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A low energy air heated solar house with transparent insulation

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ABSTRACT

The design of a single family, low energy, air heated solar house with transparent insulation has been completed. To be built in Birmingham, UK it has 91 m^2 floor space in a split level arrangement. In the Midlands climate the house requires no auxiliary heating but it needs cooling during a portion of the summer. The cooling is achieved by variable air change rate ventilation The method of stepwise parametric optimisation was used for the preliminary design using the f-load computer simulation program. The detailed design, based on the Transparent Insulation Computer Aided Design TICAD program is now being implemented.

DESIGN

Based on long term average climatic data the monthly net solar gain for the year was determined. This was augmented by internal incidental gains from cooking, electrical equipment and people. The total heat gain from all sources was balanced against heat loss through the envelope of the house and against heat loss due to infiltration.

By using transparent insulation (1) and by varying the size and insulation characteristics of the building elements it was possible to achieve a "zero heating" requirement design solution at the expense of some cooling in the summer. The design met the original specifications of the building and required only standard material most of which is readily available locally.

Part of the roof has solar air collectors which are made with transparent insulation covers, the other part has transparent insulation for direct solar gain. The east, south and west facing walls are also fitted with transparent insulation and passive solar heating provides most of the heating load. Movable insulation is provided by shutters which reduce the night time U values and increase the privacy and security of the building.

Solar heated air from the roof collectors is passed through two parallel pebble bed heat stores positioned on either side of the stairs in the center of the house and each being two story high. This and the high density walls together with the concrete floor provide a very large effective thermal mass to guarantee that indoor temperature variations will be minimised.

The north end of the building is partly earth sheltered and is well insulated. The floor of the living room is floated on 100 mm polystyrene insulation. All windows are triple glazed and equipped with insulating shutters.

SIMULATION

The preliminary design used a simple strategy of stepwise parametric optimisation. The parametric runs covered different allowable relative humidity levels and different day and night room temperatures during both the heating and cooling seasons. Minimum operating cost was the objective to reach.

By varying the ventilation rates (more in the summer) infiltration could control the comfort in the house. In practice most people would open windows and use natural or forced ventalation (2) particularly when the outside temperature was below the desired room temperature. Thus using the ambient temperature for cooling reduces (3) the number of cooling degree-days.

The quasi optimal design resulted in zero annual total heating requirement and 983 kWh annual total cooling requirement, which was considered small for Birmingham conditions if a slight rise in summer indoor temperature is accepted for a short period of time. The variable rate air cooling is designed to match the cooling load requirement. The building has low natural infiltration.

The cost of building the solar heated house was analysed and found to be competitive with conventional houses which use gas or oil fired central heating systems. The fan forced air cooling is extremly economical and cost effective.

BUILDING DESCRIPTION

The house is at 52.4 degrees northern latitude, the yearly average ambient air temperature is 10.2 °C and the annual total horizontal solar radiation is 960 kWh/m^2. The building as shown on Fig. 1. is rectangular and facing due south. The living room (L) has a glazed south wall, behind it are the dining room (D) and kitchen (K) facing east and west respectively. As the building stands on a sloping ground part of the north end of the ground floor is earth protected.

The bedrooms (B) and the bathroom are on the upper floor on the north side of the building in a split level arrangement, not on top of the living room. The stairs are between the dining room and the kitchen lead-

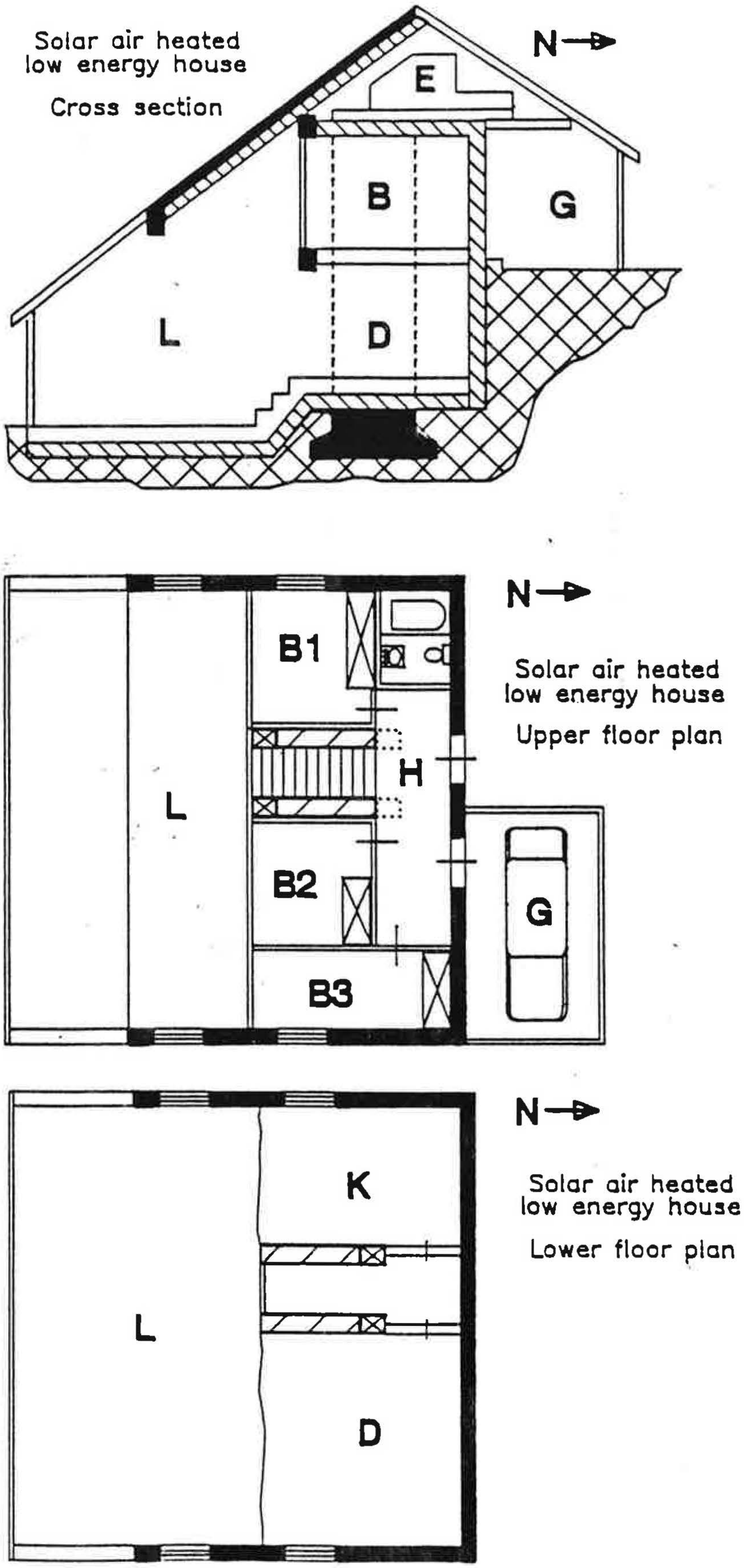

Fig.1 Cross section and floor plans of the building.

Legend: B bedrooms, D dining room, E energy equipment, G garage, H hall, K kitchen, L living room, N north.

ing from the living room to the upper level between two structures which separate them from adjacent spaces. These structures contain the pebble bed heat store.

The south facing sloping roof has solar air collectors near the apex and a glazed lower portion which joins the large window walls. Part of the design process concentrated on finding the right balance of areas and positions between glass and non transparent walls and roof. The more glass is used the less heating is needed but at the expense of summer cooling.

NATURAL LIGHTING

Using transparent insulation enabled the control of heat passage in and out of the house and improved the design by combining heat and light inside the house. The lower, southern end of the living room has much glass on three sides and transparent insulation below the glass on the roof. To avoid glare movable and adjustable shutters and louvers are used for shading, but during daytime the room will be airy and light and those in it will feel that they are in a much larger space then in reality they are.

TRANSPARENT INSULATION

The lower part of the roof, the air collectors, all east, south and west facing exposed walls have transparent insulation on the outside, supported by metal frame or wooden frame and covered by glass. Only windows and the large patio door are not covered with transparent insulation.

CONCLUSION

The limits of infiltration control strategy are recognised especially when the ambient temperature is close to room temperature or the ambient relative humidity is high. Large air flow rates can increase air velocities beyond comfortable (4) levels. In such cases it is common to use an enthalpy controller which operates the ventilation system when the enthalpy of the outside air is low enough to meet the requirements of both the latent and sensible cooling loads.

A house can be heated totally by solar energy and by normal incidental gains in a northern climate if transparent insulation is used in a carefully designed manner. The total cost of the house is competitive with similar size buildings when low energy operating costs are taken into account.

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