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SUPERINSULATED DESIGN FOR MASONRY BUILDINGS

B. Vale and R. Vale
Department of Architecture
University of Sheffield
Western Bank
Sheffield, S10 2TN, U.K.

1. Introduction

The building described in this paper is a general practice surgery for three doctors practising under the U.K. National Health Service in Sheffield. Strict cost limits, which may not be exceeded, are laid down for this building type by the Department of Health and Social Security. The aim of the project is to show that within these strict cost limits it is possible to build a highly energy efficient building.

2. Low energy design

It was decided to use modifications of traditional U.K. masonry construction methods to achieve the low-energy performance rather than the more widely known timber frame techniques (1) for the following reasons:-

2.1. It was intended to maximise the indigenous material content of the building to reduce transport energy demand of the materials. Masonry materials are widely manufactured in the U.K., but the majority of timber is imported.

2.2. The long term performance of traditional materials in the U.K. climate is well known.

2.3. The building contractor would be familiar with the basic techniques and only the modifications would be novel. This should lead to a reduction in problems during construction and less chance of high tender prices caused by uncertainty about completely novel construction methods.

3. Building description

The surgery is built of facing brick and concrete blockwork with a concrete slab ground floor and a pitched timber roof covered with concrete roof tiles. The doors and windows are of timber. These are the conventional materials of almost all small buildings in the U.K. The plan area is 249 m2, mostly on one level, with an additional meeting room built into the roof space at the East End. The ratio of width to depth is 4:1, with, the long axis running East-West. The building is divided laterally by a brick spine wall which supports the roof ridge and divides the flat-ceilinged consulting and treatment rooms on the north side from the south facing waiting area which has a sloping ceiling open to the roof ridge.

4. Elemental design

4.1. Ground floor slab

Very poor ground conditions require the use of reinforcement in the ground floor slab which is of 150 mm concrete. Expanded polystyrene insulation 150 mm thick is laid under the slab, giving a U-value of 0.17 W/m2K.

4.2. External walls

British Standard Code of Practice CP 121: Part 1:1973 (2) allows a loadbearing masonry cavity wall to be constructed with a cavity not exceeding 150 mm. This determined the wall insulation thickness, using resin bonded glass fibre insulation batts. The outer leaf of the wall is of frost resistant clay bricks, and the inner leaf of lightweight concrete blocks. The wall ties are stainless steel vertical twist type. The calculated U-value for the wall is 0.19 W/m2K.

4.3. Openings

The jambs of openings in the wall, which would normally be closed with a return of the inner leaf, are modified to reduce cold bridging by the use of a proprietary plastic extrusion containing 75 mm foamed polyurethane insulation. This extrusion also forms the vertical damp proof course at the jambs and is used in conjunction with a short return of the inner leaf.

4.4. Lintels

To reduce the cold bridging effect of conventional pressed steel components, the lintels consist of an inner and outer unit of glue laminated timber, each 215 mm x 100 mm, separated by 150 mm extruded polystyrene insulation. A damp proof course above the lintel drains any water away from the inner leaf of the wall.

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4.4. Roof

The flat ceiling areas have a 300 micron polythene vapour barrier with joints and edges sealed with non-setting mastic. Above this is 300 mm glass fibre insulation. The sloping ceilings have a similar construction but insulation thickness is limited by the 200 mm rafter depth, leading to the addition of 50 mm extruded polystyrene above the rafters, a 50 mm ventilated air gap, and 8 mm reflective foil backed bubble film under the tiling battens. In both cases the roof U-value is 0.11 W/m2K. The roof incorporates a number of rooflights which use argon filled low-emissivity triple glazing to give a U-value of 1.4 W/m2K.

4.5. Spine wall

The 225 mm brick spine wall is insulated with 200 mm glass fibre where it adjoins the unheated roof void above the consulting and treatment rooms.

4.6. Windows

"Off-the-peg" standard softwood high performance windows are used, with draught seals to all opening sashes. The glazing is in 4-12-4 low E units with argon filling giving a U-value of 1.6 W/m2K. Only two window sizes are used, coupled as needed to provide the required glazing areas.

5. Services

5.1. Space heating

These space heating sources are used, all space heat is supplied directly to the central waiting area. The space heat emitters are as follows:-

5.1.1. A thermostatically controlled solid fuel stove operating at 70% efficiency. This is provided as a focal point in the waiting area. The use of solid fuel in the stove is a more efficient use of the fuel resources than electric space heating from the U.K's coal fired power stations.

5.1.2 Three 2000 watt electric panel heaters with built in thermostats. These are controlled by a timer clock and act as a backup to the stove.

5.1.3. Three 715 watt electric heating elements in the fresh air supply to the waiting area. These are also thermostatically controlled.

5.2. Ventilation

Three separate heat recovery ventilation systems are used to supply fresh air to the waiting room, with extract from the peripheral spaces. The use of three units reduces the length of ducting.

5.3. Hot Water

The need for hot water in all rooms has led to the choice of electric instantaneous water heaters at each point of use.

5.4. Lighting

Lighting is by means of compact flourescent units. The large number of lighting points needed would give a lighting load in excess of 4 kW if tungsten lights were used, and could lead to overheating.

6. Thermal Performance

The thermal performance of the elements of the building is set out in Table 1 below:

Table 1: Heat losses from the superinsulated building

Building Element	Dimension	U Value	Heat Loss
Ground floor slab	214.7 m2	0.17 W/m2K	36.5 W/K
External wall	166.7 m2	0.19 W/m2K	31.7 W/K
Flat ceilings	72.3 m2	0.11 W/m2K	8.0 W/K
Sloping roof	144.2 m2	0.11 W/m2K	15.9 W/K
Rooflights	11.2 m2	1.40 W/m2K	15.7 W/K
Spine wall	52.3 m2	0.16 W/m2K	8.4 W/K
Windows	34.1 m2	1.60 W/m2K	54.6 W/K
Ventilation	757.8 m2	0.2 air changes/hour	54.6 W/K
Total Heat Loss			225.4 W/K
		=	0.30 W/m3K

This table reveals some interesting aspects of the building. The main sources of heat loss are the glazing and the ventilation. The area of glazing (including rooflights) is 18% of the floor area, and the windows represent 17% of the area of external wall, but the heat loss through them is 70% greater than that through the solid wall area. Heat loss through all glazing is 31% of the total loss. In spite of efforts to reduce ventilation heat loss by use of heat recovery; it still accounts for 24% of the total. Because of the architectural decision to use a sloping ceiling the building has a volume that is 30% greater than would be the case if it were built with a standard 2.3 metre ceiling height.

It is also instructive to look at the heat losses that the building elements would have if the surgery were constructed to meet the current U.K. Building Regulations (3). These are set out in Table 2 below:-

Table 2: Heat losses from the same building built to current Regulations

Building Element	Dimension	U Value	Heat loss
Ground floor slab	214.7 m2	0.60 W/m2K*	128.8 W/K
External wall	166.7 m2	0.60 W/M2K	100.0 W/K
Flat ceiling	72.3 m2	0.35 W/m2K	25.3 W/K
Sloping roof	144.2 m2	0.35 W/m2K	50.5 W/K
Rooflights	11.2 m2	5.70 W/m2K	63.8 W/K
Spine wall	52.3 m2	0.60 W/m2K	31.4 W/K
Windows	34.1 m2	5.70 W/m2K	194.4 W/K
Ventilation	757.8 m3	1.0 air change/hour*	272.8 W/K
Total heat loss			867.0 W/K
		=	1.14 W/m3 K

* no values are laid down in the Building Regulations for these elements.

The superinsulated building has reduced the heat loss compared to the conventional Building Regulations building by 74%. The conventional building loses more heat through its glazing than the total heat loss of the insulated version. A comparison of the two buildings reveals the following elemental heat loss reductions:-

Table 3: Elemental heat loss reductions

Element	Reductions
Ground floor slab	72%
External wall	68%
Roof (all areas)	69%
Rooflights	75%
Spine wall	73%
Windows	72%
Ventilation	80%

(Note: ventilation reductions are of necessity based on assumed rates in the two buildings).

7. Costs

The lowest priced tender for the construction of the superinsulated building has been analysed elementally. The overall cost falls within that allowed by the DHSS for a 249 m2 surgery, with an increase allowed for abnormal site conditions which require excessively deep foundations and a reinforced ground floor slab.

The cost per square metre is £555.94, which would be reduced to £453.33 if the building were on a normal flat site. The abnormal site costs are 18% of the total cost. The superstructure is 37% of the total and the services represent 18%. A more detailed breakdown of costs will be made at a later date.

8. Conclusion

Perhaps more important than the detailed costings is the fact that the building falls within the allowed cost limits for a building of this type. A 74% reduction in space heat load (and an 80% reduction in lighting load) has been achieved for the same price as a conventional building.

The low energy measures have not been allowed to influence the design unduly; for example the volume of the building is 30% greater than it need be, the area of glazing is 8% greater than the rule-of-thumb minimum in the U.K. (10% of floor area), and the plan is rambling rather than a compact form to minimum surface area to volume. Insulation levels were chosen that could be achieved without contravening current U.K. Codes of Practice, and the materials and components were chosen from those available in manufacturers' catalogues. The low energy design worked always from the premise of what seemed reasonable rather than by setting targets and trying to meet them.