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THERMAL AND MOISTURE PERFORMANCE OF AN OCCUPIED LOW ENERGY HOUSE

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An experimental low-energy house, with a novel structure incorporating an unusually large amount of expanded polystyrene insulation, was subjected to extensive monitoring while occupied by a family. Measured thermal conductances are reported and compared with calculated U-values, and the moisture performance is discussed.

The house was built by a manufacture of expanded polystyrene insulation material with the aim of demonstrating the practical advantages of using expanded polystyrene for buildings with very high standards of insulation. Expanded polystyrene is a relativley inexpensive insulating material, and it has the big advantage over glass fibre mat, a major competitor, that because of its structural rigidity it can, in principle, be used as a load-bearing component of the building structure.

The appearance of the house was intended to be as conventional as possible. The structure was built with load-bearing masonry rather than a timber frame, and as far as possible, construction methods were those of the conventional building trades.

The roof structure consisted of plywood box beams with an insulating expanded polystyrene core, between which are placed prefabricated panels with an outer skin of 9mm of plywood, a core of 200mm of ordinary-density expanded polystyrene, and an inner skin of 3.2mm of hardboard with a high resistance to water vapour. The outside was finished with roofing felt (required by Building Control) and imitation slates to give a conventional appearance. Part of the inside surface was painted with a vapour barrier to assess the need for enhanced water vapour resistance. The calculated U-value was 0.168 W m^{-2} deg C^{-1}. The measured thermal conductance was 0.12 W m^{-2} deg C^{-1} for the south roof, and 0.17 W m^{-2} deg C^{-1} for the north roof (which did not receive solar radiation).

The walls were externally insulated with polystyrene sheet 150mm thick, attached to slotted dense concrete blocks with plastic clips, leaving a cavity of about 6 mm. The external surface was glass-reinforced concrete sheeting, 4.5 mm thick, coated with a flexible rendering. The insides of the walls were plastered with gypsum plaster in the usual way. The cavity was vented to the outside to allow release of water vapour, at the risk of increased heat loss. The calculated U-value was 0.21 W m^{-2} deg C^{-1}. The measured thermal conductance varied from 0.22 W m^{-2} deg C^{-1} to 0.33 W m^{-2} deg C^{-1} depending on exposure to solar radiation and also on conduction of heat up the masonry of the wall from the heated floors.

The ground floor was of conventional solid construction, but with a total insulation thickness of 150 mm of expanded polystyrene, the insulation standard was much higher than usual. The calculated U-value was 0.19 W m^{-2} deg C^{-1}. Because the floor was heated, it was not possible to get a direct comparison of the thermal insulation in service. Calculations of heat losses indicated that the insulation of the floor was adequate to overcome the increased floor temperatures, but there was some evidence of increased subfloor temperatures, in excess of 15 degrees C during very cold weather when the floor heating was most in use.

The heating system of the house used stored hot water heated to a maximum of 95 degrees Celsius by Economy-7 electricity. The ground-floor rooms had floor heating, with polybutylene pipes laid in the floor screed. To avoid excessive floor temperatures, the flow temperature was limited to 50 degrees Celsius by means of a three-port mixing valve. The upstairs rooms had conventional extended-surface radiators, designed to use the rather low flow and return temperatures of the floor heating system.

Distribution of hot water to the various rooms was regulated by solenoid valves which could be opened and closed in a variable mark-space ratio on a ten-second time base to give a degree of proportional control. A domestic-sized energy management computer controlled the temperature for each of 16 zones (usually individual rooms) in response to air temperature measurement from an electronic sensor in each zone. Separate settings could be made for each zone of both normal and set-back temperatures, and of the times for which the temperature settings were to apply. A three-term PID algorithm was used, with self-optimising optimum start and stop time control.

Great attention was paid to draughtproofing during construction, and to ensure satisfactory air-tightness, a 50-pascal pressure test was done after completion of the house. This revealed a few sources of uncontrolled infiltration which were sealed up. A final pressure test on the newly completed house indicated an infiltration rate under natural conditions of 0.2 air changes per hour, and a re-test at the end of the two-year experimental period showed only a slight reduction in air-tightness. A mechanical ventilation system allowed control of air movement throughout the occupied space, providing typically 0.3 air changes per hour in addition to natural infiltration, and a heat exchanger was installed for heat recovery from the exhausted air.

Overall, the thermal conductances measured over a two-year period were found to be approximately half the maximum values permitted in the 1990 Building Regulations for England and Wales. The proportion of heat lost in conduction through the fabric, conduction through windows and doors, and ventilation were found to be about equal, indicating that the relative amounts of insulation in the different components were not too far from optimum.

Moisture performance was found to be entirely satisfactory, with no evidence of condensation. There was some evidence of cycling of humidity in the roof structure, which was attributed to the effect of solar radiation heating on entrapped moisture. There was no evidence that the painted vapour barrier was needed on the roof, and no evidence that the wall cavity was either effective in releasing moisture, or deleterious to the insulation performance to any significant degree.

The family reported great satisfaction with the performance of the house and its heating system over the two years of the experiments. Their assistance with the work is gratefully acknowledged.