of precise estimation of cooling and heating demand increases significantly; "the energy use for different highly glazed buildings may vary more than for buildings with traditional façades since the glazed alternatives are particularly sensitive to the outdoor conditions" [4].

As the base case, a typical Cypriot house is simulated employing two building modelling tools. Detailed information on modeling procedure is presented in the following section. A discussion on thermal performance of different alternatives is carried out in this paper.

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2. Research Methods

A typical 120 square meters single-family residence of Cyprus is simulated by Autodesk REVIT which is one of the prominent and widely used simulation tools for BIM. Typical residential plan - A mass housing apartment block - is modelled according to a study by [3] which is a representative of the modern architectural design of Cyprus (Figure 1). Six cases with diverse glazing areas, ranging from 20% to 60% and different construction material for all building envelopes are regarded in this study. Two main categories were considered in this study under which "uninsulated"- the first category - is modelled based on typical construction materials which are being used in Cyprus and "insulated" - the second category - is modelled according to widely used materials for constructing energy efficient residences which are not common in Cyprus. Other factors like occupant's activity, HVAC working schedule and building shape left unchanged. The effect of changing building orientation was not considered since it was demonstrated by [4] that this factor imposes minor effect on building energy consumption if the two shorter walls and the two longer walls are the same. The impact of window blinds reported to be minimal by [5] and was not regarded in current study as well. Although it concluded by [6] that "roof construction produced less energy-efficient benefits", this factor was considered in this investigation since contrasting ideas regarding this issue was observed [7], [8], and [9]. The model is finally exported to Autodesk Ecotect thermal simulation engine as gbXML schema to estimate annual cooling and heating load as well as thermal comfort of each case.

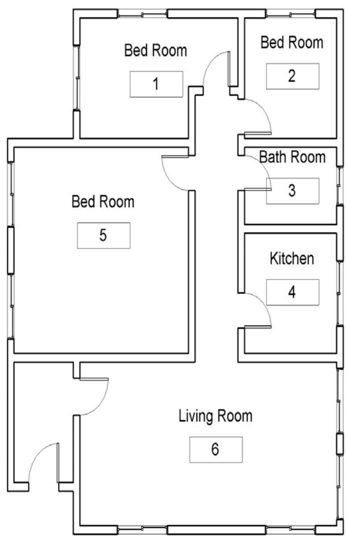


Fig. 1: Typical Residential Plan of Modern Architectural Period of Cyprus [3]

2.1. Construction Details of Models

Uninsulated category is modelled with single-glazed aluminium frame, plaster joints suspended roof, brick plaster walls and suspended concrete floor; the overall heat transfer coefficient (U-value) of these elements are 6, 4.32, 2.62 and 3 respectively. Materials of the second category - insulated category - are double glazed low-E timber frame, plaster insulation suspended roof, reverse brick veneer R-15 and "concrete slab carpeted on ground" floor with U-value of 2.26, 0.5, 0.49 and 0.92. The transmittance factor of single-glazed aluminium frame is 6 while this factor is 2.26 for double glazed low-E timber frame.

As the base case, both categories are modelled with 20% fenestration area which is increased by 20% increments, up to total 60% gazing area, consequently.

2.2. Thermal Comfort Factors Assignments

For thermal comfort calculations, there are several factors which must be considered in the software. Thus in this study, clothing factor is set to 0.6 - for using trousers and shirts in the house -, air speed to 0.3 m/s - for being barely noticeable -, lighting level to 300 lux, activity level to 70w which accounts for normal activity in a family house, air change per hour to 0.5 and, wind sensitivity to 0.25. Twenty four square meters is set for each person's activities in the model house and these factors kept unchanged for all case studies.

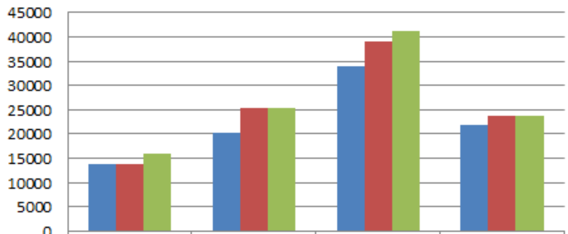
Besides, for heating and cooling load calculations, a 95% efficient air conditioning system is assigned to the model operating 24 hours a day in order to achieve thermal comfort during day and night. Additionally, lower band of the temperature range was set to 18 while 26 degrees of centigrade was set for the upper band.

It is generally believed that, 24 hours of full air conditioning cannot possibly represent the actual air conditioning operation schedule of a family house throughout the year. Most families prefer natural ventilation and neglect some levels of thermal discomfort to use as less electricity as possible. Preferences differs for every single family, therefore realistic assumptions needs specific detailed inquiries on people's life-style in every region. In case of comparison and to demonstrate the impact of different factors, simplifications on air conditioner operation schedules are carried out in this research.

Thermal comfort was calculated by "monthly comfort times" method which shows total uncomfortable times each month. Applying "average adaptive comfort" which according to Ecotect simulation tool "assumes that people are adaptive in more controlled buildings but not as much as in free running, and is computed with the formula T(c)=24.2+0.43(tave-22)x exp(-[(tave-22)/28.284]^2" total thermal uncomfortable times were calculated.

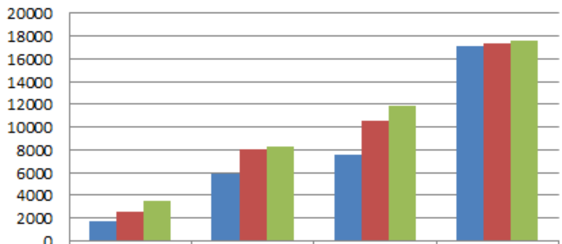
3. Result and Discussion

This research produced findings that strengthen the results of a large number of investigations in other locations and case studies.



	Heating Load	Cooling Load	Total Load	Thermal Discomfort
20% Glazed	13852.5	20176	34028.5	21955
40% Glazed	13707	25436	39143.7	23655.6
60% Glazed	15800	25432.9	41233.8	23702

Fig. 2: Loads and Thermal Discomfort Figures for "Uninsulated" Category



	Heating Load	Cooling Load	Total Load	Thermal Discomfort
20% Glazed	1735	5824.7	7559.7	17148
40% Glazed	2514	7972	10486	17355
60% Glazed	3516.5	8298	11814.8	17630

Fig. 3: Loads and Thermal Discomfort Figures for "Insulated" Category

Allegedly, the insulated series of dwellings presented comparatively normal and expected reaction to resizing fenestration area while, the heating load among uninsulated cases decreased by 0.09 % as the glazing area increased from 20 to 40% and, the cooling load in the same category fell by 0.01% as the glazing area was enlarged from 40 to 60% which is obviously in contrast with "more glass more energy consumption". The combination of heating and cooling load finally, proves the aforementioned common belief. The reason behind this unexpected reaction which was also noticed in some previous studies remained unquestioned and could be investigated in future researches [10] and [11].

In both categories the total load and thermal discomfort raised as the result of increasing fenestration areas but, figures demonstrate that the difference between two categories is quite noticeable. Total load in 60%-glazed insulated house is 3.5 times less than the equivalent uninsulated one (11814 compared to 41233 kWh) as a result of decreasing overall U-values of building envelopes. For the same compared couple, cooling load is 3.06 times and heating load is almost 4.5 times less.

Furthermore, considering energy consumption, as more glazing area is applied to case studies, the gap between insulated and uninsulated cases became smaller. A case in point is the heating load in both cases which is almost 8 times more in the uninsulated 20%-glazed case, compared to its equivalence in insulated case; this falls to less than 5 times in case of 60% fenestration area.

In addition, heating load demand for typical family house in Cyprus seems to be more sensitive than the cooling load, to building envelope insulation. Heating load is approximately 8, 5.5 and 4.5 times more, comparing uninsulated to insulated categories for 20, 40 and 60% glazing areas respectively, while the same comparison for cooling loads leads to 3.5, 3.2 and 3.06 times in the same order.

More thermal comfort is achieved in insulated houses, comparing 17141, 17355 and 17630 DegHrs for insulated case studies and different glazing areas to 21955, 23655 and 23702 for uninsulated case studies as thermal discomfort factor.

4. Conclusion

The effect of increasing fenestration area as well as insulating building envelopes in Cypriot conventional single-family dwelling is studied. As people grow interest to live in comparatively highly glazed houses which, require more energy consumption to achieve the same comfort level, insulating building -which means decreasing U-values for each envelope- leads to incredible saving in energy. On the other hand, higher comfort level is achieved in insulated dwellings. The cooling load demand in hot and humid climate like the Mediterranean climate is more than the heating load thus, applying insulation to building in these climates, should be based on the cooling load demand. Most important findings of this study are listed below:

- Increasing fenestration area to 60% leads to a surge in energy demand of residences but, applying insulation to building envelopes is a measure taking which, leads to a reduction in total load significantly, that it falls below the base case - uninsulated, 20%-glazed - level.
- Total load in 60%-glazed insulated house calculated to be 3.5 times less than the equivalent uninsulated one.
- Heating load was almost 8 times more in the uninsulated 20%-glazed case, compared to its equivalence in insulated case.
- Heating load demand for typical family house in Cyprus seems to be more sensitive than the cooling load to building envelope insulation.
- More thermal comfort is achieved in insulated houses.
- Insulated series of dwellings presented comparatively normal and expected reaction to resizing fenestration area.

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6. References

[1] Kahhat, R., Crittenden, J., Sharif, F., Fonseca, E., Li, K., Sawhney, A., et al. (2009). Environmental Impacts over the Life Cycle of Residential Buildings Using Different Exterior Wall Systems. *JOURNAL OF INFRASTRUCTURE SYSTEMS*, 211-221.

[2] Panayiotou, G. P., Kalogirou, S. A., Florides, G. A., Maxoulis, C. N., Papadopoulos, A. M., Neophytou, M., . . . Georgakis, G. (2010). The characteristics and the energy behaviour of the residential building stock of Cyprus in view of Directive 2002/91/EC. Energy and Buildings , 2083–2089.

[3] Ozay, N. (2005). A comparative study of climatically responsive house design at various periods of Northern Cyprus architecture. Building and Environment, 841–852.

[4] Poirazis, H., Blomsterberg, A., & Wall, M. (2008). Energy simulations for glazed office buildings in Sweden. Energy and Buildings, 1161–1170.

[5] Hester, N., Li, K., Schramski, J. R., & Crittenden, J. (2012). Dynamic modeling of potentially conflicting energy reduction strategies for residential structures in semi-arid climates. Journal of Environmental Management, 148-153.

[6] Lai, C.-M., & Wang, Y.-H. (2011). Energy-Saving Potential of Building Envelope Designs in Residential Houses in Taiwan. Energies, 2061-2076.

[7] Sisman, N., Kahya, E., Aras, N., & Aras, H. (2007). Determination of optimum insulation thicknesses of the external walls and roof (ceiling) for Turkey's different degree-day regions. *Haydar* , 5151–5155.

[8] Ozel , M., & Pihtili, K. (2007). Optimum location and distribution of insulation layers on building walls with various orientations. *Building and Environment* , 3051–3059.

[9] Ozel, M., & Pihtili, K. (2007). Investigation of the most suitable location of insulation applying on building roof from maximum load levelling point of view. *Building and Environment* , 2360–2368.

[10] Bojic, M., Yik, F., & Sat, P. (2001). Influence of thermal insulation position in cuilding envelope on the spave cooling of high-rise residential buildings in Hong Kong. *Energy and Buildings*, 269-581.

[11] Masoso , O. T., & Grobler, L. J. (2008). A new and innovative look at anti-insulation behaviour in building energy consumption. *Energy and Buildings* , 1889–1894.

[12] Krygiel, E., Read, P., & Vandezande, J. (2010). *Mastering Autodesk Revit Architecture 2011.* Indianapolis: Wiley.

[13] ASHRAE Handbook of Fundamentals, Atlanta, USA, 1997.