Thermal Performance of Insulation Samples: Applications for Malta

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ABSTRACT: The aim of this dissertation is to investigate and study how insulating materials used in local construction methods may enhance the thermal performance of a typical Maltese building envelope. The study provides a practical insight on how various insulation options within the cavity of a globigerina limestone and concrete blockwork wall effects the U-Value of the wall. This study investigates insulation materials such as expanded polystyrene, stonewool, glasswool with/without a reflective coating. Results demonstrate that in order to be in compliance with the local building regulations it is a must to use insulation within the cavity of the current building construction methods. Also, enhanced thermal performance is achieved when the insulating material is coated with a reflective surface. This dissertation quantifies in tangible terms the effectiveness of insulating materials in today's modern buildings.

1 INTRODUCTION

1.1 *Local Scene*

Current building practice ignores thermal performance since measures that improve this are generally seen as an avoidable initial cost. Developers are not concerned with the running costs and clients are often unaware of the long-term benefits of providing for indoor thermal comfort and energy efficiency. More stress is made on gaining space by building thinner external walls at the expense of energy performance. However, nowadays building more efficiently has gained a higher priority with the introduction of the EU energy directive "Energy Performance of Buildings" (2002/91/EC) in January 2006.

Since in Malta the warm-hot periods are longer than the cool-cold periods, more effort should be made on assessing how a building envelope keeps the heat out of the dwelling and thus reduce the cooling load. Therefore emphasis should not be made on how to avoid heat losses but rather how to avoid heat gains. A simple, yet efficient, way to improve on thermal performance is by using insulation within the building envelope, thus minimizing heat gains (or losses) through the building fabric.

1.2 *Study carried out*

The study should demonstrate whether incorporating insulation with local construction methods would prove beneficial and sustainable in obtaining good thermal performance of the building fabric. Though, theoretical calculations, based on the manufacturer's specifications, can be carried out to find the overall U-value of a building envelope, testing typical external walls will yield more realistic results.

The study therefore involves testing the thermal performance of typical Maltese external walls: double leaf cavity walls each constructed with globigerina limestone and concrete blockwork with a cavity (50mm wide) filled with five different insulation materials: air, glasswool, mineral wool, expanded polystyrene and glasswool coated with an aluminium reflective surface.

2 TEST SET-UP

2.1 *Suggested Code Methods*

To measure the heat transfer properties of large built-up components such as parts of walls, floors, roofs etc, the BS 874:1:1986 and EN ISO 8990:2000 codes offer two alternative methods, the guarded hot-box and the calibrated hot-box methods. These methods are intended for laboratory use and are suitable for samples larger than $1m^2$. Though non-homogeneous specimens may be tested, it is important that the test area should be sufficiently representative of the complete building element. These methods give an average thermal transmittance or conductance over the test area.

Both methods use a warm and cold chamber of known temperatures, between which a test element is placed. The basis of the hot-box methods is the determination, at steady state, of the heat flow per unit area of the test element (found from the power supplied to the warm chamber) and the appropriate temperature difference across the test element. From these quantities the thermal transmittance, thermal conductance and/or thermal resistance may be calculated.

2.2 *Construction of the test cell*

Two test cells were built, one of globigerina limestone and another of concrete blockwork, having an inner leaf of 150mm, a cavity of 50mm, an outer leaf of 230mm and a height of 780mm, Figures1&2. The 230mm concrete block was a 'dobblu' block, since this is generally used for construction. The test cells were meant to be identical in size, yet due to construction errors there was a slight discrepancy in their size. The mortar selected for the use between the masonry elements was a typical mix done on local sites. This mortar was also used to seal any joints. The limestone cell was left bare, while the concrete blockwork cell was plastered with 10mm of Buffa Intonaco T70, both internally and externally since in reality exposed concrete blockwork is never left bare.

By constructing a cell, the hot-box method would be applied. This is because the heat source would be placed in the inner core of the cell representing the warm chamber, while the laboratory environment would model the cold chamber.

2.3 *Minimizing test cell's heat losses*

It was important to minimize heat losses from the top and bottom of the cell by applying thick insulation in order to 'force' the heat to flow from the remaining four sides of the test cell. It was also important to ensure that different tests could be carried out in the same way, thus if certain heat losses are unavoidable these would be constant throughout all the experiments.

The test cells were built directly on two layers of 50mm mineral wool placed on 13mm chipboard and raised from the floor by 100mm, using wooden batts. To further minimize heat losses, mortar was used to seal any gaps between the insulation and the bottom of the test cell. The tops of the test cells were roofed by two layers of 80mm mineral wool and 13mm chipboard. Weights were placed on the chipboard to ensure a uniform contact between the top of the test cell and the insulation. The top insulation layers were placed on each other such that each joint on the lower layer of the insulation is covered by a solid piece of insulation of the upper layer, thus reducing heat loss. The purpose for the insulation was to try and minimize the heat losses through the roof and base of the test cell thus obtaining lateral heat flow through the walls of the cell.

2.4 *Heating the test cell*

Heat was supplied by means of filament heaters connected to the direct current power supply. Since testing was done in the vertical position, the code [1] suggests that for such a case circulation resulting from natural convection can be sufficient to ensure temperature uniformity. So, the filament heaters were placed close to the bottom of the test cell to allow natural convection to take place. The electrical wires connected to the heaters were isolated from the thermocouples so that there would be no interference between them.

2.5 *Monitoring the temperature*

Temperatures were read using the thermocouples which were connected to the datalogger. The code [2] recommends that at least two thermocouples be placed per square meter. Since the datalogger's CA522 card can take a maximum of 18 thermocouples, the thermocouples had to be distributed between the two test cells resulting in the minimum amount of thermocouples per square meter. Due to this not all sides of each test cell could be monitored. So it had to be assumed that heat is transferred equally through all the sides of the test cell, thus monitoring only two sides of each test cell. Side 1 of each test cell had a thermocouple placed on the inner and outer face and on each side of the cavity while Side 2 had a thermocouple placed on the inner and outer face only. Side 2 was monitored to ensure consistency with Side 1. Other thermocouples were placed at the bottom and top of each cell.

Also, the placing of the thermocouples was such that they were placed opposite each other on the hot and cold side and in the middle of the test area. They were intimately fixed to the test cells' surface by using mortar, the same type as that used between the masonry elements.

Figure1: Covered limestone test cell

Figure2: Uncovered concrete blockwork test cell with insulation within the cavity.

3 TESTS AND RESULTS

3.1 *Tests carried out*

Five sets of tests were carried out. Each test involved heating simultaneously both test cells with the heaters until steady state was reached. During each test, the same insulating material was placed in the limestone and concrete blockwork cavity. This ensured that the insulation was tested under the same environmental conditions and therefore a comparative study between its performance in the limestone test cell and in the concrete blockwork test cell could be done. Each test took about five to seven days to complete, depending on the time required to reach steady state. Tests could not be repeated due to the time constraints and availability of equipment.

The insulating materials used during the tests were air, glasswool, stonewool, expanded polystyrene (EPS) and glasswool coated with an aluminium reflective surface (ACG).

3.2 *Result*

Graph 1 depicts a comparative summary between the achieved U-Values during testing of the limestone/concrete blockwork test cell using different insulating materials with the expected U-values for each test. The yellow line on the graph represents the maximum U-value, (1.51W/m^{2}K) allowed for exposed walls by the local regulations [3]. The expected U-values were calculated using the combined method as given in the local regulations.

4 ANALYSIS OF RESULT

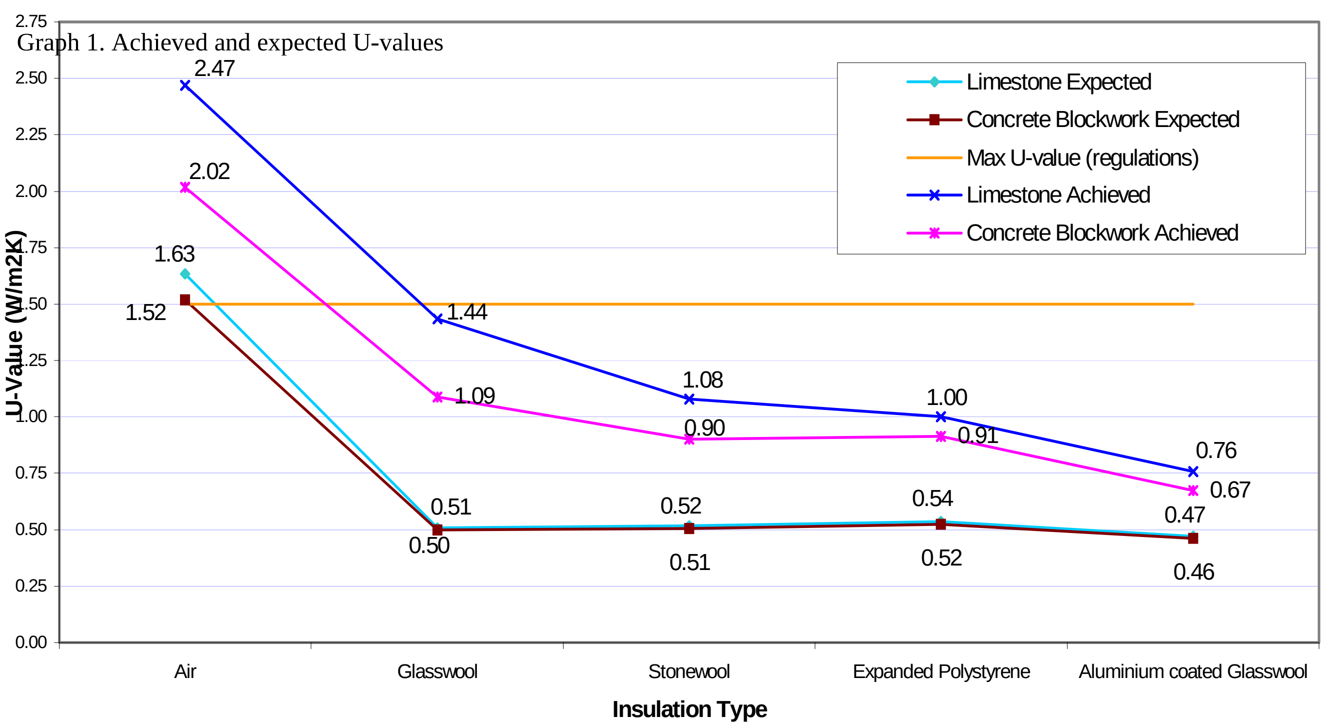
Graph 1 clearly shows that the **expected U-values were lower than those achieved during testing**. In practice U-values for external walls may be higher that those calculated using the method proposed by the regulations and might even be higher than those achieved during testing due to the presence of openings, draughts, orientation etc.

Nonetheless, the benefits of the insulating material are clearly seen. Without insulation both test cells obtain a U-Value greater than the maximum allowed by the regulations. **Thus, it is a must to use insulation within the cavity**. Improvements on thermal performance are immediately obtained without the need to increase the cavity width from 50mm or use thicker masonry elements. However, if local regulations had to become more stringent, thus be comparable to those abroad, the cavity width may need to be increased to 75mm or 100mm, unless a more efficient material is used.

4.1 *Materials' performance*

As can be seen from Graph 1, the **most efficient insulating material is the aluminium coated glasswool** (ACG), that is, the glasswool is coated on one side with a perforated kraft aluminium vapour barrier. Due to this reflective material, the main mechanism of resisting heat transfer is now no longer conduction, as it was for the other materials, but a combination of conduction and radiation, thus improving its performance. In fact, when comparing the performance of this type of insulating material with that of glasswool only, the U-value of the limestone and concrete blockwork test cell is reduced by 47.3% and 38.1% respectively [4]. Note that the percentage calculated for limestone test cell (47.3%) must be seen within the context that the limestone

Graph 1. Achieved and expected U-values



test cell was more moist when the glasswool was tested than it was when ACG was used causing the heat transfer to be accelerated thus resulting in a higher U-value. So most probably a lower percentage of decrease in U-value would have been obtained had the limestone been dry.

It is interesting to note that glasswool is generally used for sound proofing yet as was shown in this study, it may perform well for heat insulating purposes, especially if it is amalgamated with a reflective surface. Glasswool, stonewool and EPS have a similar performance, due to the similar thermal conductivities. Nowadays, use of such materials is simplified as these materials come in lightweight sheets that are easy to cut in any shape; therefore there are no excuses for not using such materials!

4.2 *Concrete blockwork vs. limestone*

The graph shows a trend that **concrete blockwork performs better than limestone**. This may be due to the fact the concrete blockwork has air cavities which contribute to the resistivity of heat flow. Nowadays, concrete blockwork is being used more often during construction, thus such a benefit in thermal performance is essential in tomorrow's buildings. Adding to this is the advantage that concrete is man-made and therefore, is not a limited natural resource like limestone. However, note that the limestone was initially wet which could have resulted in higher U-values. Nonetheless, the expected U-values also show a better performance from the concrete blockwork.

4.3 *Cost of Insulation*

To fully assess the costing of the insulating materials one would require a substantial amount of time to be able to carry out a detailed and significant life-cycle analysis. However, in the table below the price per square meter is compared with the achieved U-Value for each material, thus enabling one to make a simplified cost analysis. As can be seen the more efficient the material the higher is the cost. In the case of EPS the cost is lower than that of stonewool even though a similar, if not better, thermal performance is obtained. However, the comparison of cost should not be based just on the selling price of the insulation. Other implications must be taken into account, such as, the cost to manufacture the insulation and its effect on the surrounding environment. For instance, polystyrene may have a relatively low cost of production thus a lower selling price but adverse effect on the environment when compared to the production of glasswool and stonewool due to its higher embodied energy.

In spite of this, the client generally puts more weight on the selling price of the insulation. It may be the case that for the use in small homes, a relatively cheap insulation with good thermal properties such as EPS may be chosen. However, in large buildings that have a high energy heating and cooling cost, investing in more expensive insulation that yields an optimum thermal performance may be more beneficial and results in more financial savings. Therefore, a balance between optimum thermal performance and cost should be carefully assessed in order to choose an insulating material which yields the required results. Ultimately one would have to balance the capital outlay versus the energy savings made over a period of time, better known as the payback period. This is not delved into in this study as it was beyond the scope of the project.

Table 1. Insulation - Price/m^2 &achieved U-value

Material	*Price/m^2 (Lm)	U-Value (W/m^{2}K) Limestone	U-Value (W/m^{2}K) Concrete blockwork
Glasswool	1.39	1.44	1.09
Stonewool	2.92	1.08	0.90
EPS*	1.50	1.00	0.91
ACG *	4.30	0.76	0.67

*Prices obtained from manufacturers and exclude VAT
*EPS: expanded polystyrene
*ACG: Aluminium coated glasswool

5 CONCLUSION

Designing for enhanced thermal performance will always be the optimum way to reduce energy consumption and achieve satisfactory thermal comfort levels. In fact, results have shown that the thermal performance of the building envelope does improve with the introduction of insulating materials. Malta's construction industry needs to embrace this change by being more aware of the benefits of such energy efficient measures. The challenges set for these coming years are interesting and they are calling for co-operation of the research community, the industry and legislative authorities.

REFERENCES

[1] MSA (2005). EN ISO 8990:2000. Thermal Insulation– Determination of Steady-state thermal transmission properties; Calibrated and guarded hot- box, clause 2.3.2

[2] MSA (2005). EN ISO 8990:2000. Thermal Insulation– Determination of Steady-state thermal transmission properties; Calibrated and guarded hot- box, clause 2.7

[3] Malta Building Regulations, Part F – Conservation of Fuel, Energy and natural Resources, August 2003, Table F.1. Building Construction Industry Department, Floriana.

[4] Percentages derived from the U-Values achieved during the tests using glasswool and ACG as insulation materials.