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DOMESTIC LOW ENERGY
1 NEW HOUSING

Improving the energy performance of housing is not too difficult. But widespread detailed effects on the construction may result, plus implications for built form and planning. Barrie Evans draws together current thinking.

For many clients the minimum insulation standards of the new Building Regulations will set the standards for energy performance.[1] But even if these are accepted, such regulations are not the whole story for housing designers. Design decisions with energy implications still have to be made about site layout and orientation, building form and planning, thermal capacity and thermal response, ventilation and air leakage, condensation, fuel choice, heating and its control, and making all this buildable. Sometimes there is also the chance to influence the selection of energy-efficient lighting and appliances. Energy can be saved and often at no cost.

Where beyond Part L?
It had been said that energy conversation does not sell houses. So the form of the Part L Approved Document can be looked at, cynically, as a successful piece of lobbying by housebuilding interests: as long as houses are double-glazed nothing much else needs changing. And double glazing can help to sell houses. But there are signs of a change of mood, an interest in raising standards. It is evident that low-energy design does not have to produce poor or unconventional (unsaleable) architecture, *1*. It is evident that good standards are not that difficult to achieve, *2*, *4*. The beginnings of energy labelling and green labelling suggest it is timely and feasible to focus public attention on building performance in a straightforward way. A few developers, such as Wimpey with its Superspec house, are now testing the market, *3*.

If there are opportunities to raise the insulation standards beyond Part L, what are the priorities? To picture this imagine a simple square plan two-storey house of 100 m^2, insulated to Part L, *5*. Part L offers three options in its elemental approach: single-glazed or alternatives of half or fully double-glazed with corresponding reductions in insulation standards.

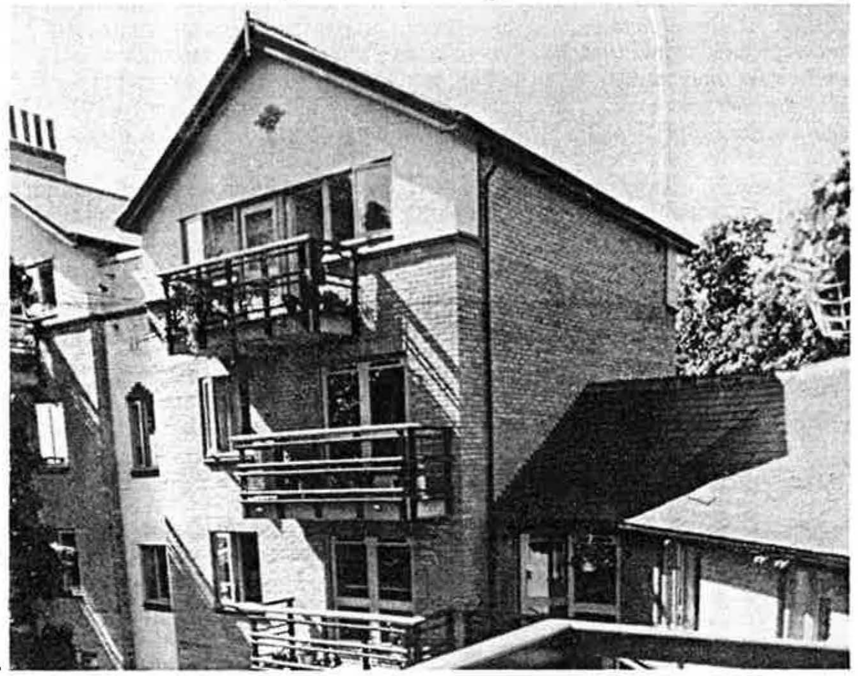
The amount of heat each insulated house option requires is about the same, but where the main heat losses occur vary significantly. Table I sets out the three options with percentage heat losses attributed to ground floor, solid wall, windows and roof. If you look at the first case for example, the basic elemental approach, you can see that some 48 per cent of heat loss is through the single-glazed windows. Yet these cover an area equivalent to only 15 per cent of the floor area, 6 per cent of the envelope area. The designer could look at where the percentages are greatest as the starting-point for improving standards.

However, this is to take a short-term view. If we assume that insulation standards will rise in the future, or think they should, then we also need to think about the ease of upgrading thermal performance by concentrating now on insulating those elements that will be difficult to upgrade. Though each building needs thinking through, a typical priority list would be ground floor which is the most difficult, then retrofitting double glazing, then wall insulation (assuming we leave an unfilled cavity), then the easiest, roofspaces.

(The details of Part L were given in Peter Burberry's recent article AJ 28.2.90 p61.)

Towards a new tradition
Already domestic masonry construction, however traditional its appearance, is built in non-traditional ways. Methods of construction and materials are not just different to traditional ones, they are often more tightly engineered to their purpose. Margins for error are reduced. Filling cavities with insulation is an evident but by no means isolated example. This section briefly notes where lower-energy design is further reducing the margins of error, making constructions less robust and even 'disproving' proven details. The ideas are not new, but we may need to rethink fundamental principles about some aspects of construction.

Temperature ranges
For example we are aware that the typical working temperature ranges of exterior building materials are from, say, -25°C to 60°C for light materials, and up to 80°C for dark ones. This has not been of great concern



1 Low-energy design can be good design. Housing at Islington, London by ECD Partnership.

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in domestic construction but may become more so. Insulation behind surface materials and finishes inhibits solar heat conduction into the construction. The surface materials now get hotter. And in cold weather, with insulation standards rising, heat leaks less quickly through the construction; the outer layers stay colder and the thermal movement range may increase. Embrittlement may be accelerated. Freeze-thaw cycling may become more extreme. The most obvious areas for concern are flat roof finishes, surface coatings and facing brickwork. In the latter case there is as yet no clear evidence of spalling brickwork due to increased insulation, but should we be looking for a few cases now or widespread cases in 40 years?

Cold bridges
Cold bridging is an obvious concern and one that becomes more critical as insulation standards rise: cold bridges can be relatively colder. And elements of construction that were not thought of seriously as cold bridges, such as pieces of brick, may now be so.

The insulation strategy is to create continuity of insulation, taking special care at roof-to-wall and wall-to-floor junctions, at openings such as windows, doors and hatches, and where elements penetrate the envelope such as pipes, ducts and flues.

Moisture regime
Constructions typically have an increasing number of layers. Temperature gradients and vapour flow paths are changed. For example, vapour checks (say for rooms in the roof or warm deck flat roofs) and vapour barriers (say on cold deck flat roofs) are becoming normal practice in domestic construction. Relying on precedent becomes increasingly risky.

The need to provide ventilation on the cold side of insulation is well accepted. As insulation standards rise, creating this air flow throughout the construction is increasingly important, and difficult. There are now doubts that the typical form of construction of domestic cold deck flat roofs can be effectively ventilated. And where there are rooms in the roof, the main roof planes are easily enough ventilated, but what about the tricky bits like the roof structure of dormer windows? BS 5250: 1989,[2] — a useful piece of general design guidance — sets out suggested requirements for ventilation if not how to solve it, *6*.

Controlled ventilation
We are gradually moving from adventitious to controlled ventilation. We make the dwelling relatively airtight and then introduce ventilation in a controlled way. There are two main aims. One is to limit ventilation heat loss. The sample house with which we began for example, designed to the new Part L, *5*, has a space-heating supply-rate requirement of about 4.5 kW (for a design temperature difference of 25°C). If there was one air change per hour, that would require a further 2 kW for air heating. Thus ventilation heat loss is a significant part of total building heat loss and is becoming increasingly important as fabric heat loss reduces.

The second aim of controlling ventilation is to limit surface condensation and mould growth, and inhibit airborne moisture diffusing deeply into the construction. Moisture conditions should be improving with better insulation standards and use of extract fans (*Approved Document F: F1 means of ventilation)*. But whole house ventilation may still be ineffective. Researchers at the Welsh School of Architecture reported from one study of air movement in houses that 'ventilation air tended to enter the house via the front door and kitchen window and leave from the bathroom, bypassing the living rooms and bedrooms'. The new requirement for 4000 mm² of openings for background ventilation in all habitable rooms (part F1) should help. (A 15 x 266 mm trickle vent would do the job.)

The BRE has shown that window opening is not very effective for ventilation both because it is too rarely done in the heating season and because it is wasteful of energy. A window opened to the first notch typically creates an air-change rate of three or more in the room.

In planning the building, draught lobbies are an important control measure. And in selecting heating appliances, try to avoid open-flued and especially flueless appliances, table II.

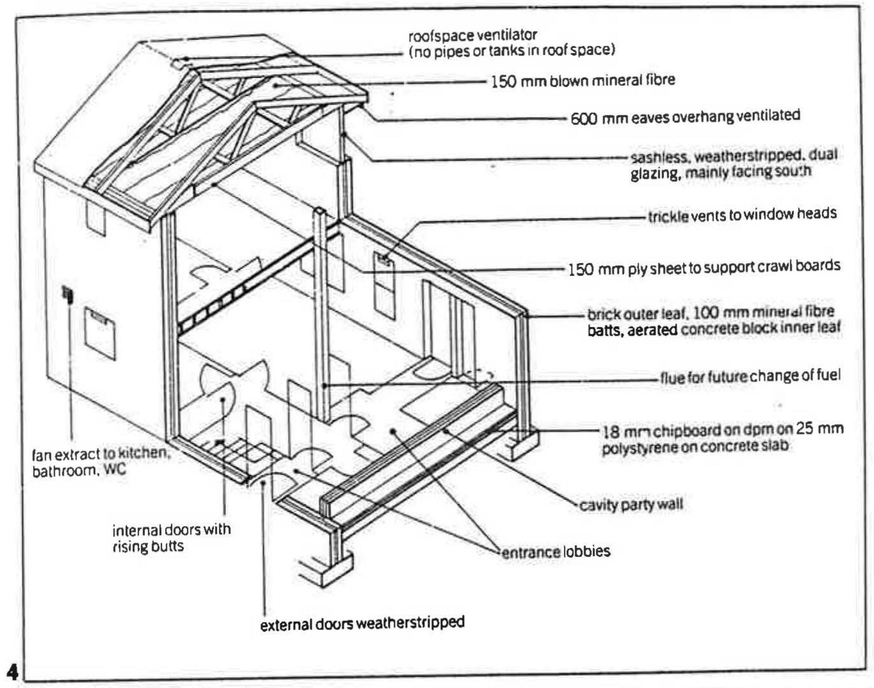
Health and safety
Controlled ventilation should lead to acceptable indoor air quality: domestically the biggest health hazard is usually condensation. *Hazardous building materials*[3] provides a good guide to risks generally. One current concern is the disputed claim that the mineral fibres of insulation can promote cancer. For some time, site operatives have been recommended to wear masks and gloves when handling these materials.

Another concern is the fumes given off during burning of plastics insulation. The BRE carried out tests on cavity insulation which were broadly reassuring.[4] These were for fully filled cavities and thus the air supply to contribute to burning was more restricted than for partial fill.

Table 1 Sample house heat loss distribution

Element	*Elemental approach U-value (W/m²K)*	*Elemental approach Percentage heat loss (%)*	*Alternative 1.3(a) U-value (W/m²K)*	*Alternative 1.3(a) Percentage heat loss (%)*	*Alternative 1.3(b) U-value (W/m²K)*	*Alternative 1.3(b) Percentage heat loss (%)*
Windows						
all single-glazed	5.7	48				
half single-glazed			5.7	24	-	
half double-glazed			2.8	11.5		
all double-glazed					2.8	24
Solid walls	0.45	32	0.6	42	0.6	43
Roof	0.25	7	0.35	10	0.35	10
Ground floor	0.45	12.5	0.45	12.5	0.8*	23

*Uninsulated concrete slab



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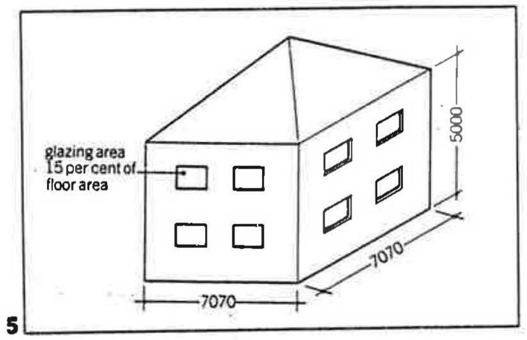
2, 4 Low-cost local authority housing in Manchester demonstrating that low-energy design need not be problematic nor costly: this scheme was set up in 1980. (See AJ 21.11.84 p79.)
3 Developer Wimpey trying out the low energy housing market. Cavities have 100 mm insulation, floors 50 mm, lofts 150 mm, windows double-glazed, doors insulated, both weather-stripped. The selling price is likely to be less than 1 per cent above a house built to 1990 regulations.
5 Sample two-storey house, 100 m² floor area, 15 per cent glazing area, insulated to 1990 regulations — see table I.
6 Recommended pattern of ventilation through roof construction to inhibit condensation; from BS 5250 (reference 2). But what about the dormer cheeks?



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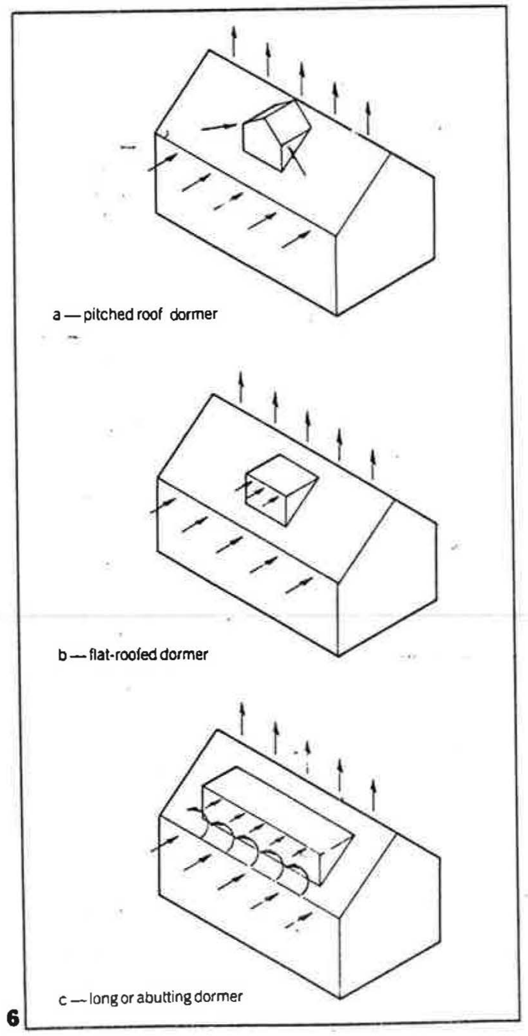

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Site planning and orientation
The state of the art in shelter planting was described in our Greenscape series last year.[5] It is as yet an inexact science, but shelter planting certainly can improve the microclimate of sites. If housing is to be oriented south then wind protection may have to be traded off against solar overshading.

How important is southerly orientation? It is a significant constraint on housing layout even on green field sites, gets worse as densities rise and may be impossible to achieve effectively on infill sites.

Orientation between SE and SW is near enough, but even so it is likely that you will need to design house types which face more than one direction.

The energy argument about whether to choose southerly orientation comes in two parts: is there a benefit in distributing most of the necessary glazing on southerly facades?, and is there a benefit in increasing window areas to collect more solar energy?

Distributing glazing to the south
Other constraints permitting, orienting those windows needed anyway for view and light to the south can produce a significant energy benefit. The price paid is constraints on site layout and house planning.

A case study illustrates the point. The houses have an annual heat requirement of about 8700 kWh. It is estimated that, potentially, up to 1000 kWh of heating energy might be saved by means of orientation (backed by appropriate shading, curtaining, distribution of thermal capacity, responsive heating controls, and so on).

Figure *9a* shows the original estate layout of detached houses. Half the houses are truly detached, the other half linked by garages: 80 per cent face well away from the south. It is calculated that these houses would collect about 40 per cent of the solar potential. Figure *9b* shows a revised layout by MacCormac Jamieson (as it was then), which improves solar access to the houses generally although close spacing increases obstruction in a few places. The calculated solar gain was 80 per cent of the potential. Figure *9c* shows the revision by Stillman Eastwick-Field. The solar access is generally good, though the north of the site is perhaps underused. The calculated solar gain was 90 per cent of the potential. So it can be done.

Increasing glazing area
Can you usefully increase window area further to increase solar gain without losing more heat in the process? It depends on wall and window performance. Jake Chapman has suggested (AJ 9.11.88 p73) that if, say,

7 Just as contractors are getting to grips with insulation workmanship, along comes floor insulation, tighter ventilation heat loss control and the like.

the solid wall U-value is 0.6 W/m^2K and the windows are double-glazed, then there could be a net benefit. If wall U-value is improved to, say, 0.3 W/m^2K — 10 times better than the window — then there will not be a net benefit.

This balance could be changed in future by better U-value walls or windows, or, say, the use of insulating shutters. Net curtaining significantly reduces solar input. Large-windowed designs must address privacy.

Planning implications

The case study plans, *9*, suggest some of the planning constraints that a southerly orientation of principal windows imposes. The most obvious constraint is the limitation of orientation to between south-east and south-west. There is thus a tendency for houses to be grouped into east/west rows in relatively narrow plots in order to limit overshadowing as the sun goes round from east to west. House forms are compact, a good thing from an energy point of view anyway. To get the amount of solar access shown here, densities are likely to be limited to from 25 to 30 houses per hectare.

Roof pitch, thus ridge height, can become critical if houses are less than 21 m apart. Other things being equal, a taller narrower house produces less daily overshading than a lower wider one of the same floor area. However for solar access there is a tendency to design broad-fronted houses.

Where there are mixed house types such as bungalows which can be placed to the south and a southerly slope, these clearly help solar access. For houses at 21 m spacing, a 5° slope down to the north was calculated to reduce solar gain by 400 kWh and a 5° slope to the south to increase it by 150 kWh per year.

House planning and thermal response

Opening a house to the south normally entails locating principal rooms to the south, provided with significant thermal capacity in floor and walls plus shading devices such as blinds to allow people to limit overheating. Rooms where heat is generated — bathrooms and kitchens — are located to the north, easing the problem of overheating control. Controls, such as thermostatic radiator valves, are needed to allow the heating system to respond locally to solar gain: this argues against open planning.

In masonry construction, building with extra thermal mass to mop up solar gains should not be necessary. Concrete floors promise well until carpets, cork tiles or lino are put on top, then thermal response becomes rather slow.

It may anyway be constructionally preferable to put the floor insulation on top of the slab, making the concrete's thermal capacity largely inaccessible, though a screed may be used over the insulation. So the walls are the main thermal store, thus partitions need to be masonry rather than stud, at least on the south side of the plan, and insulation should preferably not be an internal dry-lining.

It is sometimes argued that very intermittent use of a building justifies dry-lining to create fast thermal response. But most dwellings are used intermittently and respond reasonably. Overheating appears to be the priority, an increasing risk as U-values reduce. Even if the eccentric behaviour of a particular occupant appeared to justify fast-response construction, it is not a robust approach for a building that could have 20 different occupants in its lifetime.

Insulation

It may seem odd that this section, on insulation, is the shortest in the article, when insulation accounts for most constructional difficulties. The blame lies with a BRE document, *Thermal insulation: avoiding risks*.[6] You need to have it. Not only is it good. It has a quasi-official status through being cited in the Approved Document to Part L. It focuses primarily on masonry low-rise construction, setting out the problems of higher insulation construction.

For those working on timber houses, Trada has produced a comprehensive guide, *Energy efficient housing: a timber frame approach*.[7] Its bias is to masonry-clad timber frames.

Airtightness

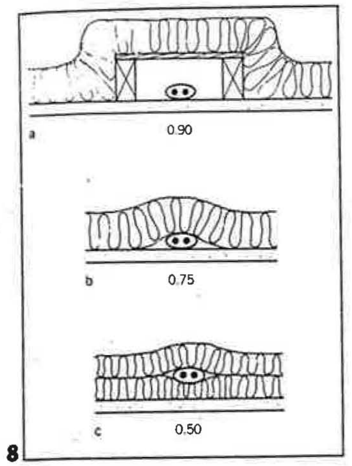
We now expect to buy windows and doors ready gasketed, maybe ready glazed, and they can also be factory fitted with trickle vents. Make sure that the timber is of reasonable quality so as to limit warping over time: the tolerance of gaskets to maintain an effective seal is often only 1-2 mm. This limited tolerance becomes more of a problem if you choose site fixing of gaskets with its generally lower standard of workmanship.

It is continuity that is important to control air leakage over the whole envelope. Good workmanship should solve most of the problems: check sealing especially around penetrations through the envelope such as pipes, cables, ducts and flues, at wall-to-ceiling junctions, around roof access traps, doors and windows.

Table II Air supply requirements for fuel-burning space-heating appliances

Type of appliance	*Requirements for permanent opening to the outside air in the room or space containing the appliance as specified in British Standards*
1 Balanced-flue heating appliance	None — air supply provided directly from outside
2 Open-flued gas appliance including gas fire with back boiler but excluding room gas fire	Permanent opening required: (i) for a decorative (solid fuel effect) appliance, an area of 1800 mm^2 for each kW of rated input over 2 kW (ii) for any other appliance, an area of 450 mm^2 for every kW of input rating over 7 kW
3 Room gas fire, open-flued	No requirement for permanent openings; it is assumed that there is a minimum adventitious area of 3500 mm^2
4 Flueless gas space heater (fixed)	Permanent opening of at least 9500 mm^2 and an openable window required. Appliance must not be fixed in a bedroom or bathroom
5 Open solid fuel fire	Permanent opening of at least 5500 mm^2 or 50 per cent of the throat opening, whichever is the greater
6 Other solid fuel flued appliance	Permanent opening with a total area equal to at least the combined areas of the primary and secondary air inlets to the appliance
7 Oil-burning flued appliance	Permanent opening of at least 550 mm^2 per kW of appliance rated output

Note: In the case of flueless space heating appliances (LPG, paraffin), no requirement for permanent opening but adequate ventilation air is essential. Ventilation as in 4 above is recommended.
From the BRE Defect Action Sheet 136



8 Recommended de-rating of cables so that they do not overheat.
9 Design study of southerly orientation: a, original estate; b, MacCormac Jamieson reorientation; c, Stillman Eastwick-Field reorientation. From Energy Technology Support Unit project summary 045 (0235 432450).

Services

As fabric and ventilation heat loss standards improve, design heat loads reduce. Make sure central heating is not oversized. Lightweight, low water content radiators improve system response. Condensing boilers (AJ 9.8.89 p59) can improve system efficiency by 10 per cent or more. They have good part-load efficiency, which is important with the UK's long mild interseasonal periods. When these boilers are working most effectively, in condensing mode, they emit some steam from the flue. It is harmless but may surprise householders.

In some of the Department of Energy's low-energy demonstration projects there has been no central heating. Individual room space-heaters downstairs, and perhaps one in bathrooms upstairs, have proved acceptable to occupants. The result is energy conservation measures saving capital expenditure as well.[8]

Zoned controls are important in central heating systems to prevent unnecessary heating of the whole house. Thermostatic radiator valves are usually adequate. Try to pick a central time clock/control unit that is comprehensible to the occupants. The old electro-mechanical ones were counter-intuitive. The 'hands' were stationary clips on the edge of the face. The face itself went round, backwards, confusing occupants. New ones often have clear electronic displays, but can be confusing to reprogramme.

Insulation standards may be such that there is no need to put radiators under windows to combat downdraughts and cold radiation (and for convenience of furniture layout). Some heat radiates through the wall and pipe runs can be long. If radiators are on outside walls, insulate behind them.

Tanks and pipes need to be on the warm side of the insulation and kept out of roofspaces where possible. Unvented plumbing systems provide a head without a header tank and thus make this easier. Pipe insulation thickness (Part L) is given as the pipe diameter, making a substantial size overall. Such thick insulation is not yet widely available.

However cables do suffer from being closed in by insulation. It is recommended that you derate cables by 0.9 if they are boxed, by 0.75 if they have insulation on one side, and by 0.5 if on both sides, *8*. This applies especially to the more heavily loaded cables for cookers, power circuits and so on.

Don't forget changes to the regulations set out in *Approved Document J: J1/2/3 Heat producing appliances* and *Approved Document G: G3 Hot water storage*.

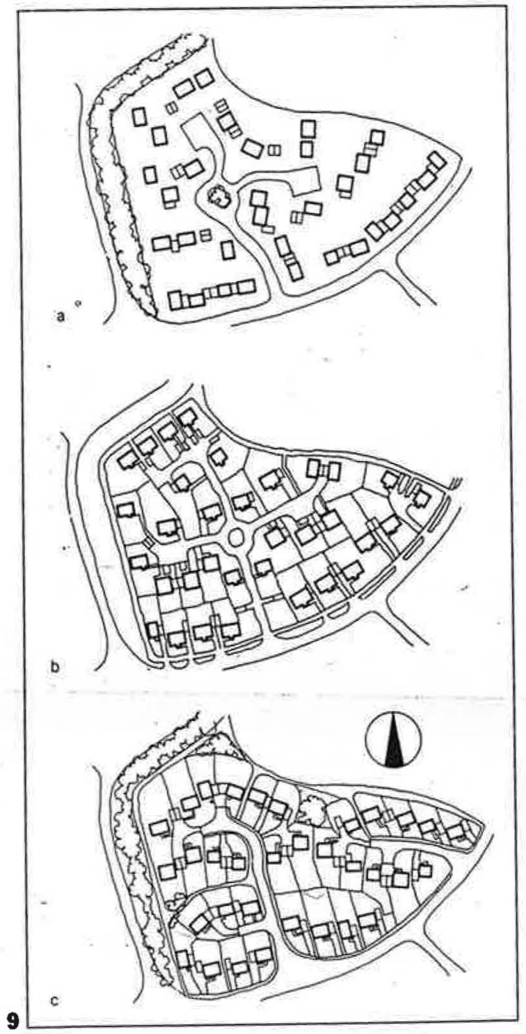
Workmanship

Many of the points relating to workmanship are covered in references 6 and 7. The BRE is still finding examples of poor cavity filling — mortar droppings, the grain of fibre insulation oriented the wrong way, poor insulation fixing in partial fill, gaps where batts do not course with wall ties, gaps around doors and windows, in lintels, and especially under sills. There is also some evidence of mineral-fibre insulation compressing under its own weight. In roofspaces this can be seen, and results in an overall loss of performance. It is not clear that this is also happening to cavity insulation batts, since these are typically much stiffer than roll insulation. The risk would be of cold bridges opening up between courses of batts, especially in partially filled cavities where frictional support is less. Where mineral-fibre batts are used, make sure that odd corners are completed with cut pieces of batt, not bits of roll insulation.

There is now a need for a new round of explaining to site staff about improved airtightness and insulating floors, *7*. Floor insulation is especially vulnerable to damage during construction. The volume of insulation required overall can create problems of dry storage and protection from damage on site.

It may also be necessary to think through trade sequences, for example for a suspended ground floor, if there are to be pipes (on the warm side of the insulation) and cables (on the cold side).

An article such as this inevitably reads a bit like a chapter of accidents, stressing the new difficulties and points to watch. Certainly, traditional practices need checking through anew. But there is nothing fundamentally difficult in low-energy design. It might even act as a stimulant to architectural form-making. ■



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References
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2 BS 5250:1989 *Control of Condensation in buildings*. BSI. £56.
3 *Hazardous building materials: a guide to the specification of alternatives*. S.R. Curwell and C.G. March. London. Spon £9.95.
4 *Fire risk from combustable cavity insulation*. BRE Digest 294, HMSO.
5 'Greenscape'. Jeremy Dodd. AJs 12.4.89 p65, 19.4.89 p81, 26.4.89 p55, 3.5.89 p61, 10.5.89 p61.
6 *Thermal Insulation: avoiding risks*. BRE. HMSO. £10.
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8 *Low-energy local authority housing with reduced construction costs*. Energy Efficiency Office Expanded Project Profile 245. BRECSU (0923 664258).