CIM

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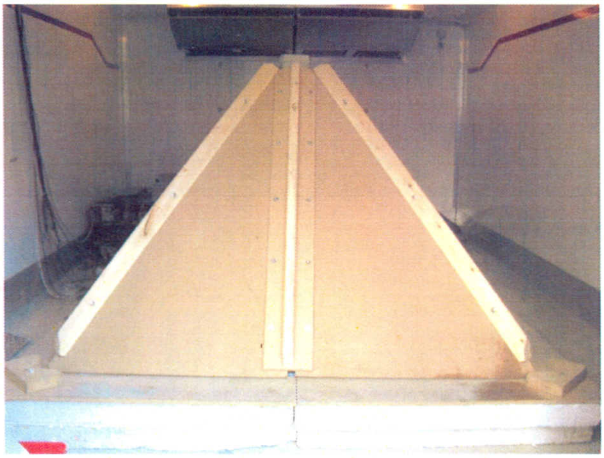
BELGIUM

Comparative assessment of Aluthermo Quattro® reflective insulation in simulated unoccupied roof spaces



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Executive Summary

The Centre for Infrastructure Management (CIM) at Sheffield Hallam University were requested by Aluthermo, Belgium, in the absence of a standard thermal conductivity test for thermo reflective insulants, to evaluate the insulation performance of Aluthermo Quattro® against 200mm of mineral glasswool in a custom built roof space at extreme winter temperatures.

The tests were conducted in series in an enclosure replicating an unoccupied roof space which was placed in a temperature controlled environmental chamber. The aim of the test was to maintain a temperature of 21°C in the enclosure whilst the external target temperature was varied between -5°C and +5°C in 5°C increments. The roof enclosure was insulated in accordance with standard procedures for the relevant materials. Six thermocouples were placed in the enclosure, two in the base, two at mid height on the rafters and two in the apex of the roof. Three thermocouples were also used to measure the external temperature. Hotspot ceramic heaters were used to provide heat inside the enclosure and a thermostat was located in each enclosure to control the heaters. A data logger was used to record the temperatures within the enclosure and a single phase residential meter was used to record the energy consumed in heating the enclosure throughout the monitoring periods. Each insulating material was monitored over a two day period for each temperature increment.

The quantity of apparent specific heat required to maintain the internal target temperature (21°C), taking into account variations in internal and external measured temperatures and volume of heated airspace, was determined for all tests. The results showed that the Aluthermo Quattro® insulation exhibited a fairly consistent performance in all tests and required lower apparent specific heat input for all test increments (-5, 0, +5 °C). The Aluthermo Quattro® was 24.2%, 15.1% and 0.3% more efficient than Glasswool at -5°C, 0°C and +5°C external temperatures respectively over a 40 hour monitoring period. The effective thermal resistance for Aluthermo Quattro® in this comparative test, whilst not directly measured or calculated, is considered to be at least equal to the thermal resistance of the Glasswool (4.5 m^2K/W) as a result of the relative performances observed in this study.

1 Aims

The aim of the test was to carry out a comparative evaluation of Aluthermo Quattro® thermo reflective insulation relative to a standard Glasswool insulation by conducting tests on a scaled down insulated roof truss exposed to controlled winter temperatures.

2 Objectives

A custom built enclosure replicating a roof void was insulated with conventional glasswool and the Aluthermo Quattro® thermo reflective insulation in series to make a comparison between their performances. The enclosure was heated with a Hotspot ceramic heater and the energy required to maintain a target temperature of 21°C was monitored. In addition, the enclosure was instrumented with thermocouples to monitor both the internal and external temperatures. The data was analysed to provide time-performance characteristics of the two insulation systems over the monitoring period.

3 Test Programme

The test programme was carried out as follows:

a) plan and specify the test programme
b) design and manufacture the test enclosure
c) instrumentation (calibration of thermocouples)
d) set up data monitoring equipment
e) monitor and collate data
f) analyse data
g) final report

4 Methodology

4.1 Enclosure

One enclosure was used to evaluate the comparative performance of Aluthermo Quattro® against conventional glasswool insulation. The enclosure was constructed of timber members (Fig. 1) and was supported on a 100mm polystyrene base to prevent heat loss to the ground. The plan area was approximately 1.77m x 1.77m with a height of approximately 1.2m.

The insulation materials were applied in accordance with standard procedures. Referring to Fig. 2, 100mm thick glasswool was placed between rafters (approx. 100 x 46mm cross-section) with a further 100mm layer placed at right angles over the top of the rafters (Total thickness 200mm, Fig. 3). An air gap, approximately 40mm wide, was maintained between the insulation and the external MDF boards. The same roof was used to monitor the performance of Aluthermo Quattro® as shown in Fig 4 with the Aluthermo Quattro® insulation wrapped over the outer surface of the rafters.

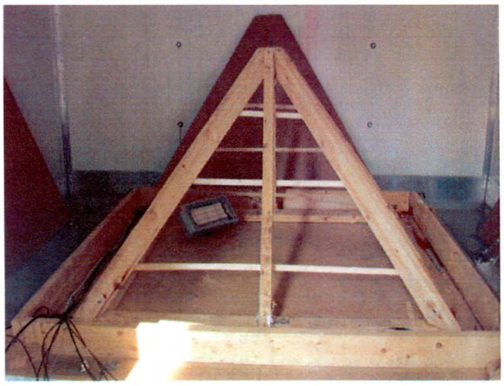


Fig. 1 Roof construction on polystyrene base

Fig. 2 An image from inside showing glasswool applied on rafters

Fig. 3 Glasswool applied over rafters

Fig. 4 Aluthermo Quattro® applied over rafter

Two types of jointing techniques were used for the Aluthermo Quattro® as shown in Figure 5. Type A were vertical joints where the Aluthermo Quattro® was taped using aluminium tape. Type B joint was horizontal and the insulation was overlapped by 100mm and joined by aluminium tape. An air gap of approximately 40mm was maintained between the insulation and the external MDF boards. The enclosure was located in a temperature controlled environmental chamber with a target set-point between -5°C and +5°C in 5°C increments for approximately two days per increment (Fig. 6). The same monitoring equipment was used to monitor the performance of both insulants (Section 4.2-4.4).

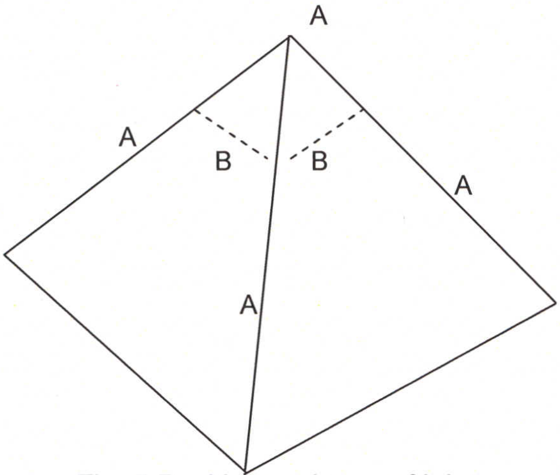
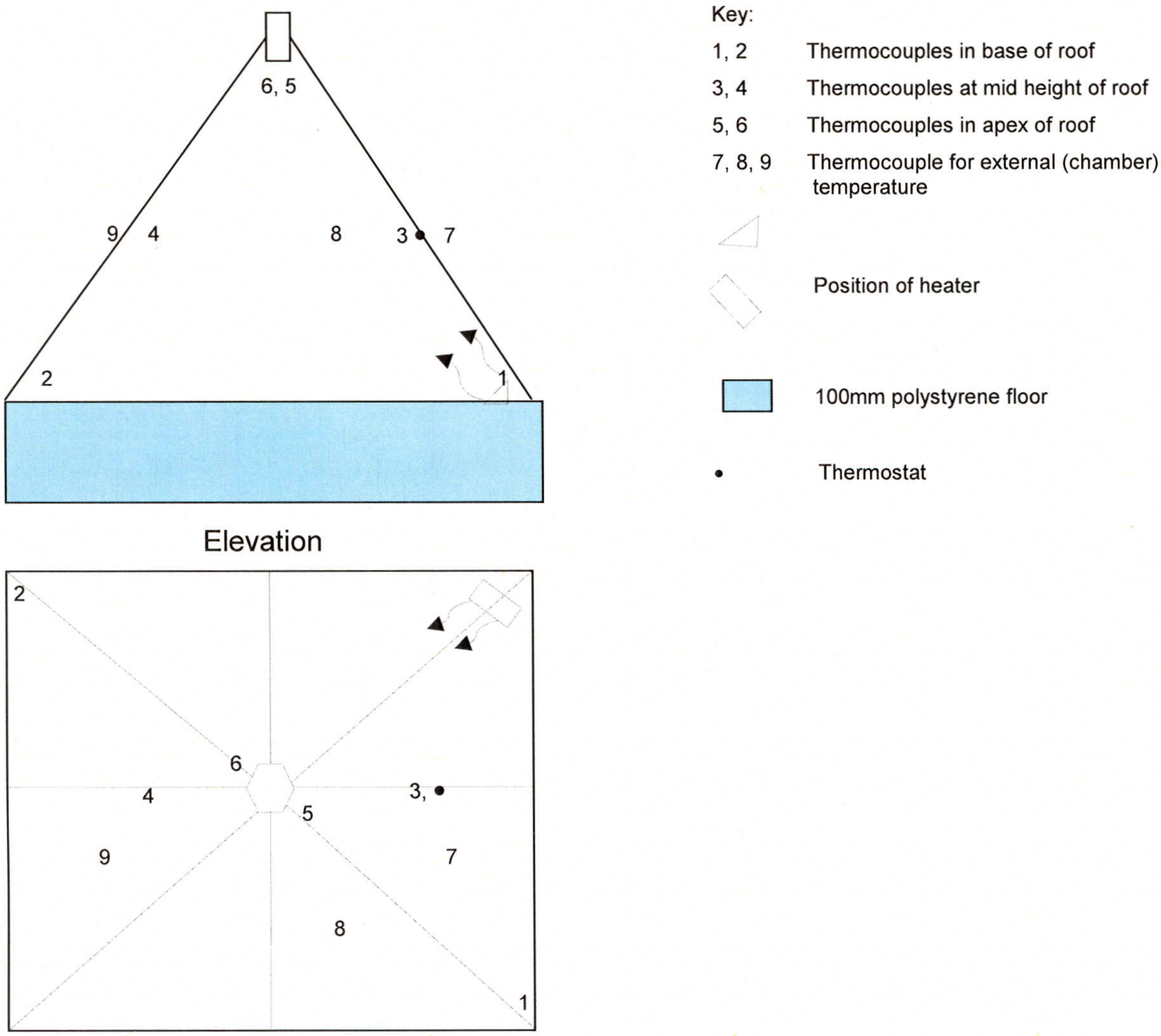


Fig. 5 Position and type of joints

Fig. 6 Finished enclosure under test

4.2 Thermocouples

A total of nine thermocouples (type T) were employed to measure the internal and external temperatures. All thermocouples were calibrated before application. The approximate locations of the thermocouples are shown in Fig. 7. Two thermocouples were placed internally in the base on the roof (labelled 1 and 2), a further two thermocouples were placed internally on the rafters at mid height (labelled 3 and 4) and two were located internally in the apex of the roof (labelled 5 and 6) as shown in Figure 7. The external temperature was monitored by three thermocouples positioned at mid-height in the centre of three faces of the roof (labelled 7, 8 and 9, Fig. 7).



(not to scale)

Fig. 7 Location of thermocouples, thermostat and heaters

4.3 Heating equipment

The enclosure was provided with a Hotspot Ceramic Heater (model HSE 1500, Fig. 8). This is a 1.5kW radiant heat source with dimensions of 340 x 210x x 210 mm. The heater had a set point of 21°C and was controlled by a thermostat attached internally to the central rafter as shown in Fig. 7.

Fig. 8 Ceramic heater in position

4.4 Data logging equipment

The data logging equipment is shown in Figs. 9 and 10. The energy consumed by the heater was monitored by a single phase residential meter (Fig. 9) and the cumulative usage in kWh was recorded. The temperature at the thermocouples (Fig. 6) was monitored at 10 minute intervals by an automatic logging device (Datataker DT615 and a channel expansion module) as shown in Fig. 10. Stored data was downloaded at the end of each test (approximately every two days) for analysis.

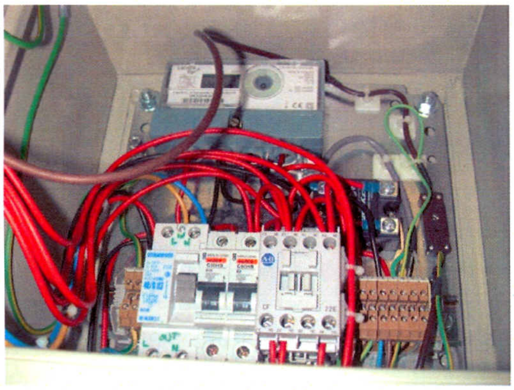


Fig. 9 Energy consumption meter

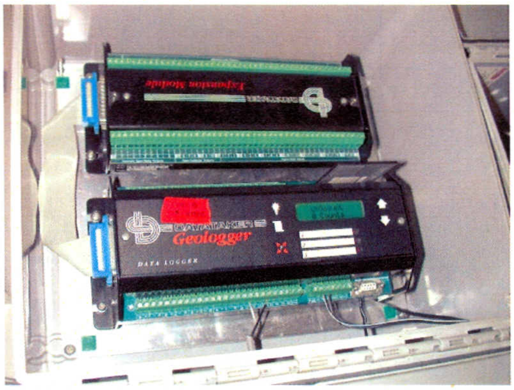
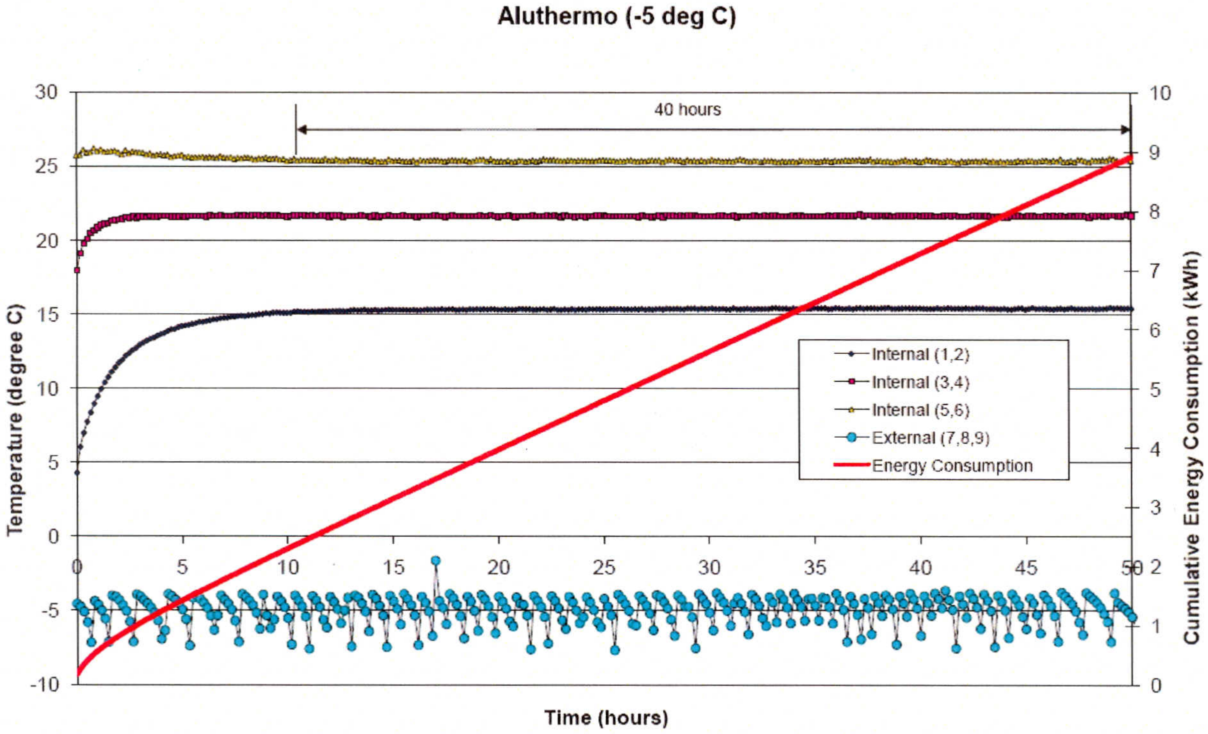


Fig. 10 Data logger (lower) and channel expansion module (top)

5 Results

5.1 Influence of insulation materials on internal temperatures

Figs. 11-13 show the recorded temperature profiles and energy consumed within the monitoring period which enables a comparison of performance between Aluthermo Quattro® and Glasswool as insulation materials when tested as described in Section 4. The data is presented over a period of up to 50 hours but the analysis concentrates only on the steady state data (the final 40 hours of monitoring). Therefore, the early age data is ignored as this will include the influence of changeover of test increment where the climatic chamber is either heating up or cooling down to reach the desired target temperature. Referring to Figs. 11-13, four temperature profiles are presented in the graphs. Internal (1, 2), (3, 4) and (5, 6) refers to the average of the two thermocouples at locations 1 & 2, 3 & 4 and 5 & 6 respectively (Figure 7). The data showed that there was a larger variation in average temperature for Glasswool thermocouples 'Internal 1' and 'Internal 2' of up to 5°C for the three test increments (+5, 0 and -5°C respectively). External (7, 8, 9) refers to the external temperature recorded from thermocouples 7, 8 and 9 (Fig. 7). External (7, 8, 9) in the relevant figures represents the target external temperature of -5°C (Fig. 11), 0°C (Fig. 12) and +5°C (Fig. 13). The heater inside the roof space had a set point of 21°C as described in Section 4.3. Analysis of the data presented in Figs. 11-13 is presented in Section 5.2.



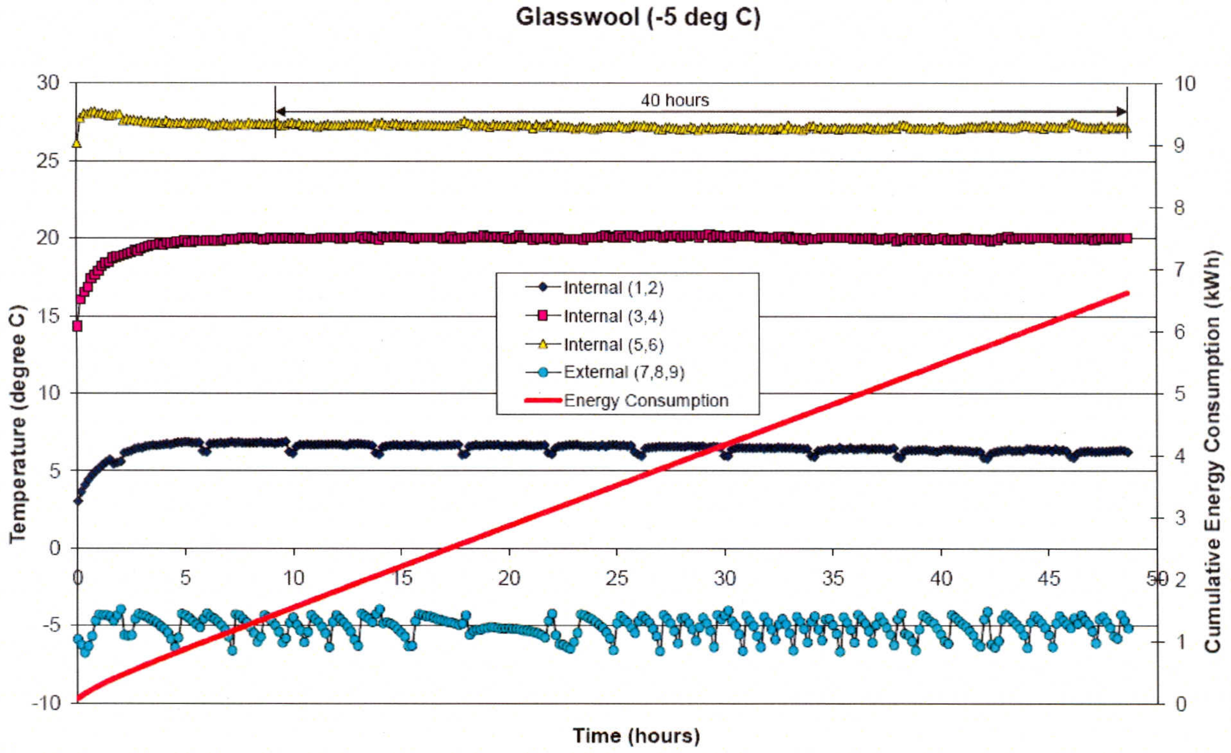
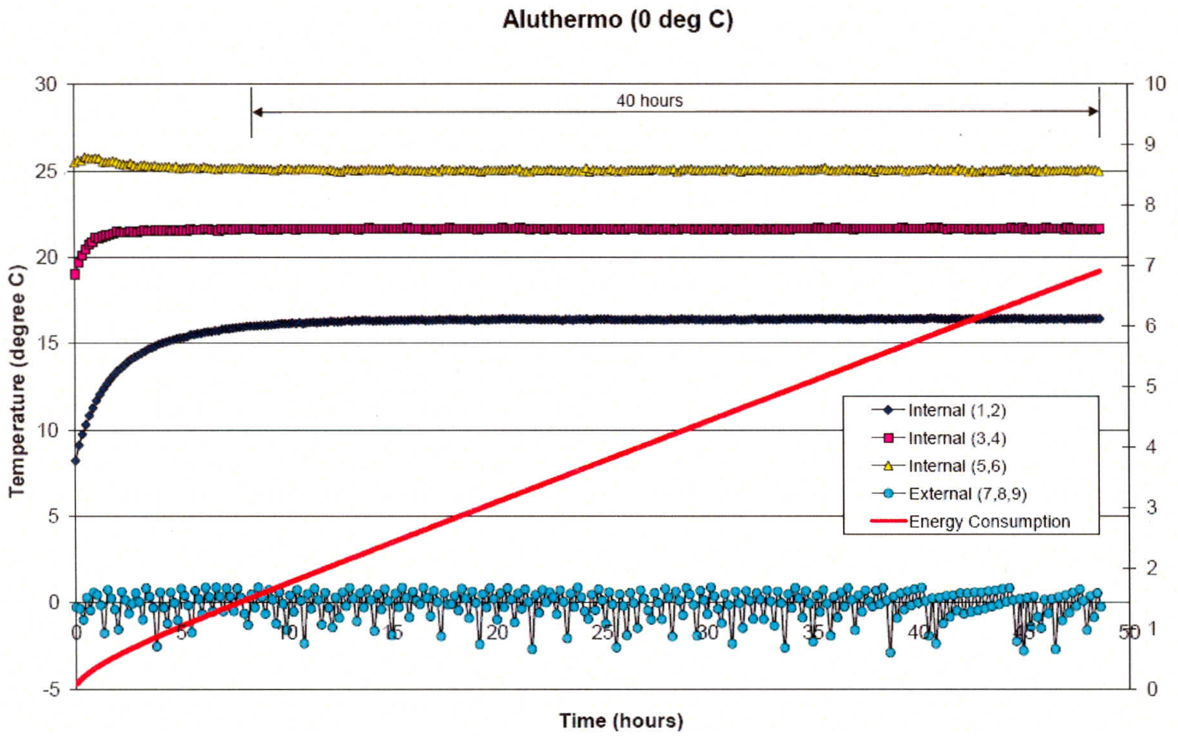


Fig. 11 Temperature profiles at -5°C



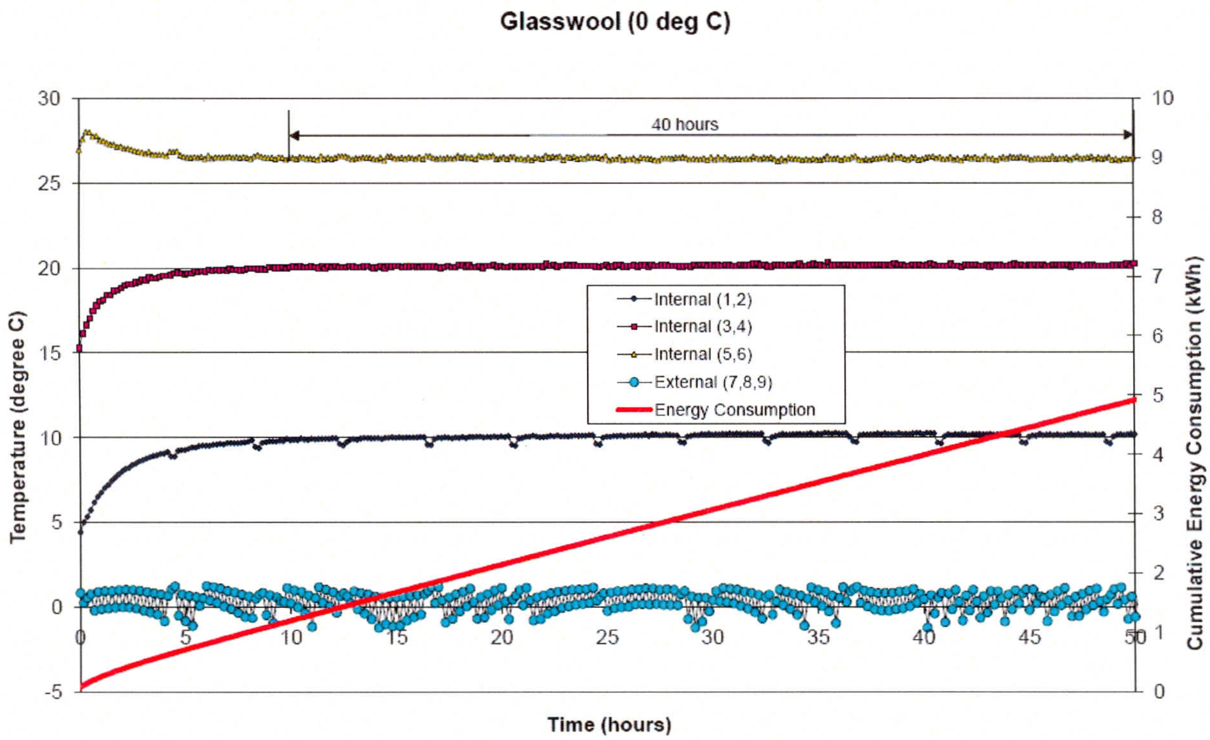
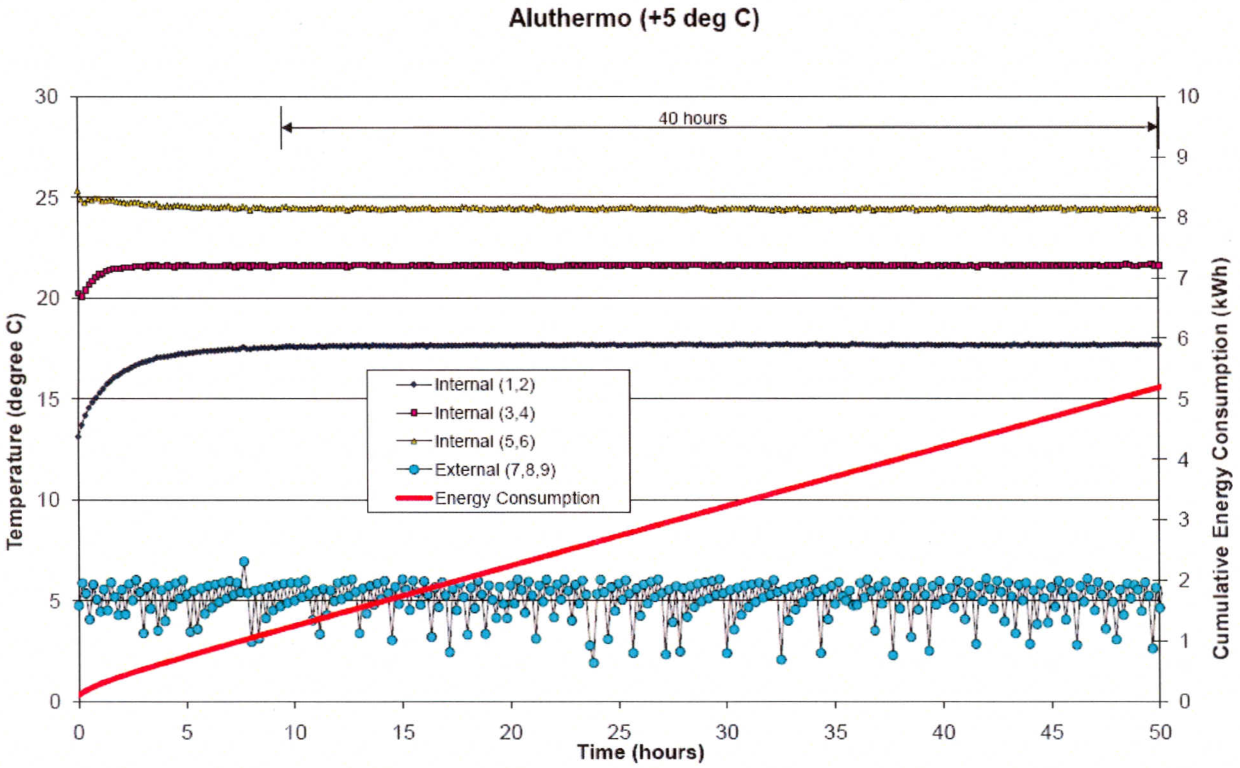


Fig. 12 Temperature profiles at 0°C



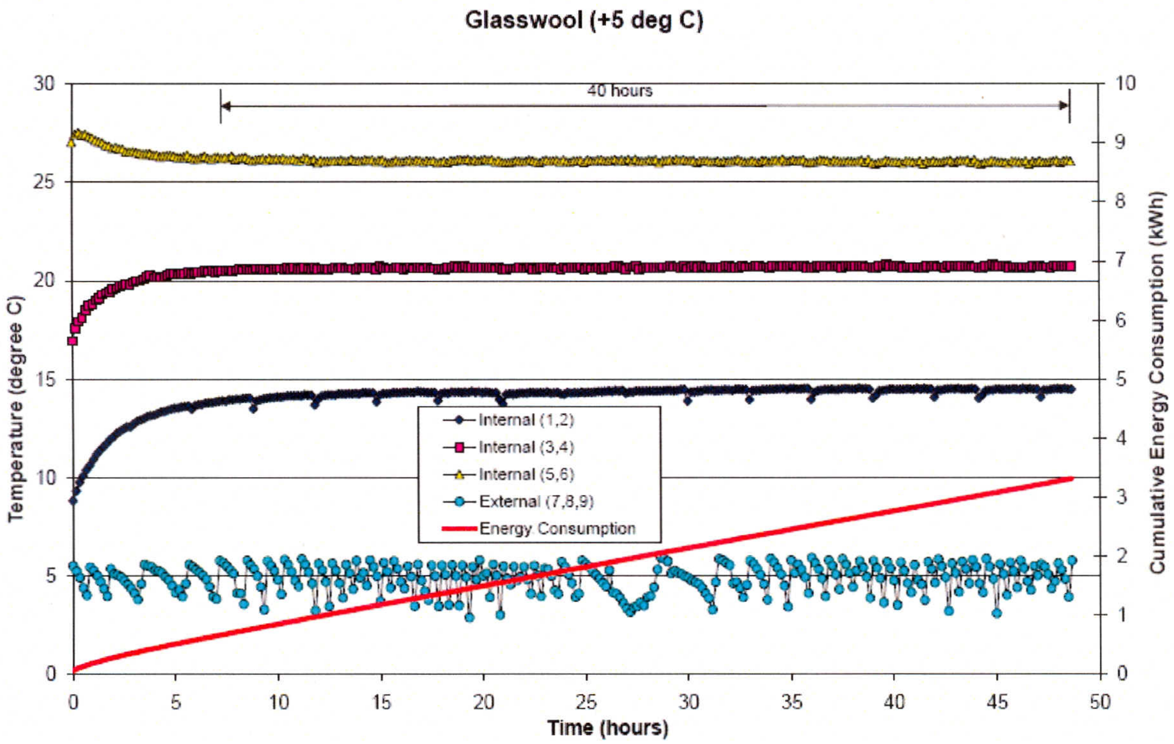


Fig. 13 Temperature profiles at +5°C

5.2 Analysis of data

Referring to Figs. 11-13, a similar trend is evident in all profiles. In the early stages of testing, the external temperature in the environmental chamber is allowed to stabilise. The heaters are then switched on in the enclosure. The energy consumption steadily increases as energy input is required to maintain a target temperature of 21°C.

The profiles from the internal gauges in Figs. 11-13 are predominantly horizontal indicating that a steady state is reached. It is clear, however, that the temperature profiles in the Aluthermo Quattro® insulated roof are closer together (especially at lower external temperatures) indicating a lower temperature variation between the floor and apex of the roof as opposed to the Glasswool insulated roof (the reflective material is more efficient in circulating heat within the enclosure in these tests).

Since the consumption of energy is used to assess the performance of the insulation materials, a steady state period of 40 hours is used throughout in the analysis to eliminate the effects of the initial settling period experienced by all materials. This period is taken as the final 40 hours of testing when a steady state has materialised.

The data presented in Table 1 gives a comparison of the performance of the insulation materials. The data is used to calculate the apparent heat required to maintain the internal temperature at 21°C, taking into account differences such as internal air volume and measured average internal and external temperatures. The apparent specific heat required to maintain the internal temperature is calculated from the specific heat capacity equation as follows:

$$c = \frac{Q}{(m)(\Delta T)} \qquad \text{Equation 1}$$

where c is the apparent specific heat required to maintain the internal temperature at 21°C (kJ/kg°C), Q is the cumulative heat input of the heater (kJ), m is the mass of air (kg) and ΔT is the temperature gradient (°C).

Col. 1 shows the materials under consideration and col. 2 gives the target external temperatures of -5°C, 0°C and +5°C. The actual average external temperatures over the 40 hour monitoring period are given in col. 3 (taken from 'External (7, 8, 9)', Figs. 11-13), and the average internal temperature is shown in col. 4. Since the temperature within the respective roof increases from the base to the apex as shown in Figs. 11-13, the internal average temperature is obtained through a process of integration to account for the variation in increasing temperature and decreasing volume along the height of the roof. Col. 4 also shows that despite the set-point of the thermostat being 21°C (positioned at mid height, Figure 7), the highest and lowest average internal temperature in the Aluthermo Quattro® was 20.14°C and 19.32°C for the +5°C and -5°C tests respectively. The temperatures for the corresponding Glasswool tests exhibited lower internal temperatures of 18.30°C and 15.01°C respectively. Col. 5 gives the internal and external temperature gradient (col. 4 - col. 3). The cumulative energy consumed at the start and end of the 40 hour analysis period is given in cols. 6 and 7 respectively for each test (from 'Energy Consumption' in Figs. 11-13) and the total energy consumed in kWh over this 40 hour period is given in col. 8 (col. 7 - col. 6). The energy consumed in col. 8 is converted to kJ in col. 9 (col. 8 x 3.6 e10^6). A constant density of 1.204 kg/m^3 is assumed for the air inside the enclosure (col. 10) and the volume of airspace is estimated in col. 11 (the thicker Glasswool insulation leads to a reduction in the volume of air inside the enclosure). The resulting mass of air in the enclosure is shown in col. 12. The apparent specific heat, c, required to maintain the target temperature of 21°C inside the enclosure is given in col. 13 and is calculated from Equation 1. The percentage difference in specific heat is shown in col. 14 and indicates that the performance of the Aluthermo Quattro® insulation material is 24.2%, 15.1% and 0.3% more efficient than the Glasswool when tested at -5°C, 0°C and +5°C respectively.

5.3 Discussion

Referring to the total energy consumption data in col. 8 (Table 1), the Aluthermo Quattro® exhibit higher energy consumptions at all test increments (-5°C, 0°C and +5°C). However, when the marginal difference in internal and external temperatures is taken into account (col. 5) along with the difference in internal volumes of air (col. 11), the analysis shows that the apparent specific heat required to maintain the internal temperature at 21˚C is lower for the Aluthermo Quattro® material at all three temperature increments (-5, 0, +5˚C, col. 13).

Table 1 Analysis of data

1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Target External Temp	Average External Temp °C	Average Internal Temp* °C	ΔT (col. 4- col. 3) °C	Energy kWh	Energy kWh	Total Energy (col. 7- col. 6) kWh	Total Energy kJ	Density of Air kg/m³	Volume of Air m³	Mass of Air kg	Apparent Specific Heat, c** Eq. 1 kJ/kg°C	% diff
Aluthermo Quattro®	-5	-4.94	19.32	24.26	2.379	8.996	6.617	23821	1.204	1.21	1.457	673	24.2
	0	-0.16	19.67	19.83	1.557	6.906	5.349	19256	1.204	1.21	1.457	666	15.1
	5	5.01	20.14	15.13	1.297	5.236	3.939	14180	1.204	1.21	1.457	643	0.3
Glasswool	-5	-5.10	15.01	20.11	1.358	6.622	5.264	18950	1.204	0.88	1.060	889	
	0	0.32	16.38	16.06	1.241	4.954	3.713	13366	1.204	0.88	1.060	785	
	5	4.89	18.30	13.41	0.764	3.314	2.55	9180	1.204	0.88	1.060	645	

** Obtained through integration to account for the variation in increasing temperature and decreasing volume*

*** These are relative values given by a common monitoring system. They should not be used to compare the performance of materials of different manufacturers given elsewhere*

In addition, the apparent specific heat calculated for the Aluthermo Quattro® at -5, 0 and +5°C is within 5% (673-643) kJ/kg°C) indicating that the insulant performed consistently irrespective of the external temperature. This value is more variable in the Glasswool tests (889-645) kJ/kg°C giving a maximum variation of 27%.

6 Conclusions

The following conclusions are based on the results and analysis of the tests conducted to evaluate the performance of Aluthermo Quattro® in relation to Glasswool as an insulation material in simulated roof spaces:

- Less heat is required in the Aluthermo Quattro® insulated enclosures to maintain a target temperature of 21°C when variations in the temperature gradient and volume of airspace within the enclosure are taken into account.
- Aluthermo Quattro® exhibited a consistent performance under all target external temperatures (-5, 0, +5°C) whereas the performance of the Glasswool varies across the three test increments.
- Aluthermo Quattro® is 24.2%, 15.1% and 0.3% more efficient than the Glasswool when tested at -5°C, 0°C and +5°C external temperature respectively.
- The effective thermal resistance for Aluthermo Quattro® obtained in this comparative test, whilst not measured or calculated directly, is considered to be at least equal to the thermal resistance of the Glasswool (4.5 m^2K/W) in the absence of a standard thermal conductivity test for reflective insulants. The relative performances observed are within the limits of this study.