#4369

PASSIVE SOLAR DESIGN
LOOE PRIMARY SCHOOL

A year's monitoring of energy performance and building use provides revealing insights into the passive solar design of Looe Junior and Infant School in Cornwall.

Looe Primary School is a success. As its headmaster has said, 'Most people are very satisfied with the building and are hard pressed to find fault with it.' Systematic questioning of the staff confirms this view. The recent assessment of energy, amenity and cost sponsored by the Department of Energy puts the building under an unusual degree of scrutiny and comes up with some questions on the building's passive solar design, which should be seen in the context of the ultimately favourable verdict.

Addressing the sun

Set on an open site exposed to strong south-westerly winds, the school is a low brick and tile building. The first signs of passive solar design are the southerly orientation of all of the classrooms, with apparently 100 per cent glazing on that face, 0.75 m deep roof overhangs, and little glazing to the north, *1,2,3,6*. Closer inspection reveals that the bottom 40 per cent of the southerly glazing is backed by masonry, a 'Trombe bench' see below.

The plan of this 10-class, 300-pupil school, *3*, shows draught lobbies at all entrances. The high quality of construction is also intended to reduce ventilation heat loss through tight building, as well as providing for low maintenance on this exposed site.

As with most passive solar buildings laid out linearly to address the sun, the section, *4*, gives most of the passive solar flavour. Reading the sections from the right (the south) shows the large glazed areas and shading by overhang and blinds; the Trombe bench; the deep space for increasing the number of rooms that are oriented south within a compact envelope; ancillary spaces to the rear (the north) with small windows; and the attempts made to bring daylight into the depth of the section.

Details of construction, *5,7*, show a good standard of insulation for a building conceived in 1981 by Cornwall's county architects and completed in 1984 — table I. Most glazing is double. There is 1 m deep insulation around the slab perimeter. Opaque wall construction is cavity brick/

1 Looe school's southerly face, with deep overhangs and full-height glazing. The light areas at low level in the windows are Trombe benches.


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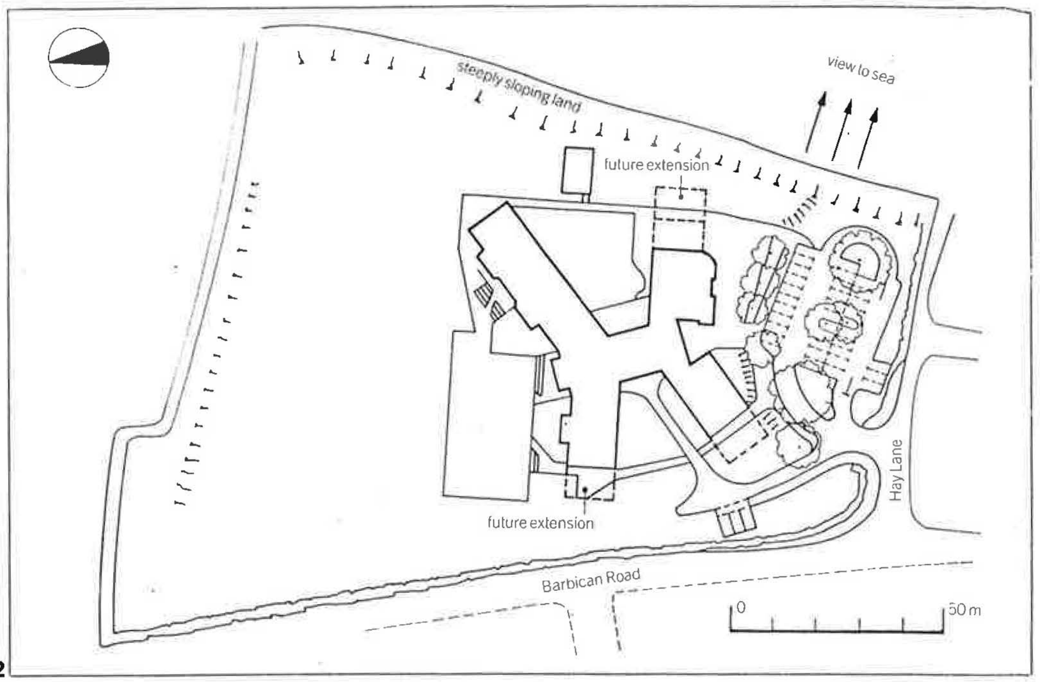
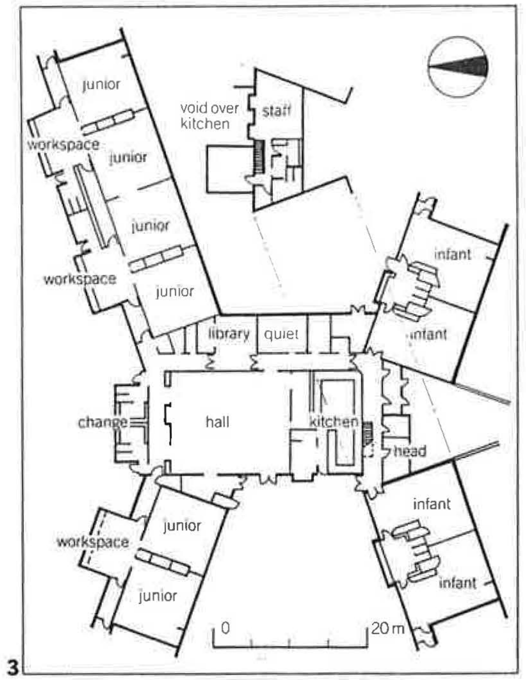


2 Site plan, open towards the sea to the south-east.



3 Southerly facing classrooms, all approached through lobbied entrances.

Table 1 Energy design data

Element	*area A (m²)*	*U-value (W/m² °C)*
Opaque wall	659	0.43
Ground floor	1290	0.30
Ceiling/roof	1486	0.34
Windows:		
single-glazed	77	7.00
double-glazed	259	4.00
Rooflights:		
double-glazed	73	4.00
Services		*Capacity (W/m²)*
Space heating		149
Hot water		35
Lighting		12
*Targets**		
Ventilation rate		2.4 ac/h
Ventilation loss coefficient		2.2 W/m² °C
Fabric loss coefficient		2.2 W/m² °C
Design day heat loss		84 W/m²

* Targets relate to DES Design Note 17. Area measurements/m² of gross floor area (1374 m²).

medium-weight block incorporating 30 mm urethane foam foil-faced insulation board. Partitions are thermally heavyweight and do not penetrate ceilings to cause cold bridging; the floor contributes little to useful thermal mass because it is carpeted.

Overall performance

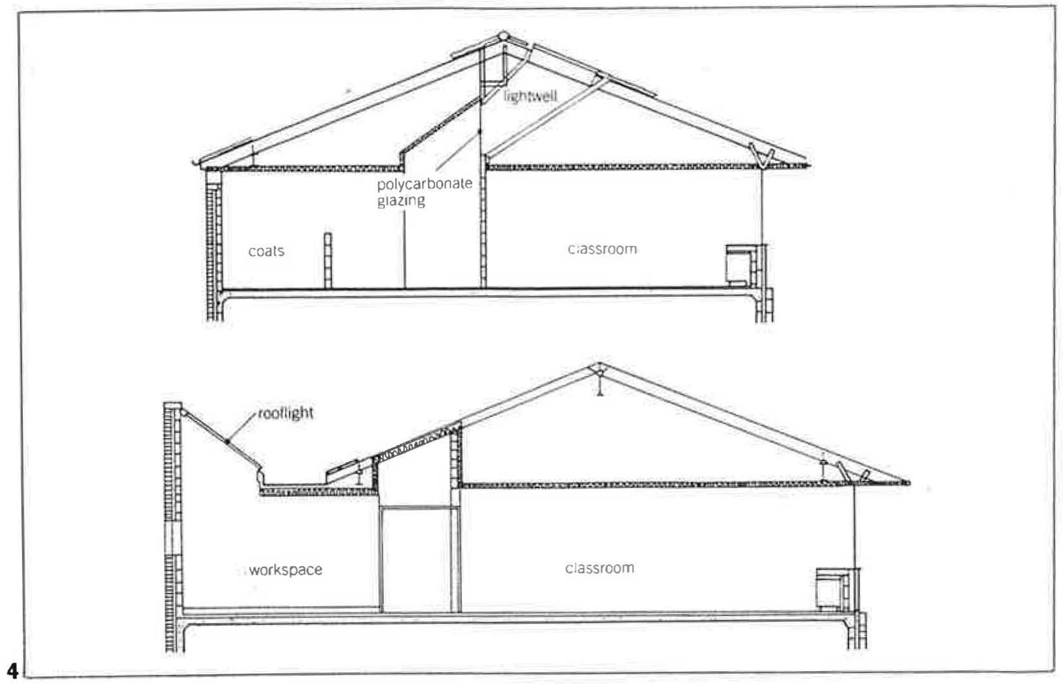
The assessors, from the Welsh School of Architecture and Databuild, have not attempted to rate Looe school against some mythical standard building in what is a continually changing design field. They offer two measures of success: one is to set Looe school among others in terms of overall energy consumption, *10*; the other is the estimate that some 40 per cent of the measured average space-heating requirement is provided by solar gains. (Fuel is predominantly for space heating, *8*.) Checks show that solar gains raise room temperatures significantly in the heating season, *9*, and that these gains are converted into useful heating with simple controls. The low-pressure hot water convectors are thermostatically controlled, and staff have control of window-opening, blinds and lighting.

Trombe bench

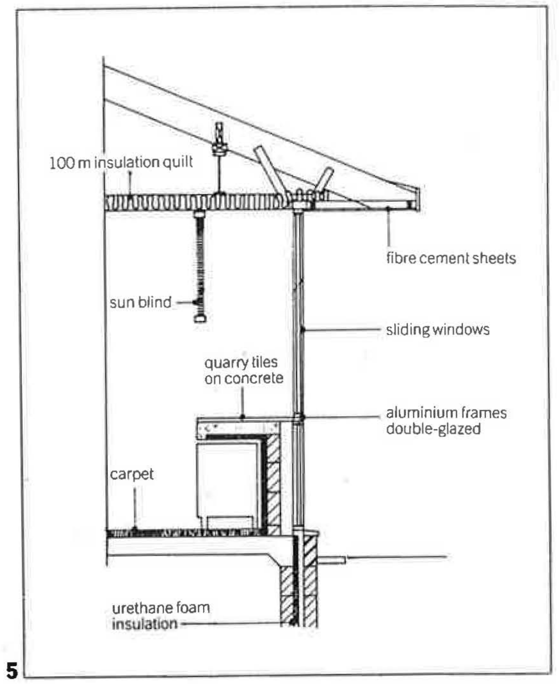
A Trombe wall is a glazed wall backed by an air space, then solid masonry. Direct solar energy passes through the glass, warming the masonry; the air in the 'greenhouse' space is then warmed. Convection, controlled by vent flaps, allows this warmed air to circulate to the rest of the building, *12*.

A 'Trombe bench' was invented at Looe, *13*. It was expected to act as a small Trombe wall, and to provide a safety barrier between children and glazing, surface for displaying pupils' work, and an addition to the thermal mass of the building. For this latter reason the venetian blinds are on the classroom side of the bench. But this positioning conflicts with the use of the bench for displays.

The bench design did not derive from testing and has not been found to be very effective. It is calculated by the assessors to contribute, at its peak, less than 1°C to



4 The section – the energy picture – overhangs, predominant orientation of the room, extensive glazing, insulation, but less attention to daylighting than would be found today.
5,7 Double-glazed and insulated envelope with Trombe bench near the window, 5, and detail of north side rooflighting, 7 (see also 11).
6 Bluff, closed north side, very much the back of the building.



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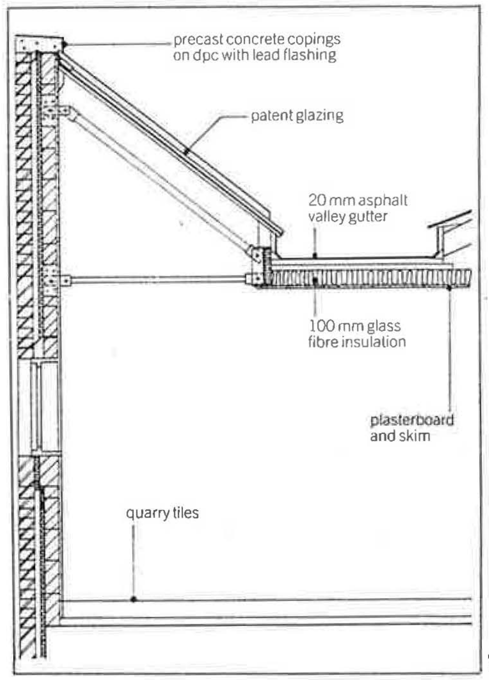

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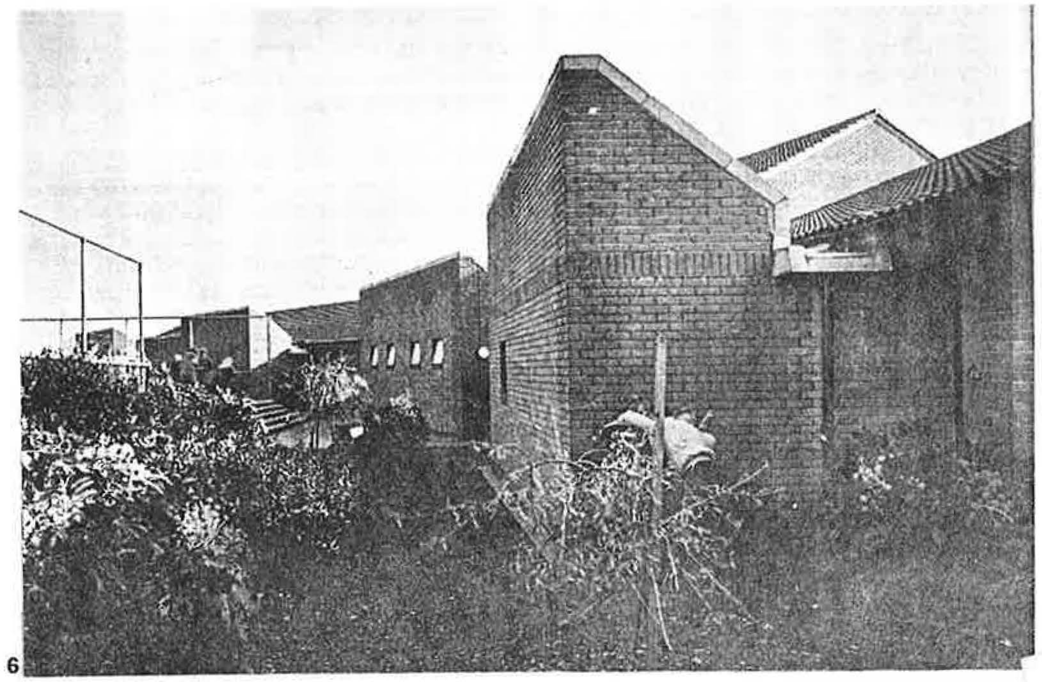

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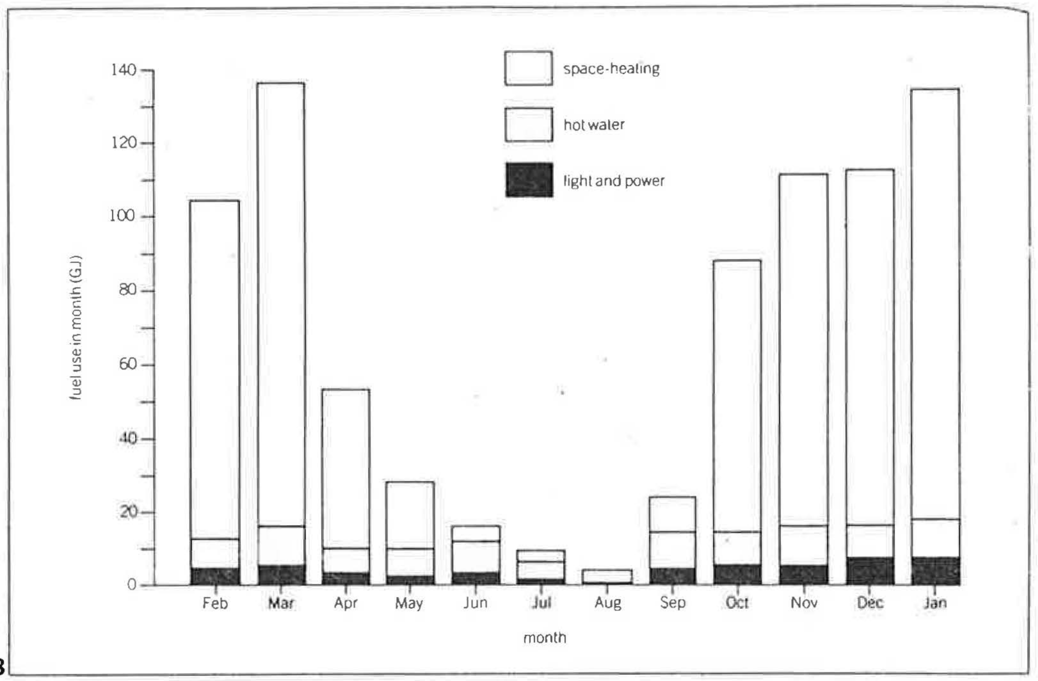
8 Fuel use as far as it could be split up using available metering. Summer space-heating fuel use may be due to evening activities and pilot lights on gas boilers.
9 Sample November day showing that the classroom can usefully respond to direct solar gain.
10 Looe in the pantheon of low-energy schools. (For the Deanery see AJ 11.9.85 p67; for Yateley see AJs 12.3.80 p519, 24.6.81 p1199, 11.5.83 p67, 28.11.84 p73.)



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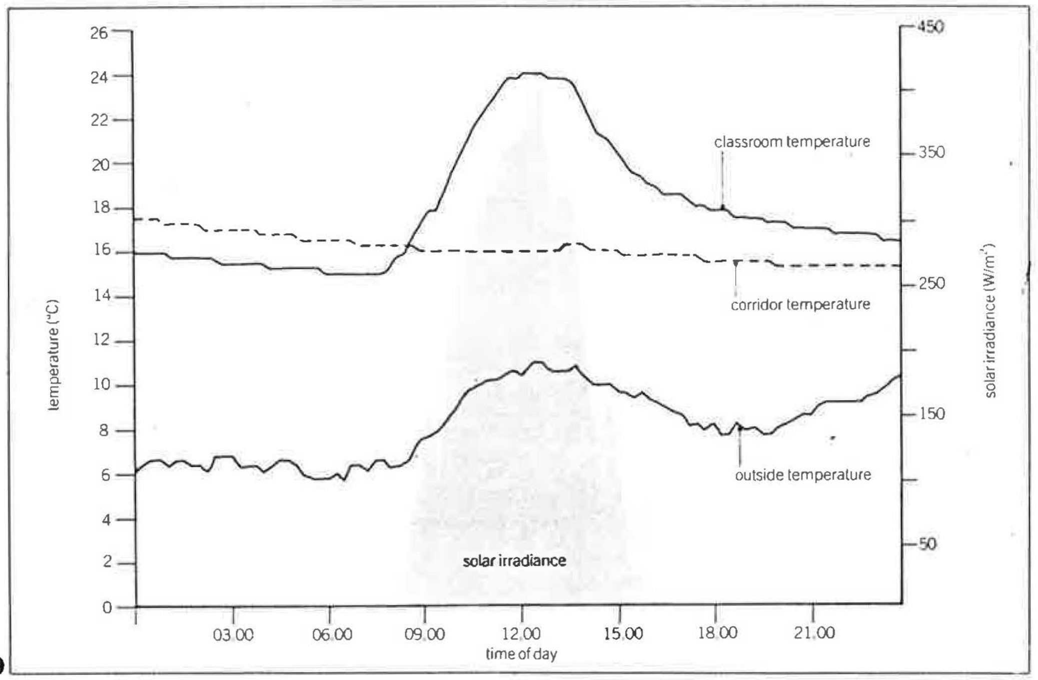

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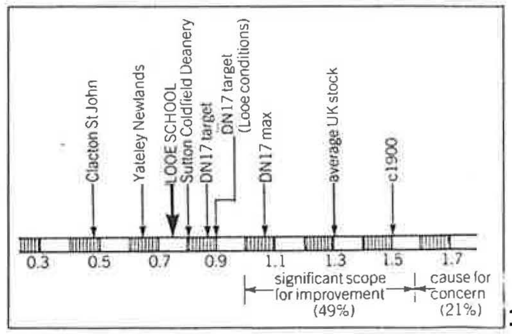
room-warming — an output of up to 2 kWh, when solar gain through the remaining glazing can be 20 kWh. Even so, the assessors feel it is still an idea worth pursuing.

Overheating

In opening up a building to the sun, solar overheating and glare become greater risks, not just in summer but whenever the sun shines directly into spaces in the building.

At Looe the roof overhang shades classrooms from direct sunlight at noon from mid-April to mid-September; only in June and July does it shade them for the whole of the working day — 09.00 to 15.00. At other times, teachers are expected to use the venetian blinds positioned to the rear of the Trombe benches to cut out direct sunlight, *16*. The designers of the heating system expected some use of the windows for air-freshening, despite the energy penalty, as well as anticipating that they would be used for cooling too. Windows were intended to be the main cooling devices in summer.



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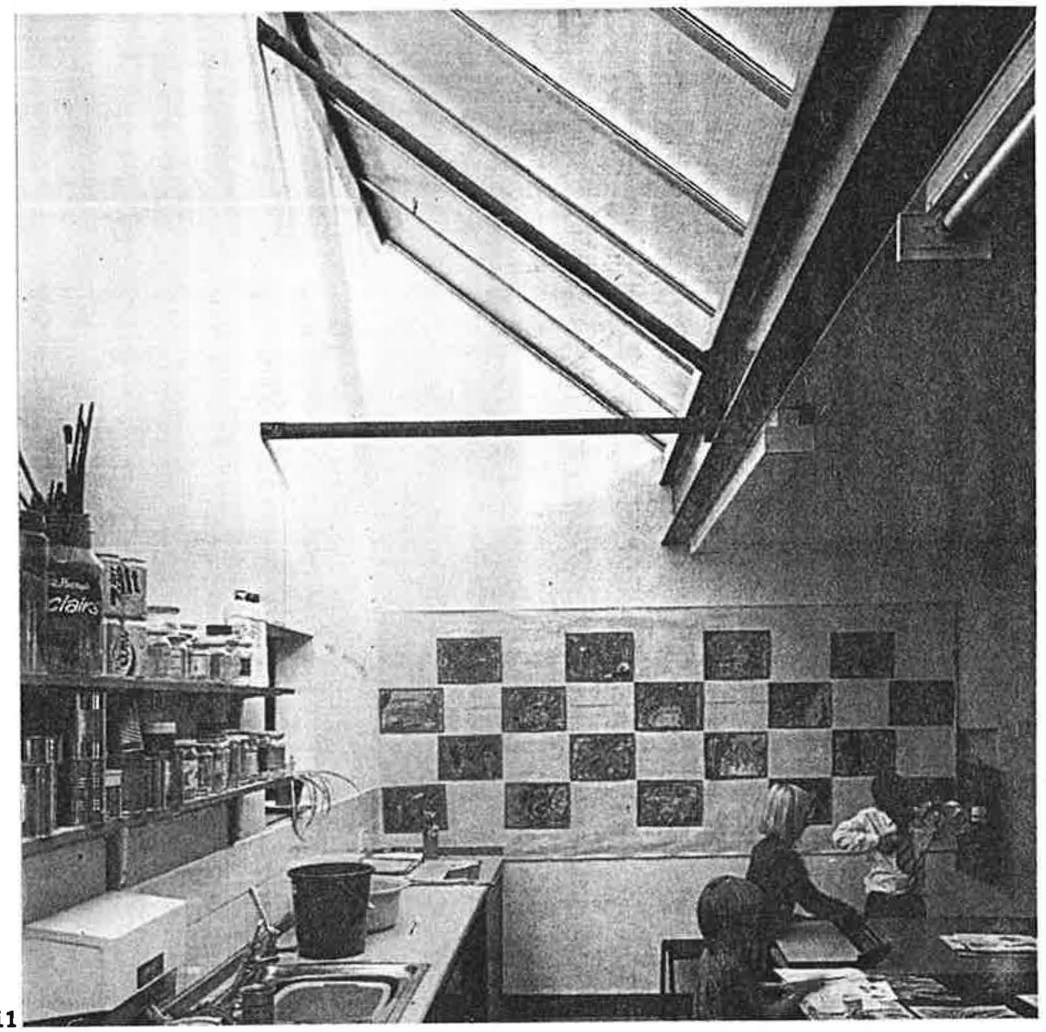
The measured temperatures, *15*, suggest that overheating should not have been a significant problem, but there have been several complaints from staff, especially in summer. These appear to arise due to several factors: the difficulty of using blinds; the lack of cross-ventilation paths; the difficulty of using the horizontal sliding windows to produce controlled air input, except on still days; and 'the sun shining directly through the windows' was cited by staff as a cause of overheating, which may mean that the complaints about overheating also encompass glare and other unfavourable lighting conditions.

11 Workspace area to the north of the junior classrooms with (uncontrolled) lighting.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Lighting

Many staff were complimentary about the quality and particularly the ambience of the lighting throughout the school.

As noted above, direct sunlight is on occasions a problem, and is perhaps exacerbated by excessive contrast — overall daylight levels are not high. The daylight factor contours, *14*, show factors of only around 2 per cent for much of the space. The laylights in the infants' classroom roofs have a negligible effect. The rooflights in the junior workspaces are much more effective, though they potentially create some problems of glare and overheating; they have no blinds, *11*.

Monitoring suggests that artificial lights are often used when solar intensity is low. The building makes relatively limited use of the daylight aspect of solar design, though, as the fuel consumption graph, *8*, and energy targets in table I indicate, lighting is not proportionally a large energy-consumer in this building.

Ventilation and odour

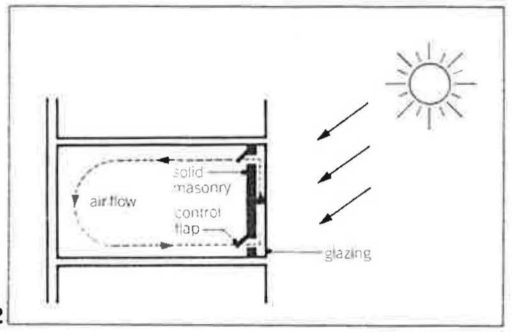
At first sight, the strategy of closing off adventitious ventilation in order to introduce controlled ventilation has been successful. This strategy serves to balance ventilation heat loss against allowing staff to freshen the air. The measured background air infiltration rate is only about 0.25 ac/h (air changes per hour), a compliment to the construction and choice of windows and doors. The designers were also relying partly on open doors and on pupils moving between rooms to produce air changes. The doors do not help much and children in primary schools tend not to move from room to room.

The opening of windows represents the controlled ventilation. Staff have found it difficult to adjust the large, horizontally sliding windows to produce finely controlled ventilation except in calm weather. At other times work is blown off the bench, walls and desks. The average air change rates may be only slightly above the DES minimum of 2.4 ac/h, but this appears to be made up of two components: 1-2 ac/h when windows are closed or the weather is calm, and 5-10 ac/h with windows open, often in windy weather. This latter rate can be used effectively at break times to flush out the air, but otherwise there is a real risk of odour build-up.

Given that the estimated average air change rate is above the minimum, the assessors do not feel on balance that the building's good energy performance derives in significant part from inadequate ventilation keeping down heat losses.

Cost

Quantity surveyor Davis Langdon & Everest was employed to look at capital costs. Its view is that the building costs for Looe school are not greatly affected by the passive solar aspects. There are some greater costs for the envelope — the roof accounted for 17 per cent of costs — plus



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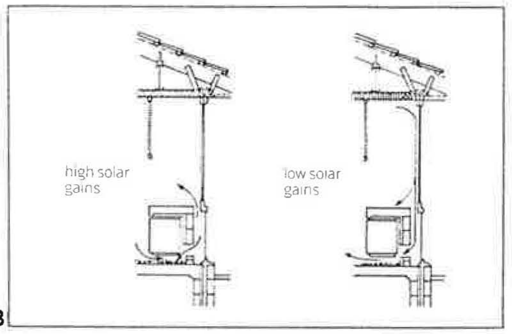

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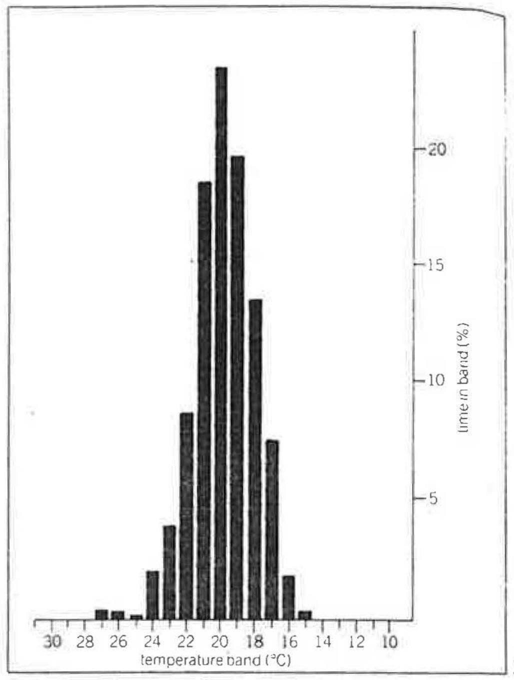

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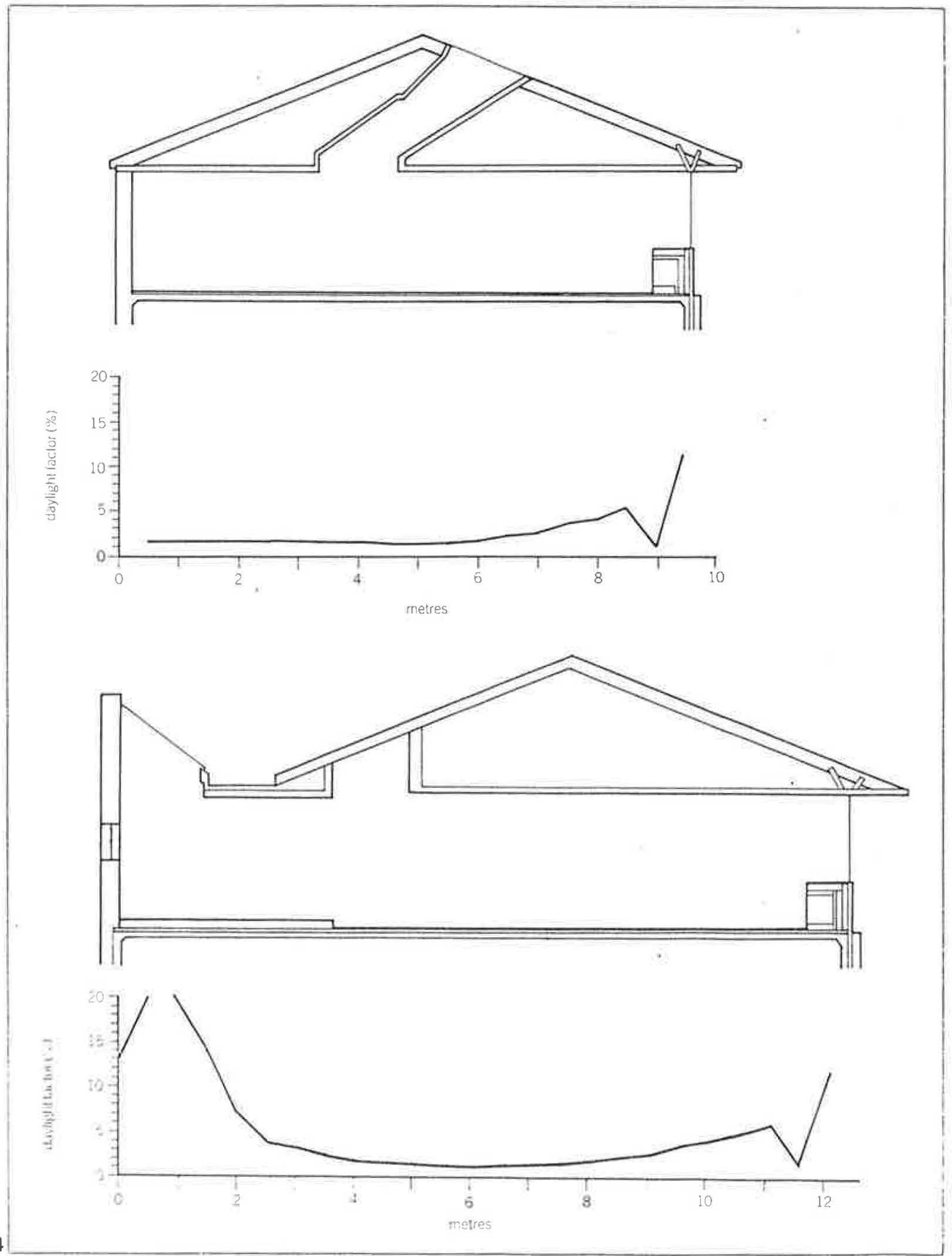

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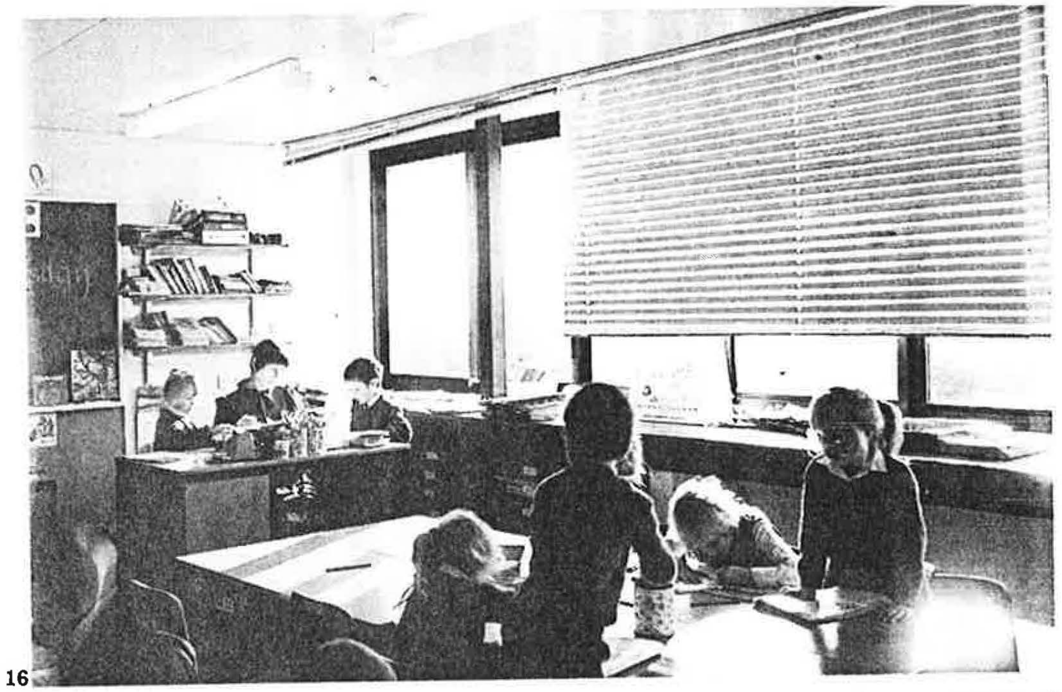
12 The Trombe wall in principle. Solar radiation is absorbed by the masonry which warms the air and leads to air circulation by convection.
13 The Trombe bench. The two diagrams for high and low solar gains show reverse air flow. Not surprisingly, in moderate conditions there is no marked directional air flow.
14 Daylight factor graphs plotted beneath the corresponding sections for an overcast day (7000 to 10 000 lux – the usual conditions for such measurement). Daylight factors are not high, less than 2 per cent through much of the room.
15 Temperature occurrence in a classroom within school hours over the year. The toned strip represents a notional comfort band, predicting less complaint about overheating than in fact occurred.



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16 Blinds down to keep out the sun, but lights on, and still high contrast on the working plane.
17 Is the 'unwelcoming back' an inevitable feature of direct-gain passive solar design?

double glazing, but also good materials were used to reduce maintenance costs. This is partly compensated for by lower heating system costs for a smaller installation. For the second quarter of 1986, the cost was £417/m^2 (£660/m^2 at today's prices, updated with the AJ's cost forecast mileage chart — AJ 27.9.89 p84). The Building Cost Information Service average for such schools is £398/m^2, the range being £208-610/m^2, with 75 per cent of schools below £445/m^2.

Conclusion

Several pointers emerge for anyone trying to design passive solar buildings that rely primarily on direct gain from a radiant sunshine. Overheating, especially in summer, is a key to design. Cross-ventilation could help at Looe school, but from surveys of the staff, the heading 'overheating' may include other aspects of bright incident sunshine, such as glare and shifting light conditions, and sensations of freshness and so on.

Controlled ventilation is needed to balance ventilation heat loss against the need to freshen air. On this windy site, finer control is needed than the large, horizontally sliding windows provide, perhaps slot ventilators.

Over the years we have gradually become more aware of daylight design as part of passive solar design. Looe school is not very subtle in its approach to energy-saving through using daylight. On some bright days, blinds are pulled down and lights turned on. The rooflights improve light levels, but need thermal control and lighting control — perhaps just the use of blinds. Reflectors or light shelves might be used to throw daylight into the depth of space.

Looe school is the first project in a new Department of Energy programme of energy performance assessments. The draft report[1] uses a one-to-five-star system, like ratings for hotels and restaurants. The assessors award four stars for cost, four for amenity, three for solar design, and five for energy performance overall. This building achieves low energy use in low-tech ways that add to its prime role as a school. ■

References
1 *Solar Building Study: Looe Junior and Infant School*. Energy performance assessment (Draft 8 89). ETSU (Energy Technology Support Unit). 0235 821000.
2 *Looe Junior and Infant School: EPA Technical Report* April 1989 by D. Alexander, N. Vaughan, H. Jenkins, P. Jones, P.E. O'Sullivan. ETSU 1163 (draft).
3 'Energy performance assessment of Looe Junior and Infant School' by D.K. Alexander, N.D. Vaughan, H.G. Jenkins, P.E. O'Sullivan. *Ambient Energy* January 1990.

Credits
client Cornwall County Council Education Committee
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