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Building Serv. Eng. Res. Technol. 15(1) 35–36 (1994) Printed in Great Britain B246

Technical Note

Summary Experimental *U*-values based on measured heat flows through the walls of some houses have been found to be significantly higher than predicted by conventional calculation procedures. The work was carried out in ordinary occupied houses, and included measurements on party, internal and external walls. There are a number of possible reasons for the differences including thermal bridging, high thermal conductivities and excessive air movement in the wall cavities and behind plasterboard dry lining.

Experimental *U*-values of some house walls

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Received 24 May 1993, in final form 9 September 1993

1 Introduction

EA Technology has been actively engaged in both experimental and theoretical work on the thermal performance and thermal reliability of dwellings. The results given here were obtained from a number of owner-occupied houses using experimental techniques developed by EA Technology for measuring heat flows through building structures to obtain *in situ* *U*-values.

2 Experimental method

The experimental method involves first the use of an infra-red camera to identify positions on the inside surfaces of the walls of the dwelling which are representative of the walls as a whole in terms of surface temperature and heat loss. This is necessary because the heat flux sensors (HFS) which are fixed in these positions are small (25 mm diameter), and therefore measure local heat flows. The sensors are fixed in position on the inside wall surface, preferably using silicone grease, or otherwise double-sided adhesive tape. The infra-red camera is used again an hour or so later when the thermal disturbances caused by fixing the sensor have passed. This is to check that the sensor is not visible and that fixing it has not distorted the temperature pattern on the wall.

To obtain a *U*-value from the heat flow measurement requires a temperature difference. This is usually measured using a differential thermocouple between the room and outside. The junction in the room is normally positioned at the same height as the HFS, about one metre away. Outside, the junction is fixed in a reasonably exposed position out of the sun's direct rays, for example under the soffit. The thermocouple wires are run through the gap around an openable window, and the window closed afterwards.

Measurements are normally made during the heating season, with the house's own heating system on. The data are recorded on a strip chart and processed after about five days. Generally there are quite large swings of both heat flux and temperature difference resulting from the control of the heating system, and normal diurnal temperature swings externally. A large difference in either internal or external temperature between start and finish is avoided to minimise the effects of the thermal capacity of the structure. To monitor this one of these temperatures is also measured.

By processing the data recorded over five days, to give a cumulative *U*-value with time, the fluctuating effects are normally quickly eliminated. If this is not so, or the results appear unreliable in other ways, then additional results are recorded over longer periods and examined.

3 Results

The results of measurements in five houses are given in Table 1 with brief references to the types of houses and walls. The construction of all the walls was brick/cavity/block, with a plasterboard finish except for house E which was wet plastered. In all but two cases the *U*-values derived from the measurements were calculated directly from the experimental results of heat flow and temperature difference. The two exceptions are for the party and internal walls of house B. For these the numerical value given is based on the comparison of the infra-red images for these walls with that of the external wall for which heat flow measurements were made. In addition to the experimental results Table 1 contains the theoretical *U*-values based on conventional calculation procedures as given in Reference 1.

4 Discussion

A number of factors in the results require discussion. Firstly, the experimental *U*-values for the four unfilled external walls are very similar and in the range 0.83 to 0.88 W $m^{-2}K^{-1}$. They were all built to meet the Regulation requirement of 0.6 W $m^{-2}K^{-1}$ as conventionally calculated. All were of typical construction of brick, unfilled cavity, lightweight block, and finished with plasterboard on dabs. Each wall was examined from the loft and this included a measurement of block and cavity dimensions. The walls were not examined physically at the positions of heat flow measurement because this would have necessitated repair afterwards.

Three possible mechanisms of failure are suggested: cold air movement behind the plasterboard; thermal bridging of the blockwork by the mortar joints, which is not allowed for in the conventional calculations; and a higher thermal conductivity for the block than that used in the calculations. A combination of all three mechanisms is likely. Previous work[(2)] indicated an incremental increase of 0.2 W $m^{-2}K^{-1}$ arising from air movement in the air space behind the plasterboard.

Table 1 Wall information and *U*-values

House reference	Wall type and finish	Wall position	*U*-value (W $m^{-2}K^{-1}$) Conventional calculations (theoretical)	From measurements (experimental)
C Detached	Unfilled cavity Plasterboard	External	0.6	0.85
D Detached	Unfilled cavity Plasterboard	External	0.6	0.83
	Filled cavity Plasterboard	External	0.34	0.51
G Semi-detached	Unfilled cavity Plasterboard	External	0.6	0.88
		Party	—	0.44
B Terraced	Unfilled cavity Plasterboard	External	0.56	0.85
		Party	—	About 0.85
		Internal	—	Varied
E Terraced	Cavity Wet plaster	Party	—	0.80

Calculations show that thermal bridging of the inner leaf by ordinary mortar[3] and a conductivity for the block of 0.14 instead of 0.11 W $m^{-2}K^{-1}$ can each add about 0.1 W $m^{-2}K^{-1}$ to the *U*-value. Together they easily account for the difference between calculated and measured results.

House D was subsequently subjected to a complete cavity fill of blown fibre thermal insulation. The measuring equipment had been left in place and a new experimental *U*-value of 0.51 was obtained. However, this better value is not only worse than the value given by conventional calculations, but also worse than the 0.44 W$m^{-2}K^{-1}$ calculated by adding the extra theoretical thermal resistance offered by the cavity insulation to the experimental value of 0.83 W$m^{-2}K^{-1}$.

The other results given are for party walls and an internal wall. Heat flows were measured through the party walls of houses G and E and their *U*-value derived using the measured internal to external temperature difference. For house B the experimental *U*-values for both the party and internal walls were deduced from infra-red imaging. This technique involved comparing the infra-red images of the party and internal walls with that of the external wall on which heat flow was measured. The images for the party wall were very similar over the whole of the area examined to that for the external wall, and therefore the same *U*-value of 0.85 W $m^{-2}K^{-1}$ has been assigned by comparison. This assigned value is much larger than the 0.44 W $m^{-2}K^{-1}$ obtained from the measurements for the similar wall in house G, but about the same as that for the wet-plastered wall of house E.

The infra-red imaging of the internal wall was also very similar to that of the external wall close to where it abutted the external wall. It showed a diminishing heat loss effect further into the house, reaching zero by about 2.5 m in from the external wall.

House E was stepped terraced, so that the wall subject to investigation was external over part of its length. Because it was wet-plastered the infra-red imaging of this part showed the high-conductivity mortar joints 'grinning through' around the low-conductivity blockwork. This image changed on reaching the party wall to an approximately uniform appearance at a temperature similar to that of the mortar. This supports the high value measured for the heat loss on which the given *U*-value is based.

The suggested reason for the heat loss through the party and internal walls is the movement of cold air in their cavities. Significant air movement between the loft and the cavity of one of the party walls through incomplete vertical mortar joints was detected using a small hand-held smoke generator of the type used in air tightness testing. Fire stopping of such walls could be expected to reduce airflow considerably in such cavities, but it would not be expected to make them completely airtight. From the house plans it was deduced that the internal wall which lost heat was an external cavity wall in an earlier design.

The accuracy of such heat flow measurements and derived *U*-values are generally quoted to be better than ± 10%.

5 Conclusions

(*a*) The results show that in practice the *U*-values of external walls can be significantly higher than those calculated using conventional procedures.

(*b*) Party walls and an internal wall were found to lose heat and therefore to have a *U*-value.

(*c*) Likely causes are cold air movement behind plasterboard, thermal bridging and inaccurate thermal conductivity values.

References

1 *CIBSE Guide* Section A3: Thermal properties of building structures (London: Chartered Institution of Building Services Engineers) (1986)

2 Siviour J B *Plasterboard fixing for thermal integrity* Building Technical File 25 (April 1989)

3 Siviour J B and Mould A E Thermal bridging: Significance in *U*-value calculation *Building Serv. Eng. Res. Technol.* **9**(3) 133–135 (1988)