Thermal performance of shredded carpet

Prepared for Spruce Carpets by Dr. Paul Baker
Centre for Research on Climate and Indoor Health
School of the Built and Natural Environment
Glasgow Caledonian University
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Introduction

This report summarises the results of tests on two samples of shredded carpet to determine their thermal conductivity using an *in situ* heat flux method. The work was carried out by the Centre for Research on Indoor Climate & Health, Glasgow Caledonian University (GCU) on behalf of Spruce Carpets.

Test Procedure

Test were carried out in the GCU Environmental Chamber (Figure 1) which designed to test the performance of building materials & components under the range of climate conditions experienced in the UK. The chamber consists of two walk-in rooms, an “Exterior” room which can be used to simulated outdoor weather and an “Interior” room to simulate typical indoor environmental conditions. The exterior room also has the facilities to simulate driving rain and solar radiation (using infra-red lamps) on a wall surface. Both rooms can be pressurised. The aperture formed between the rooms can accommodate a wall up to 3m wide by 2.4m high. By moving the interior room different wall thicknesses can be constructed. The two rooms can be controlled within the temperature and humidity ranges as shown in Table 1. The temperature and humidity in both rooms and the driving rainfall and infra-red lamps are fully controllable from either built-in controllers or a PC.

Figure 1: The GCU Environmental Chamber
Table 1: Temperature and humidity ranges for GCU Environmental Chamber

<table>
<thead>
<tr>
<th></th>
<th>Temperature</th>
<th>Relative Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior room:</td>
<td>-20°C to + 30°C</td>
<td>20% to 90%*</td>
</tr>
<tr>
<td>Interior room:</td>
<td>+10°C to + 40°C</td>
<td>20% to 90%*</td>
</tr>
</tbody>
</table>

*Note: relative humidity is not controlled if the set point temperature is below 10°C.

A plywood box designed to give an insulation thickness of 100mm was constructed and mounted within an insulated panel between the exterior room and the interior room (Figures 2-5). The box was split into two sections divided by a piece of extruded polystyrene insulation. Temperature sensors (type-T thermocouples) were affixed to the inside faces of the plywood in each section (Figure 3). Two different samples of shredded carpet, RS40 and LRK1400, were used to fill the box (Figure 4). RS40 is coarser than LRK1400. The box was fully assembled with the shredded carpet inside, the box was then stood vertically on one of its long sides, the top side panel removed, the samples of insulation allowed to settle and then topped up with extra insulation to ensure a complete fill. The box was left overnight and the topping up repeated. The box was then sealed up and installed in the Environmental Chamber.

Heat flux meters (Hukesflux Type HFP01), mounted on the warm face of the box (Figure 5), were used to measure the heat flow directly through the insulation. All sensors were logged at 5 second intervals and stored as 10 minute averages using a Campbell Scientific CR1000 data logger.

Test conditions generally used were 2°C in the exterior room and 22°C in the interior room. The test was run for a sufficient duration to allow the environmental conditions in the test rooms and the heat flow through the box to stabilise and then collect at least two to three days data for analysis. A schematic diagram of the test set up is shown in Figure 6.
Figure 4: Shredded carpet fill installed (above)

Figure 5: Box installed in GCU Environmental Chamber with heat flux sensors mounted on warm face (right)

Figure 6: Schematic diagram of test set up

Whilst the test is non-standard, it is suitable for larger, more representative sample sizes.

After the completion of the test, the materials were removed and weighed to calculate the packing density of each sample.
Results

80 hours of data were collected for analysis between 21st and 24th June 2008. The averages and standard deviations of the measurements are given in Table 2.

Table 2: Averages and standard deviations of test measurements

<table>
<thead>
<tr>
<th>Sample LRK1400</th>
<th>Warm Side Temperature [C]</th>
<th>Cold Side Temperature [C]</th>
<th>Heat Flux [W/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor LRK1400 T1</td>
<td>19.6</td>
<td>4.0</td>
<td>8.3</td>
</tr>
<tr>
<td>Sensor LRK1400 T2</td>
<td>0.1</td>
<td>0.2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample RS40</th>
<th>Warm Side Temperature [C]</th>
<th>Cold Side Temperature [C]</th>
<th>Heat Flux [W/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor RS40 T1</td>
<td>19.5</td>
<td>3.6</td>
<td>7.5</td>
</tr>
<tr>
<td>Sensor RS40 T2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

The thermal conductivity ($\lambda$, W/mK) of each material was calculated as follows:

$$\lambda = \frac{Q}{d \Delta T}$$

where $d$ is the thickness (nominally 0.1m), $Q$ is the measured heat flux and $\Delta T$ is the temperature difference across the sample.

The thermal conductivities of the shredded carpet are as follows:

Sample RS40  $0.047W/mK \pm 7\%$
Sample LRK1400 $0.054W/mK \pm 8\%$

The coarser material (RS40) is slightly better, however in terms of accuracy of measurement the difference is not be significant.

Rounding the thermal conductivity to two decimal places gives a value of 0.05W/mK. Using the BRE Conventions for U-value measurement [1], the depth of insulation required to achieve a U-value of 0.2 W/m²K to meet current Scottish Building Standards [2] for a roof was calculated for shredded carpet and glass wool, assuming a thermal conductivity of 0.04W/mK for the latter. A joist area of 9% was assumed with insulation between and covering the joists. The results are as follows:

Shredded carpet  250mm
Glass wool  200mm

Allowing for the joists, the volume of shredded carpet required would be about 26% more than that of mineral wool.
The packing densities of the two samples are as follows:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS40</td>
<td>124</td>
</tr>
<tr>
<td>LRK1400</td>
<td>115</td>
</tr>
</tbody>
</table>

For comparison, glass wool with a thermal conductivity of 0.04 W/mK has a density of 10-20 kg/m³.

**Conclusions**

The thermal conductivity of two samples of shredded carpet have been measured in the GCU environmental chamber using an *in situ* heat flux method. The thermal conductivity of both samples is 0.05 W/mK. The level of uncertainty of the measurements is within 8%.

In order to meet the current Scottish Building Standards for roof insulation a depth of 250mm would be required compared to 200mm for glass wool, i.e. 26% more by volume. Since the packing density of the shredded carpet is 6-12 times that of glass wool, 7-15 times the weight of material would be needed to insulate a roof.

**References**