EC1310

Thermal Resistance of a Block Wall

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Thermal Resistance of a Block Wall

1. CLIENT

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2. TEST SPECIMEN

The test specimen was a section of lightweight concrete block wall (Figure 2) with face dimensions 1.5 m wide by 2.6 m high, constructed at the BRANZ Judgeford site by the client. The blocks were set-out in a staggered bond layout. No interior lining or exterior plaster finish was applied to the wall. The concrete masonry units (CMU's) were supplied by the client who stated that although the blocks were made by hand they are representative of what would be made commercially.

Figure 1. Benex Block

Figure 2. Test Wall

Figure 3. Guarded Hotbox

The block has a hollow two core construction with three webs (Figure 1). The blocks are 600 mm long, by 200 mm deep, by 200 mm high. Both faces and end webs of the blocks have average thickness of 44 mm (38mm at the bottom and 50mm at the top). The centre web average thickness is 38 mm (25mm at the bottom and 50mm at the top). Total volume of the block is 24 litres with 10.6 litres in the two voids and 13.4 litres of solid material with an average density of 1000 kg/m^3, giving the blocks a weight of 13.4 kg. The density is lower than standard masonry because of the addition of 3mm diameter expanded polystyrene (EPS) beads.

The wall was constructed by the client on 17th April and allowed to set for 6 days before testing for four days from 24th to 27th April 2007.

3. THERMAL CONDUCTIVITY OF THE BLOCK MATERIAL

A separate sample of the block material was supplied by the client for thermal conductivity measurement using the BRANZ Heat Flow Meter Apparatus. The sample consisted of a solid slab with dimensions 600 x 600 mm and thickness of 50 mm. The sample was testing according to the procedures of ASTM C518 and the thermal conductivity was determined to be 0.45 ± 0.02 W/m°C for a density of 950 kg/m^3. The average density of the block is slightly higher than this because the faces are finished with material which does not have the EPS beads.

4. APPARATUS

See Figures 3 & 4.

- Two insulated, open faced, temperature controlled chambers plus associated exterior heating and cooling equipment
- A large diameter, slow rotation, mixing fan in each chamber
- Insulating surround panel to fit the test specimens to the faces of the chambers
- Insulated heat flow metering box (meter box) including DC electrical heating elements and circulation fans
- 25 element thermopile embedded into the interior and exterior surfaces of the walls and back face of the meter box
- 16 pairs of type ‘T’ thermocouples for measuring the air-to-air temperature difference between the two chambers (100mm form the surface)
- 16 pairs of type ‘T’ thermocouples for measuring the surface-to-surface temperature difference between the faces of the test specimen
- Set of 16 type ‘T’ thermocouples for measuring air temperature on the interior side of the test specimen
- Set of 16 type ‘T’ thermocouples for measuring air temperature on the exterior side of the test specimen
- PC based data acquisition and control system, sampling every 5 seconds and recording at 1 minute intervals

4.1 Chambers

The test apparatus was the BRANZ Guarded Hot Box and consists of two insulated chambers of approximate face area 2.4 m x 2.4 m, with an internal depth of 1.2 m. The four sides and one face of the chambers include 100 mm of rigid foam insulation (R 4 m^2°C/W). The open faces of the chambers are held against the faces of the test specimen. The test specimen was made to fit the face dimensions of the chambers by adding a surround panel with a width of 400 mm and a thickness the same as the test specimen. The surround panel was constructed of rigid foam insulation and had an R-value estimated as 5 m^2°C/W. The temperature of the air in the two chambers is controlled independently using heating and cooling equipment which is connected to the chambers using 300 mm diameter supply and extract ducts on opposite sides of each chamber. There is also a large diameter, slow rotation, mixing fan in each chamber.

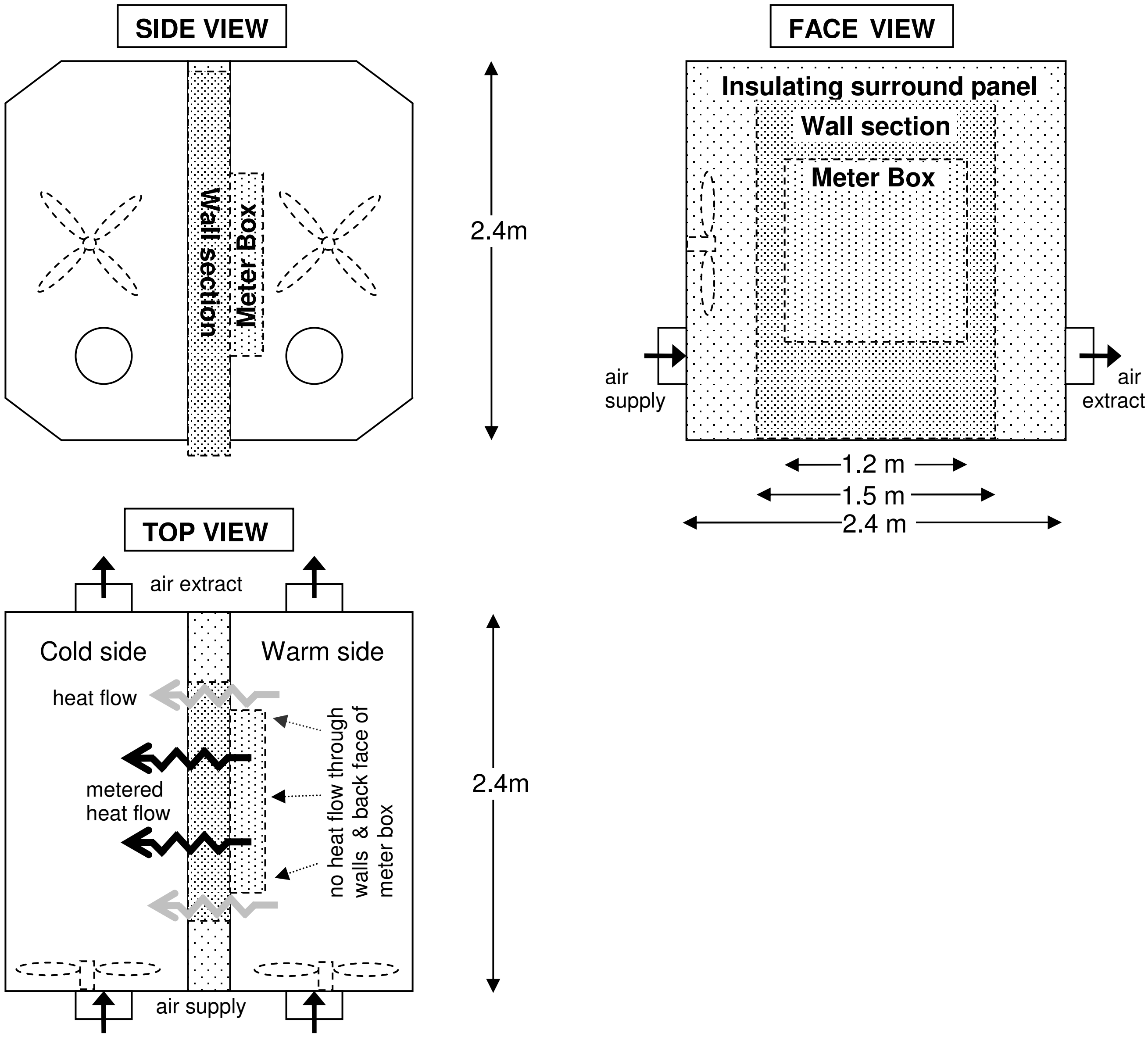

Figure 4. Schematics of Guarded Hot Box Apparatus

4.2 Meter Box

One chamber is kept warmer than the other so that there is a constant temperature difference across the test specimen, generating a constant heat flow, which is measured using a 1.2 m x 1.2 m face area metering box. The 1.6 m x 1.6 m dimensions of the test specimens allows for a so called 'guard' area of 150 mm between the edges of the meter box and the edge of the specimen in addition to the 400 mm of insulation between the edges of the specimen and the walls of the chambers. The guard area minimizes lateral heat flow in the test specimen near the metering area. The meter box has a depth of 240 mm including 50 mm of rigid foam insulation (R 2.0 m^2°C/W) on all four sides and the back face. The front face is open and is kept against the face of the specimen under test.

Inside the meter box there are DC electrical heating elements and mixing fans. Fans and baffles within the meter box produce downward air movement against the face of the sample. Embedded into the surfaces of the four sides and one face of the meter box is a 25 element thermopile, which gives a null output when the resistive heating power supplied to the inside of the meter box is such that the inside surfaces are being maintained at exactly the same temperature as the outside surfaces. There is then no heat flow through the walls and back face of the meter box and all of the heating energy from the elements is therefore being transferred by air movement through the open front face, and then by conduction through the specimen.

4.3 Thermocouples

The air-to-air temperature difference between the two chambers is measured using 16 pairs of type 'T' thermocouples. Surface-to-surface temperature differences between the faces of the samples are also measured using a set of 16 thermocouple pairs. Because the thermocouples form differential pairs, there is no need to measure and include a junction temperature into the determination of temperature difference, leading to increased accuracy and precision above what is normally expected from thermocouple based temperature measurement. All of the thermocouple wire used in association with the apparatus comes from a single batch of wire for which the particular temperature characteristic has been determined.

5. METHOD

The apparatus is constructed and operated according to ASTM C1363-97. The test method requires steady-state conditions and therefore does not simulate such effects as the combination of climatic variation and thermal mass. In fact the measurement takes at least three days to allow one day for the initial response to the change in temperature and two days to determine that there were no slow changes in behaviour due to moisture movement in the specimen or exterior environmental effects on the test chambers. The final R-value is determined by averaging the measurements over at least 24 hours.

The 600 mm x 200 mm modular nature of the block faces means that the 1.2 m x 1.2 m dimensions of the meter box cover the equivalent face area of 12 blocks (2 x 6). The wall was constructed in the apparatus so that the face with the plaster screed was on the cold chamber side of the wall.

The measured total input power to the meter box, including fans, divided by the meter box face area of 1.44 m^2 gives the heat flux in Watts per square meter. The measured temperature difference between the air in the two chambers, divided by the heat flux, gives the air-to-air thermal resistance (R-value) of the wall. The air-to-air R-value includes two air-to-surface resistances which are determined by measuring the difference between the temperature of the air near the surface and the temperature of the surface.

6. DEVIATIONS FROM STANDARD TEST METHOD

This test did not fully comply with the following provision of Test Method C1363:

- Surface air velocities were not measured
- The moisture content of the individual materials have not been measured
- The actual densities of the materials have not been measured

Although surface air velocities were not measured, the surface-to-surface and air-to-air temperature differences were both measured and hence the total surface to air temperature difference can be calculated and from that the total surface resistance. Instead of attempting to generate standard surface air velocities, the results have been corrected to include standard surface thermal resistances.

7. RESULTS

Test period	24th to 27th April
Test interval (days)	4
Approx. mean sample temp. (°C)	23
Approx. cold side air temp. (°C)	18
Approx. warm side air temp. (°C)	28
Air-to-air temp. difference (K)	9.60
Heat flux (W/m^2)	20.78
Surface-to-surface temp. diff. (K)	7.55
Total air-to-surface temp. diff (K)	2.05
Total surface resistance (m^2°C/W)	0.10
Measured air-to-air thermal resistance (R-value) m^2°C/W ± 10%	0.46
Total air-to-air Thermal Resistance (R-value) when corrected to a total surface resistance of 0.16 m^2°C/W	**0.52** ± 10%

Note: The test specimen did not include interior lining or exterior finishing such as plaster.

There was no significant change in R-value of the sample over the last two days of testing.

8. REFERENCES

American Society for Testing and Materials. ASTM 1363-97 (2004). *Standard test method for the thermal performance of building assemblies by means of a hot box apparatus.* Philadelphia, PA

9. LIST OF FIGURES