Low cost, low energy, low impact housing

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INTRODUCTION

Unlike our prosperous European neighbours, in Britain the expectation is that housing should be inexpensive. It is, therefore, not surprising that little has been achieved in the field of designing environmentally responsible housing. Compared to countries like Austria, where house building costs are between £750 - £1000 per sq metre, (1) in the United Kingdom social housing is expected to cost in the region of £500 per sq metre. Current Building Regulations do little to encourage buildings that save energy or use other methods to reduce harm to the environment. This may be because the concern is that more stringent regulations would tend to mean no houses rather than environmentally aware houses. The driving force, therefore, behind the Sheffield ecological cottages was to explore exactly what could be afforded on a normal Housing Corporation budget using a builder selected through the process of the lowest competitive tender.

In order to design any building, however, certain assumptions about what is likely to be feasible have to be made. It did not seem possible to install means of collecting renewable energy, such as the positioning of photovoltaic panels on the roof, within the budget. The current cost for such panels is £6000 per kilowatt and a house might need a 1.5 kw installation to provide all electrical needs. Nevertheless, such installations can be found on houses on the continent, feeding into the grid any surplus power and drawing from the grid when demand exceeds supply. In the same way, it did not seem feasible to install composting WCs or devise an alternative means of sewage treatment for such a limited budget on an inner city site. Indeed, the only strategy that seemed feasible was to reduce energy demand through insulation of the building fabric to a point where the natural gains from the sun and from occupants could make a significant contribution to the demand for space heating. At the same time the decision was taken to make the building air-tight and to provide fresh air to the inside through a controlled ventilation system.

DESIGN PRINCIPLES

The pair of cottages at Industry Road, Darnall, Sheffield were designed to meet a number of criteria, some suggested by the client, North Sheffield Housing Association, and some by the architects.

Firstly, they were intended as a possible prototype for the Housing Association to use on infill sites such as where existing houses had been demolished in a terrace. These are the kind of site that are available on a regular basis, whereas a site for a group of twenty or thirty houses is more difficult to find, especially in relation to existing housing, shopping and employment areas.

Secondly they were also intended to provide tenants on low incomes with affordable heating. This would both provide comfort to the tenants, and avoid the problem of building fabric deterioration that can occur when occupants can not afford to heat the houses in which they have to live, and resort either to not heating them, or to using bottled gas heaters. Both situations can result in high levels of condensation and mould growth, leading to rapid and expensive deterioration of the building fabric.

Thirdly, they were intended as a response to widely discussed global environmental problems. Buildings are responsible for at least half the "greenhouse gas" emissions that are causing global warming, with two thirds of this coming from the domestic sector. (2) The main culprit is the use of fossil fuels for space heating, lighting and power. For the long-term future of the earth it is essential that fossil fuel consumption is curtailed. The cottages were intended to show what might be possible.

Fourth, the houses embodied an investigation into the use of "environmentally friendly" materials, finishes and techniques, partly on health grounds in line with some of the principles of the German Baubiologie movement, and partly so that the energy required to make the materials could be minimised, not just the energy needed to run the finished houses.

The final point, and the most stringent, was that the cottages had to be constructed within a normal Housing Corporation budget, there was no additional money to provide any of these extra items. This criterion was seen as an opportunity rather than a constraint on design. If it proved possible to build houses that were to some extent ecologically sound for the same cost as conventional houses, there might be some chance of the ideas being taken up by other Housing Associations, by other architects and by developers of private housing. If the houses were more expensive than normal, and were funded with research grants or other special sources of money, it would be easy for them to be dismissed as "experimental". The architects were anxious to demonstrate what could be achieved in a perfectly conventional situation.

DESIGN INSPIRATION

The inspiration for the design came from a long interest in the low-cost housing schemes designed by many well-known architects at the turn of the century. These studies coincided with pressures from public health and social reformers to improve the lot of the poorer members of society, and with the growth of the Garden City movement, culminating in the well-known Letchworth Cheap Cottages Competition.(3) Several books of designs were produced, showing the demonstration of great architectural skill in the deployment of materials and space to create houses of good quality at an affordable price. Many of the designers stressed the need for simplicity of planning, and the careful integration of plan, structure and construction. (4, 5)

THE DESIGN

The site provided for the cottages was at the end of a Victorian terrace, where three houses had been demolished. To the other side lay recently built local authority houses. The demolished houses had cellars, into which the rubble from demolition had been pushed. This necessitated deeper than normal footings to go down through the rubble to firm ground beneath.

Part of the inspiration for the plan form came from the Housing Association's requirement that the houses meet the cultural requirements of Muslim tenants for separate women's and men's rooms on the ground floor. Accordingly the plan was made as simple as possible, with two equal sized ground floor rooms divided by a central passage containing the hall and staircase, with a small wc under the stair. The back room was fitted as a kitchen. The simple plan also made the structure very simple, and therefore cheap, with the two internal walls rising up to support both the first floor joists and the roof. The fact that the internal walls were loadbearing, and made of brickwork provided good sound insulation between rooms. The "front" door is in the side of the houses under this arrangement, but this is a common pattern in nineteenth century Sheffield housing, so it seemed quite appropriate to use it.

On the first floor the space is a mirror image of the ground floor, with a small bathroom over the hall and a large bedroom to the front. The back part is divided into two bedrooms by means of a partition containing built in wardrobes. Again, the loadbearing construction provides good acoustic separation between parents and children.

To reduce the volume, and therefore the cost, the first floor rooms were built into the roof and lit by roof windows. The walls were 1500 mm high at the eaves internally, as this was the minimum height that the Housing Corporation would class as "habitable space".The dimensions of the plan were determined by the width of the site, with room for access down each side.

ENERGY STRATEGY

The orientation was fixed by the need to continue the building line of the existing terrace. The street frontage of the houses faced southerly, but the need for privacy meant that it would not be appropriate to use large windows on this side to provide direct solar gain for passive heating. In fact the research carried out for the Pennyland housing scheme built in Milton Keynes in the early 1980s showed that greater energy gains could be made by the orientation of a conventional house to face north-south, than were achieved by the further concentration of glazing on the southern side. (6) The use by the Sheffield tenants of net curtains on the street front windows suggests that a greater window area would not have been popular. One passive solar technique that was employed was to build in a high thermal mass so that any solar gains would be stored in the house for later use rather than causing overheating. The high mass of the internal walls and the ground floor slab also provides a house that has a very "solid" feel with good acoustic separation between rooms. This is augmented by the use of solid core fire doors to all rooms, both for safety as well as solidity.

The energy strategy employed was to build to much higher insulation and airtightness standards than those generally employed in the United Kingdom, but to use traditional techniques. The architects had used this approach in a number of earlier medical buildings, and had found that it avoided the problem of exaggerated tender prices that can be incurred by the use of construction methods that appear unusual to the contractors who are tendering.

To give some idea of the increased insulation, the U values of the various building elements are given below, along with the construction employed for each one. The figures in brackets show the U values that would be achieved by the same design if built in accordance with the current U.K. building regulations.

[redacted] [redacted]

Table 1

element	construction	U value W/m2K
ground floor:	150 mm expanded polystyrene	0.20 (0.45)
external wall:	150 mm resin bonded glass fibre	0.20 (0.45)
roof:	200 mm glass fibre, 50 mm expanded polystyrene, 8 mm foil faced bubble film	0.13 (0.25)
windows:	triple low-E gas filled	1.2 (5.70)
roof windows:	double low-E gas filled	1.6 (5.70)
external doors:	steel faced polystyrene filled	1.0 (5.70)
ventilation:	mechanical with heat recovery	0.2 ac/h

(note: the U value for the roof allows for cold bridging through the rafters)

Some discussion of the reasons for the specifications may clarify the values given. The thickness of wall insulation was determined by the Code of Practice for masonry construction, which allows a maximum cavity width of 150 mm.(7) The floor insulation was made the same because it seemed pointless to put in less. The roof insulation is determined by the depth of rafters required to span the plan arrangement. The insulation lies in the plane of the roof to avoid having any cold voids in the building, and subsequent cold bridging through the inner leaf of the wall to an unheated loft space. Cold bridging at the foundations, at lintels, at window and door reveals and elsewhere, was rigourously avoided, largely by the evolution of new methods of detailing. The windows, made in Sweden, are the best that are readily available on the market. The roof windows could not, at the time of design, be obtained to the same performance standard as the vertical windows, so the best glazing available was used.

To minimise the ventilation heat loss, which would otherwise be the greatest single element of the heat loss, a full mechanical ventilation system was installed, with heat recovery. The design of the stairs was evolved to incorporate spaces for the ducting to run from the machine room above the bathroom to the ground floor accommodation. The heat recovery from the outgoing stale air, from kitchen, bathroom and wc, means that the house can have an air change rate approaching one per hour, while the heat loss is only the equivalent of 0.2 air changes per hour. The electricity consumption is a maximum of 120 Watts to operate the two fans in the unit. The ventilation is controlled by the tenants with a single knob on the kitchen wall.

Also in the kitchen is the programmer for the central heating. The cottages were provided with full central heating and thermostatically controlled radiators, even though the maximum heat loss, 1.7 kW when the outside temperature is minus 5 degrees, could be satisfied by a couple of gas fires, at a lower capital cost. The architects thought it essential that the cottages did not appear in any way substandard as far as the tenants were concerned, and therefore the central heating was provided as part of a concern to "do a proper job". This philosophy also extended to the provision of built in wardrobes in all bedrooms, and a number of other built in cupboards. The gas fired room sealed boiler occupies the space above the bathroom with the ventilation system, and is a combi type to avoid the need for a large, and heat losing, cylinder of stored hot water. The radiators are oversized to allow the boiler to be replaced by a condensing model in the future; in fact a condensing combi boiler was the only piece of equipment that proved too expensive to be afforded within the budget.

The strategy adopted was to put in as much insulation and energy saving technology as possible, rather than those levels that are currently regarded as "cost effective". Twenty years ago architects were told that to use the insulation levels now required by the Building Regulations would not be cost effective, so thousands of buildings were erected which are now under- insulated even by the inadequate standards of current regulations. Buildings generally have a life expectancy in excess of sixty years, so the short term thinking of what constitutes cost effectiveness is not really appropriate, since it is usually impossible to add extra insulation to a building when the economic criteria change. It is also strange that some components of housing are regarded as not subject to cost effectiveness criteria - a more expensive kitchen is seen as preferable to a cheaper one, paticularly in the private sector, although the cheaper one may perform the same function. Similarly, although a hand-made facing brick or real slates on the roof can not be shown to be cost effective over cheaper materials with the same performance, most designers would prefer to use the former materials, just as they would generally prefer to drive a BMW rather than a Ford. There seems no reason not to consider energy saving measures in the same light, particularly since they can be shown to have real environmental benefits.

With energy matters, the proof of the pudding is in the heating. Using the Building Research Establishment's BREDEM calculation method, the cottages can be shown to have a space heating energy requirement that is 83 percent less than the same design built in accordance with the current Building Regulations. The annual space heating demand is about 1500 kWh, giving a weekly heating cost about the same as the cost of a pint of beer, for a house of 88.4 m2 of usable floor area (excluding the machine room). For anyone on a low income this is a real benefit. Tenants on low incomes often live in housing of poor standard, and as a consequence they spend a much greater percentage of their income on attempts to heat it than those who can afford to live in better housing. (8) The provision of superinsulated houses means that tenants can be warm at very low cost, leading to more income for other purposes, with less degradation of the building fabric by condensation, which is controlled effectively by the ventilation system, and the fact that the house is not left unheated. The ability to heat the house continuously to a temperature of 20 degrees should also mean fewer health problems related to cold and damp conditions.

ENVIRONMENTAL IMPACT

The most serious environmental problem at a global scale is climate change brought about by the use of fossil fuels. The fossil fuel use of the cottages for space heating is reduced by 80 percent compared to a normal building, but the hot water energy use is also reduced to some extent by the avoidance of stored hot water. Electricity demand is lowered by the fact that the houses are fully equipped with electronic compact fluorescent light bulbs that use only one fifth of the power of conventional lights. Further reductions could be made if the choice of appliances, particularly refrigerators, was under the architects' control. The most efficient available refrigerator, made in Denmark, uses less than a quarter of the electricity, and therefore causes less than a quarter of the pollution, of the U.K. average. (9)

As well as tackling the use of energy for running the cottages, some attempt was made to reduce the energy required to build them. The energy required to make the materials of a building and to assemble them on site can represent more than ten times the energy used by the building in a year of operation. In the cottages materials choices were made on grounds of embodied energy, (10) as well as on performance and appearance criteria. The external walls were made of concrete facing bricks, which take less energy to manufacture than fired clay bricks. Concrete, a "low energy" material, was used also for the ground floor slab, the inner leaf of the walls, lintels, internal partitions, and for roof tiles. The rest of the structure was wood, as was the first floor surface. All timber was softwood from sustainable sources.

There is increasing concern that building materials may be harmful to those who build and to those who occupy the finished building. In the cottages attempts were made to avoid hazardous materials. No chlorofluorocarbons were used. The timber was detailed to avoid the need for toxic preservatives. All decoration was with water based paints to reduce the emission of solvents to the interior air. Glass fibre insulation was enclosed either in the cavity wall or sealed into the roof structure behind a vapour barrier, so that no fibres could get into the house to cause irritation. On the ground floor, as part of the strategy to provide a house that was as fully furnished as possible, floor covering was provided throughout, but using natural linoleum made from jute and linseed oil, rather than potentially toxic pvc based materials.

There is concern that the use of particle boards in modern furniture can allow significant levels of formaldehyde vapour from the resins used to stick the particles together to enter the dwelling. In an attempt to reduce this risk the kitchen cupboards, wardrobes and built in cupboards were all made by the contractor to the architects' designs using softwood cored blockboard rather than chipboard, as blockboard contains less adhesive and more wood for a given volume. The possibilities for "healthy building" go much further, but more could not be achieved within the budget. (11, 12)

COSTS

The design went out to tender in the normal way, with a Bill of Quantities and a full set of detailed drawings. The architects have found that this method is the best way of avoiding unforeseen cost increases during the construction process. The tender list was made up of builders with a reputation for craftsmanship and quality rather than rock bottom prices, and the contract was awarded to the lowest tenderer. The design as tendered had to be reduced from a tender of £135,000 to the budget figure of £91,000, but this was achieved by the architects with no effect on the energy performance beyond an increase in annual space heating demand of 135 kWh which resulted from the need to alter the roof U value from 0.08 W/m2K to 0.13 W/m2K in the attempt to find a cheaper construction. The reductions required the preparation of a completely new set of drawings, but the details evolved for the original version are now being recycled in the construction of a new health centre, so nothing was wasted. The cost of construction works out at £515.84 per square metre of useful floor area (not including fees or land costs). Various extras were requested by the Housing Association during the construction, such as television aerials, clothes lines and additional landscape items.

There were no problems during construction, apart from serious theft (including the loss of the entire scaffolding overnight) and vandalism. However, the heavyweight construction, coupled with the need to screw covers over all openings every night thus preventing ventilation, meant that drying out could not take place very easily, and there were initial problems with condensation and mould growth. Tenants had to be moved in on the day the contractors moved out in order to prevent destruction of the houses by vandals, and in retrospect it might have been preferable to have a longer contract period to allow a longer drying period. The contract period was 26 weeks.

FUTURE DEVELOPMENTS

A second pair of houses is now in the process of being built, with completion expected in Spring 1993. The second pair are more conventional in appearance, with front doors on the front, and they occupy a much narrower site. They have a different roof design with 400 mm insulation, using recycled cellulose. The ventilation is by means of a passive stack system using humidity sensing intakes and outlets to see if electricity consumption can thereby be avoided. The second pair of houses also incorporate rainwater collection systems for watering the garden, and very low-flush (3.75 litre) wcs to reduce water demand. The external landscaping of these houses is also more complex than for the first pair, with more planting, and porous surfaces to all areas to reduce disturbance to soil water levels. The houses are currently showing a cost reduction of £7000.00 over the permitted Housing Corporation budget for building a pair of three bedroom houses to the conventional Building Regulations standards. Calculations made using the BREDEM technique show a space heating demand reduction of 85% compared to a normal house.

It is hoped that these projects, and others, will demonstrate that houses offering far lower environmental impact can be constructed at no additional cost, for rental to low income tenants in existing settlements. Perhaps this will help bring the U.K. more into line with the developments in sustainable architecture that are taking place with the enthusiastic support of designers, local authorities and funding bodies in much of the rest of the world.

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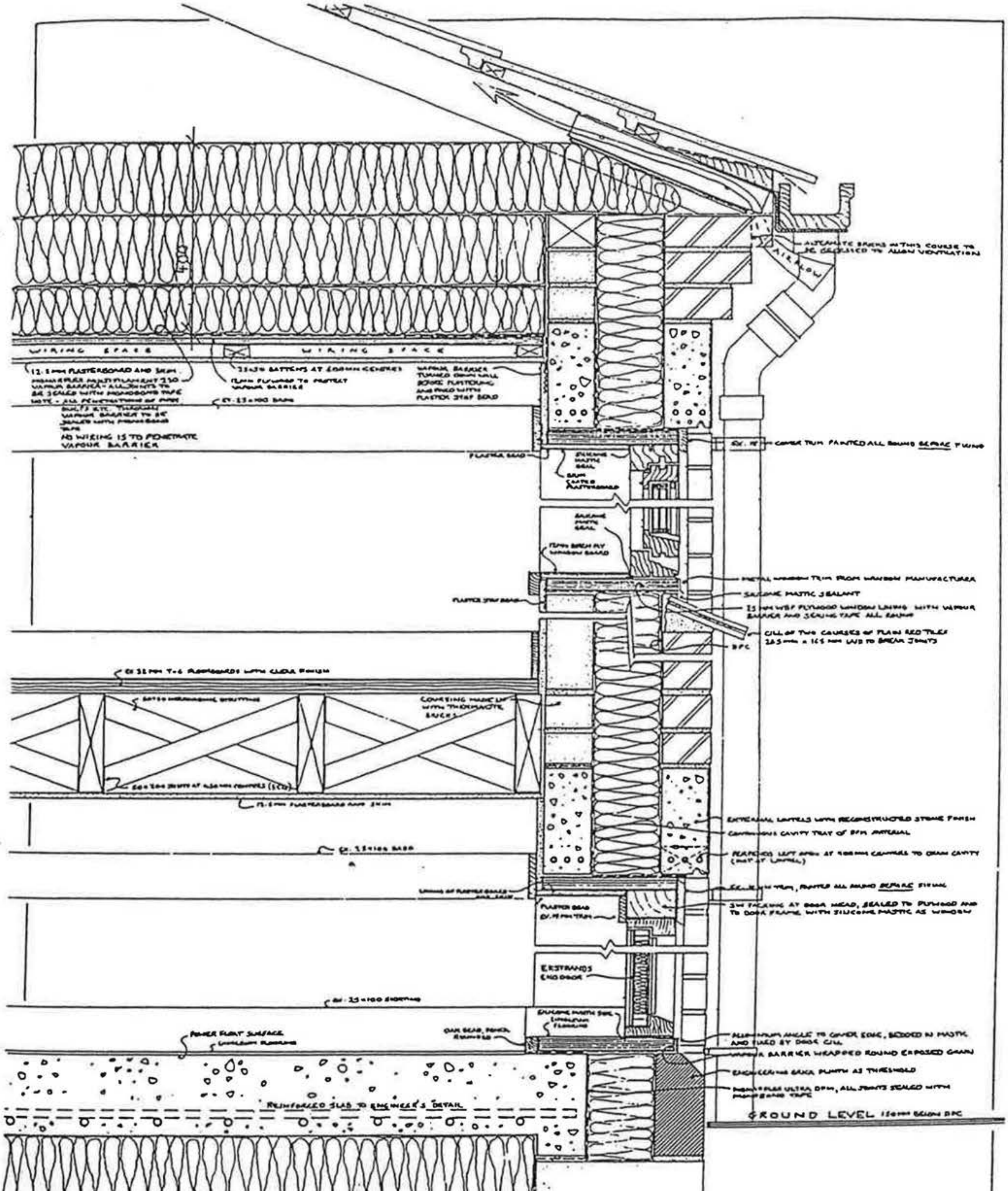
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NO WIRING IS TO PENETRATE VAPOUR BARRIER
AIRFLOW
REINFORCED SLAB TO ENGINEER'S DETAIL
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45-47 CRESSWELL ROAD ▪ SHEFFIELD ▪ SECTION AT FRONT DOOR ▪ 1:5 ▪ BRENDA & ROBERT VALE ARCHITECTS ▪ DRAWING NO. 6 ▪ 12 JULY 1992