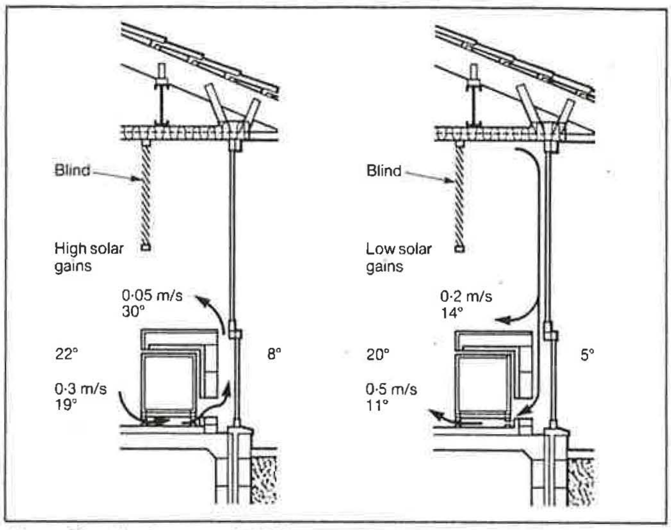
Monitoring Looe school

Looe school is a direct-gain solar building which has undergone a year's rigorous monitoring. The results of the study reveal some surprises as to the efficiency of natural ventilation combined with passive solar techniques.

The junior and infants school at East Looe, Cornwall, is one product of a desire to reduce the country's dependency on fossil fuels. Passive solar considerations were introduced early in the design process to help reduce energy costs while retaining the use of familiar techniques for the fabric and services.

The key energy themes were to maximise solar gain, to moderate and accumulate with thermally massive structures, and to minimise fabric heat loss.

Completed in 1984, the school is located on an exposed hilltop site with panoramic views to the south and east over looking the western approaches to the Atlantic Ocean. Thus the south and east frontages of the school are exposed to the often high winds coming off the sea.



Above: One disadvantage of 100% glazing can be overheating, but the trombe bench was able to reduce this effect while contributing the tempering of the down-draughts from the glazing. Here cavity air flows are shown for different weather conditions.

The ten classrooms radiate in four blocks from a central area (running along a north-south axis) comprised of a hall, kitchen and library. The two blocks overlooking the front entrance house four infant classrooms, the two other blocks, situated behind these, contain six junior classrooms.

Fabric

The solar design is a combination of direct and indirect solar heating, shading, and direct and indirect daylighting. 80% of the glazing faces south so as to maximise the potential for solar gains.

To the outside observer, the south facades present a 100% glazed facade. However, internally, 40% of the facade is made up of what is essentially a short trombe wall. This cavity is intended to intercept direct solar energy, then store and release it to the classroom as warmed air. Air openings are provided at the top and bottom of the cavity to promote the natural convection of heat.

The opaque walls are generally of traditional construction, and highly insulated. The construction, from the outside face, is: 100 mm facing brick; 50 mm cavity; 30 mm celotex insulation board, foil lined; 100 mm medium weight blockwork and finally 12 mm c/s render.

The solid floor is constructed of 50 mm concrete screed over a 150 mm concrete slab. The roof is of medium pitch and clay tiled over reinforced felt. The plasterboard ceiling is insulated with 100 mm foil-lined fibreglass quilt.

The school is, primarily, naturally ventilated with mechanical extract systems installed only in the kitchen area, staff toilet and shower, and the cleaner's storeroom. A low infiltration rate is achieved by a combination of high quality glazing frames and draught lobbies on all entrances and exits.

Space heating is provided via a lphw system serving fan assisted convectors.

Above: The south facade of Looe junior and infants school. The trombe wall is shown here below the glazing, and makes up 40% of the facade.

Evaluation

Two classrooms were chosen for the long term measurement of internal conditions. Globe temperature was measured at a height of 2 m from the floor and air temperature was measured at 0·3 m. In the trombe wall, cavity air and wall surface temperatures were measured, thermistors being used in each instance. Data were collected at hourly intervals over one year.

The temperature records indicated a well controlled environment over the full school year. 88% of temperatures recorded in normal school hours were between 17 and 23°C.

During a three week period in November 1987, an intensive monitoring exercise was undertaken. More internal parameters, than were monitored in the long-term study, were measured throughout the building every 15 minutes. The measurements showed that the passive solar classrooms experienced greater temperature swings through the day than the more internal spaces like halls and corridors.

Air quality

During the period of intensive monitoring, measurements were made in one of the classrooms to investigate air quality, infiltration, ventilation and the use of windows and average CO_2 levels and window opening status were recorded.

Air quality was consistently among the most poorly rated of the attributes of the classroom environment which the teachers were asked to score. The problem would seem to stem from an inability to obtain adequate draught-free ventilation, which itself would appear to be a result of the design intent to reduce, as far as possible, the background infiltration rate.

Due to uncertainty of the number of children present at any given time, and their CO_2 generation rate, no given accuracy could be stated. However, CO_2 levels were found to be in excess of 1200 ppm with a peak of greater than 3000 ppm. These levels, thought to be caused by low ventilation rates are regarded as very high. This may account for the incidence of opened windows even under adverse conditions.

Daylighting

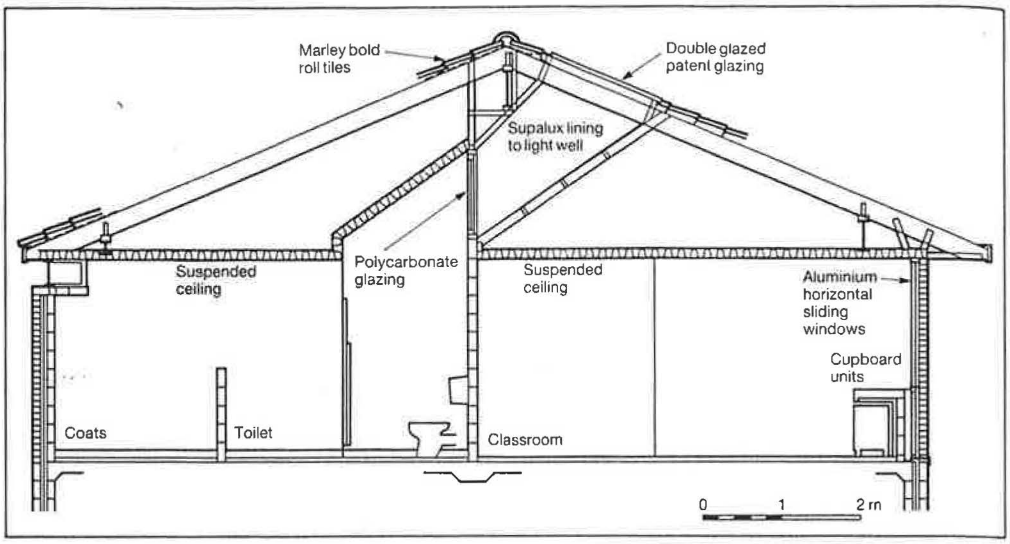
In general, daylight factors were not high, being less than 2% through much of the room. The generally low daylight levels in the classrooms have undoubtedly been affected by the wide overhang of the roof which acts to reduce the view of the sky vault as well as to reduce direct solar gains. In the junior part of the school, the daylight levels were significantly increased by the south facing rooflights in the separate work areas to the north of the main classrooms.

The designer allowed teachers some control over room emitters, ventilation and solar irradiation through individual room thermostats, openable windows and venetian blinds respectively.

Measured energy use

Full physical monitoring took place between January 1987 and February 1988, focusing only on fuel use. Short-term intensive monitoring was carried out in one junior classroom, and focused on energy flows in the trombe bench area and on air infiltration and lighting use.

Annual energy use was found to be 0·75 GJ/m^2. This was less than all design targets. The DES Design Note 17 indicates a maximum acceptable annual energy use of 1·06 GJ/m^2, an expected annual target of 0·87 GJ/m^2 under design conditions, and 0·89 GJ/m^2 under the conditions and the use observed.



Above: Section through the infants classroom showing the passive solar design.

It was estimated that, under average conditions, solar gain accounted for 7 GJ/week (or 26%) of the school's energy balance. Free floating classroom temperatures were also responsive to solar gain. Using central corridor temperatures as an indicator, free floating classroom temperatures (when the central heating was off and the building unoccupied) were found to rise by as much as 9°C during a sunny autumn day.

The trombe bench

One of the energy objectives achieved by the trombe bench was to delay solar gain to the classroom by absorbtion of the gain and its gradual release over a period of time. Furthermore, the estimated peak figure of 1 kWh stored in the bench under November clear sky conditions probably contributed marginally to delaying the drop in space temperatures at the end of the day.

The designer's second energy objective for the bench was for it to act as a heat source for the classroom. Under high solar conditions this did occur, but during low solar gain conditions the reverse occurred with cool air flowing from the window above the cavity and entering the main classroom area at floor level.

Recommendations

Most people are very satisfied with the building and are hard pressed to find fault with it. Nevertheless, there have been problems with overheating and inadequate ventilation.

The overhanging eaves were judged a success as they reduced the potential for overheating. However, they also reduced the incidence of daylight into the building. Although the designer anticipated this and placed a lightwell in the infant classrooms, in practice this had little measurable effect on daylight levels in these rooms.

Above: Three south facing lightwells have been set into each classroom wing. The light is channelled down a well to the rear part of classroom and to the toilets.

The school also demonstrates the conflict between reducing infiltration rates on energy grounds, and maintaining adequate ventilation on hygienic grounds. Through a combination of low overnight infiltration and a lack of fine control of ventilation, the designer erred in favour of energy and has consequently incurred an air quality penalty.

The trombe bench, which did not act entirely according to the designer's expectations, was felt to contribute little to displacing the building's energy needs and only marginally affects classroom conditions by absorbing unwanted solar gains.

The study concludes that the solar features could be made to work better should the design be replicated or adapted for use elsewhere. These cover:

☐ the inclusion of a small ventilation window high up in the existing window configuration for winter ventilation;

☐ The inclusion of trickle ventilators in the windows;

☐ The addition of a ventilator at the bottom of the bench so that external air is drawn into the cavity and preheated by solar gain before circulating into the room;

☐ the addition of one-way valves at the air inlets at the bottom of the bench to stop cool air under low solar conditions flowing through the cavity and being injected into the classroom at floor level;

☐ resolving the conflict between the trombe bench's amenity and accumulator roles by moving the blinds to the window edge of the bench;

☐ the addition of variable shading devices to the rooflights in the workspaces and the inclusion of more openings in its current configuration, so as to relieve overheating.

Project data

Looe junior and infant school,
Looe, Cornwall.

Site data
Latitude: 50.4N, 4.5W
Altitude: 80 m
Average degree days/y: 1950
Observed degree days: 2025
Average sun-hours/y: 1661

Building details
Completion: August 1984
Monitoring period: 12/86 – 2/88
Design occupancy: 300 pupils
Gross floor area: 1374 m^2
Volume: 3600 m^3
Opaque wall area: 659 m^2
Total window area: 335 m^2

Design targets (DN17)
Floor area: 4·6 m^2/pupil
Ventilation: 30 m^3/h/per pupil
Ventilation rate: 2·4 ac/h
Lighting: 150 lux (minimum)
Energy design value (primary energy units): 115 W/m^2

Thermal characteristics
U-values W/m²/°C
Floor: 0·30
Opaque walls: 0·38
Ceiling/roof: 0·35
Windows: 4·00
Design-day heat loss: 84 W/m^2 GFA

Services installation
Space heating: 150 W/m^2
Boilers: 3 x 50 kW modular boilers
Hot water: 35 W/m^2 (1 x 60 kW)
Lighting: 12 W/m^2

Costs
Total cost: £417/m^2
BCIS reference mean tender cost: £398/m^2

This article is based upon information contained in EPA technical report 1163/1. The EPA project is sponsored by the Energy Technology Support Unit on behalf of the DEn and aims to accelerate the uptake of low energy and passive solar design of buildings through the use field trials on occupied buildings.