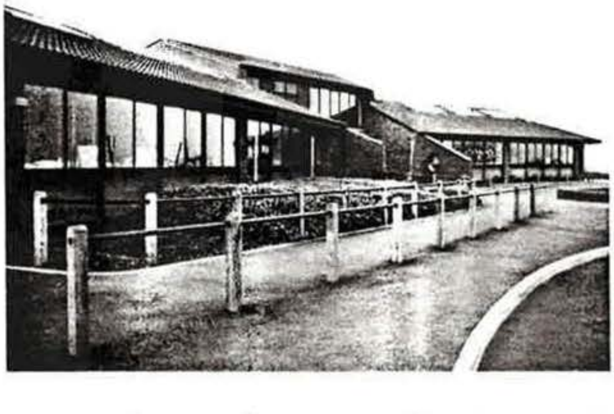
SOLAR ENERGY
A Renewable Energy

SOLAR BUILDING STUDY

Summary Report



Looe Junior and Infants School

ETSU 1163/SBS/1

The work described in this report was funded by the Department of Energy and managed by the Energy Technology Support Unit (ETSU) at Harwell. The views and judgements expressed in the report are those of the contractor and do not necessarily reflect those of ETSU or the Department of Energy.

In preparing this report we acknowledge the assistance of the Building Research Establishment, who provide technical consultancy services to the Department of Energy's Passive Solar Design Programme.

"This report is one product of
the Energy Performance
Assessments project, a
programme of field trials in a
wide range of occupied
buildings, covering the range of
UK latitudes and climates.

The aim of the field trials is to
assess the costs and benefits
(energy, financial and
amenity/environment)
associated with incorporating
passive solar principles
within building design."

ENERGY PERFORMANCE
ASSESSMENTS

SOLAR BUILDING STUDY

EPA SUMMARY REPORT

LOOE JUNIOR AND INFANTS SCHOOL

ENERGY PERFORMANCE ASSESSMENTS

Client :
Cornwall County Council Education Committee

Architect :
Cornwall County Architect's Department

Building Type :
Primary School

Solar Features :
Direct Gain
"Mini-Trombe" Bench
Rooflights

Location :
Semi-rural, Cornwall

Date Occupied :
September 1984

Size :
Gross Floor Area 1374 m^2

Total annual fuel use (166 kWh/m^2 GFA) in this "Low-Tech" passive solar building compared very favourably with contemporary primary schools.

The good energy performance was not achieved at the expense of thermal comfort or amenity as the building was highly appreciated by the staff for its comfortable and safe working environment and its visual appeal. The local authority are very satisfied with the building.

Despite an exceptionally high level of finish and fabric specification the building's normalised cost was £417/m2 GFA (2nd Q '86), which was just above the average for primary school costs.

The energy performance was strongly influenced by solar gains. Gas use for space heating would be 40% higher were it not for solar gains.

The Trombe-bench in each classroom contributed little to this performance, had little affect on comfort and had only limited amenity value.

EVALUATIONS

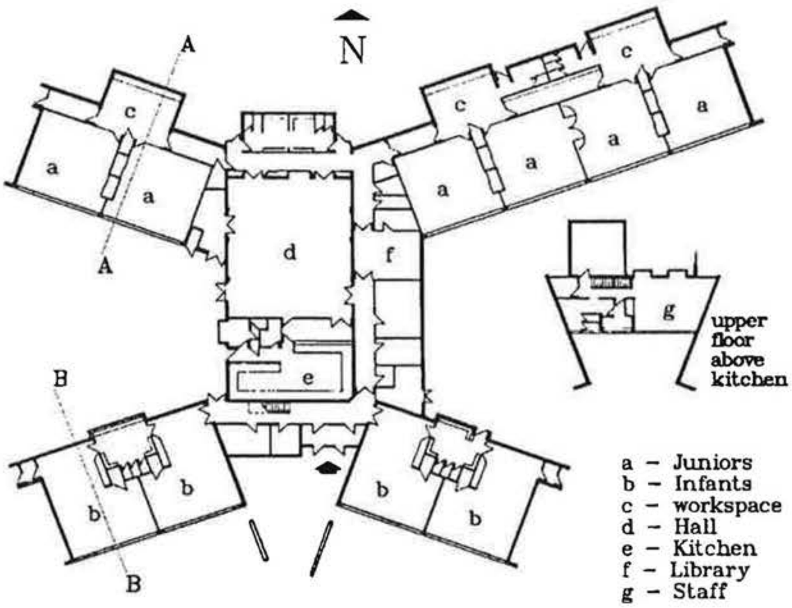
ENERGY	★★★★★
SOLAR DESIGN	★★★★
AMENITY	★★★★
COST	★★★★

These ratings are based on 12 months monitoring, interviews, questionnaires, and modelling studies. Five stars indicate an excellent, three an average, and one a poor standard.

THE BUILDING

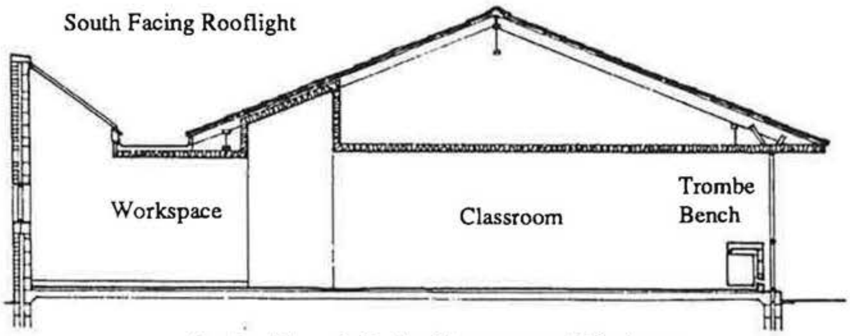
DESIGN

The Junior and Infants School at Looe is one product of a desire to reduce the county's dependency on fossil fuels. Passive solar considerations were introduced early in the design process, to help reduce energy costs whilst retaining the use of familiar techniques for the fabric and services. The architects' past experiences had convinced them that by careful design, significant energy savings could be achieved without substantially increased capital costs. The key energy themes became: maximise solar gains, moderate and accumulate those gains with heavyweight structures, and minimise fabric heat loss. Throughout the design process, a guiding principle was to achieve technical correctness, whilst maintaining visual appeal.



BUILDING DESCRIPTION

The cruciform plan provides each classroom with a large southerly facade, corridors and utility areas are placed along the north faces. The hall, kitchen, library and staff rooms are contained in a central block. Classroom access is through that block or via draught lobbies on the north facade. The internal thermal mass has been increased through the use of cement rendered concrete blockwork. High insulation levels and low infiltration rates are intended throughout. The ceiling has been well sealed and care has been taken to avoid cold-bridging of partition walls to the loft space. Foil



Section Through Junior Classroom and Workspace

Site Details :

Looe, Cornwall	50°4'N, 4°5'W
Altitude:	80m
Average Degree-Days/year	1950
Average Sun-hours/year	1661
Exposure	Severe
Site	unobstructed and exposed on S/E to on-shore winds

Dates :

Conception	September 1981
Tender	March 1982
Commencement	March 1983
Completion	August 1984
Occupied	September 1984

Design Occupancy 300 pupils

Design Aids Used included :

DES Design Note 17
RIBA Energy Calculator

Design Targets (DN17) :

Floor area	4.6 m²/pupil
Ventilation	30 m³/hr per pupil
Lighting	150 lux minimum
Energy design value (PEU)	115 w/m²

Building information :

Gross floor area	1374 m²
Volume	3600 m³
Opaque wall area	659 m²
Window area, South	259 m²
Non-south	77 m²
Rooflights	79 m²

Construction :

Brick & block external walls
Heavy concrete render
Coated aluminium frame window
Tiled pitched roof
Solid floor

Consultants :

Jenkins and Potter (structural)
Andrews Weatherfoil Ltd. (mechanical)

U-values (severe exposure) :

	W/m² °C
Opaque walls	0.43
Ground floor	0.30
Ceiling/roof	0.34
Windows	4.00

Heat Loss Coefficients :

Fabric	2.2W/°C/m² GFA
Ventilation	2.2 W/°C /m² GFA
Design Day Heat Loss	84 W/m² GFA

Services Installations :

Space Heating 150 W/m²

LPHW fan assisted, thermostatically controlled, convectors in each room.

3 x 50 kW gas modular boilers under optimum start/stop controller.

Hot Water 35 W/m²

1 x 60 kW gas boiler, independent of space heating boilers.

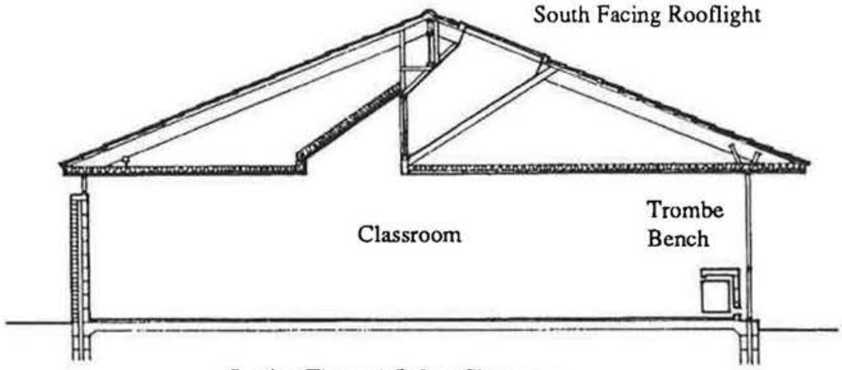
Lighting 12 W/m²

Primarily fluorescent, installed in rows parallel to windows. Manually switched in each room.

Ventilation target 2.4 AC/h

Naturally ventilated, aside from simple extractors in toilets and kitchen.

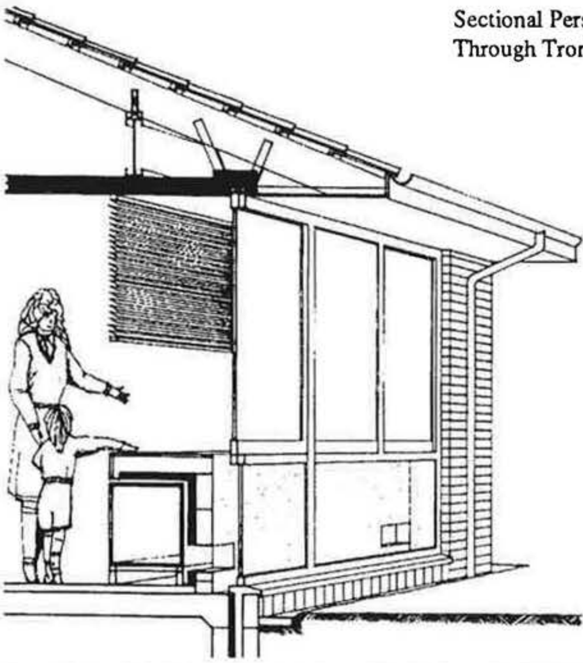
backed insulation is used to gain further insulation efficiency. The floor slab has been given perimeter insulation to a depth of 1 meter. Windows are standard doubled glazed units to improve comfort levels, and are set in high specification horizontal sliding aluminium frames to reduce infiltration rates. Draught lobbies have been added to all entrances to limit ventilation losses.



Section Through Infant Classroom

Direct solar heating and daylighting of classrooms is obtained through the 100% glazed south facade. Lightwells and clerestories serve the toilets and utility areas to the rear of the classrooms. Along the window in each classroom, a quarry tiled concrete bench tops a blockwork "mini-Trombe" wall. The glazed cavity created by the bench acts as an accumulator with ventilation pathways being provided at the bottom and top to promote warm air circulation. The bench is intended to act as a heat sink, to reduce the incidence of over- and under-heating, as a source of solar heated air, and as a safety barrier, isolating the pupils from the large area of glazing. Floor area is not lost, in that the worktop doubles-up as a display surface and storage cupboards are built underneath it. It is intended that the energy advantages of a fully glazed facade will be retained with the reduced likelihood of the usual problems of overheating, glare, and cold surfaces.

Sectional Perspective Through Trombe Bench

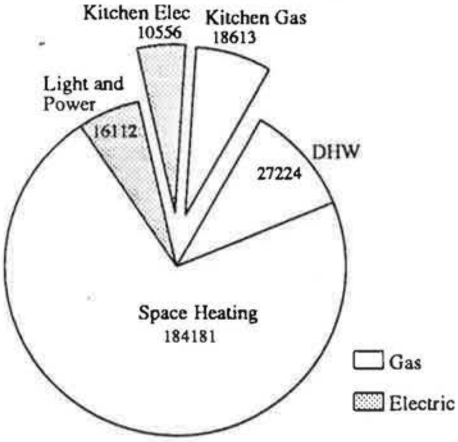


PERFORMANCE

ENERGY AND ENVIRONMENT

Delivered Fuel Use
(excluding kitchen & out-buildings)

Gas	211405	kWh
Electricity	16112	kWh
Total	227517	kWh
or	166	kWh/m²
Primary Energy	288417	kWh
or	210	kWh/m²



Monitoring took place between December 1986 - February 1988. During this period, the school was in normal use, including evening civic uses. No special energy efficiency techniques were introduced by the investigators during this period. The weather conditions were typical for the area, slightly colder and cloudier than the long-term average.

For comparability with design targets, energy use of kitchen and temporary outbuildings were excluded from the data.

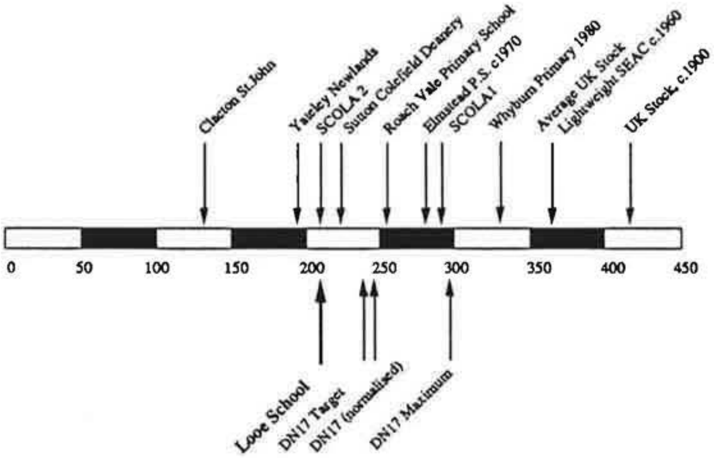
Delivered fuel was primarily used for space heating. Lighting represented a small proportion of the total fuel use. In comparison with other UK primary schools, and with current DES targets, the overall energy performance of the school was good, only being bettered by schools utilising complex technological solutions.

Observed Degree Days 2025

20 year average Degree Days 1950

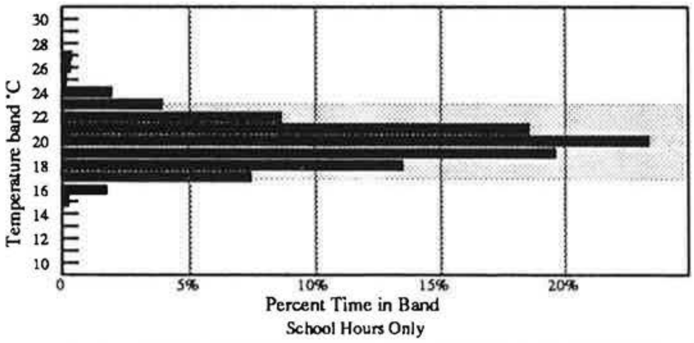
Monitored space heating 184181 kWh

Space Heating normalised
to long term degree days 177359 kWh



Annual energy targets and comparators for primary schools (kWh/m² PEUs).

Recorded classroom temperatures were generally in the acceptable range 18 to 23°C during normal school hours, with little indication of severe over- or under- heating. Although thermal comfort was generally good and no underheating was reported overheating was a problem at specific times of the day and year. In the teachers' opinion this was principally due to the sun shining directly through the windows. Air quality was the facet of the classroom environment least appreciated by the teachers. Whilst aiming for a tight building the designer had acknowledged the problems that can arise with this and had left extensive window opening capability in the hands



Recommended resultant temperatures in classrooms .... 18 -23° C

Maximum temperatures should not exceed .... 27 °C

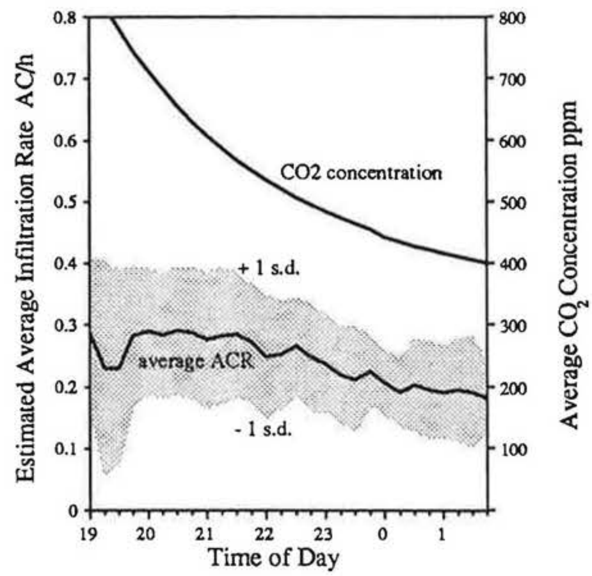
Proportion of occupied day in the range 18-23 °C 88%

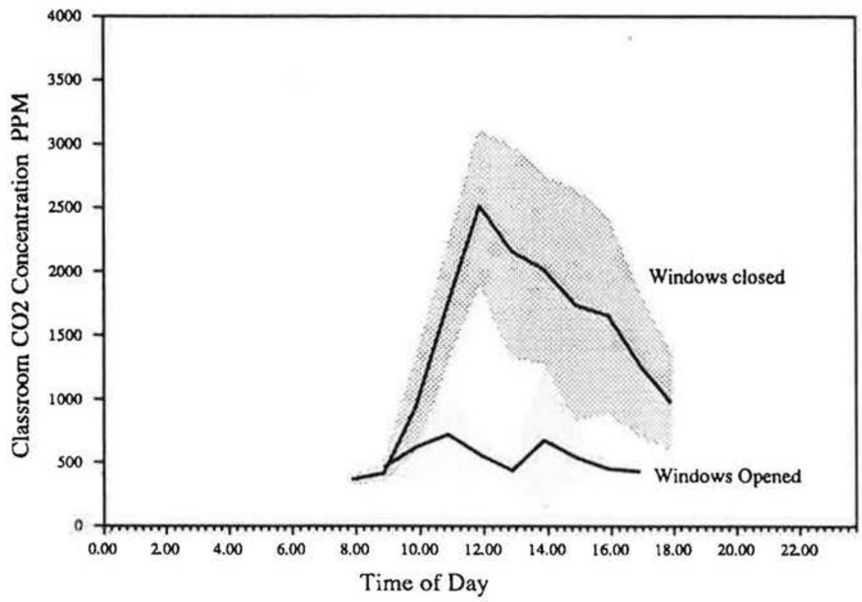
Additional detailed physical measurements were carried out over 3 weeks in November & December 1987 During that time the following were determined :-

Overnight infiltration rate	0.2 - 0.4 AC/hr
Average ventilation rate in school hours	2-3 AC/hr
Peak CO2 level recorded	3300 PPM
Average CO2 level during occupancy	1200 PPM

of the occupants. Unfortunately, in practice teachers found that opening the windows by even a small amount could lead to extensive draughts across the adjacent workbench with disruptive effects upon displayed teaching material. The air quality and ventilation problems may be partly responsible for some of the reported thermal discomfort. Other instances of overheating were reported in the workspaces at the rear of junior classrooms where there was no shading on the south facing glazing and little opportunity to ventilate the area because of the limited area of window that could be opened.

CO2 measurements confirmed the success of the designer's strategy to reduce overnight infiltration rates through having a tight envelope. Daytime air change rates varied between 1-2 air, with the windows closed, to 5 - 10 AC/hr with the windows open.



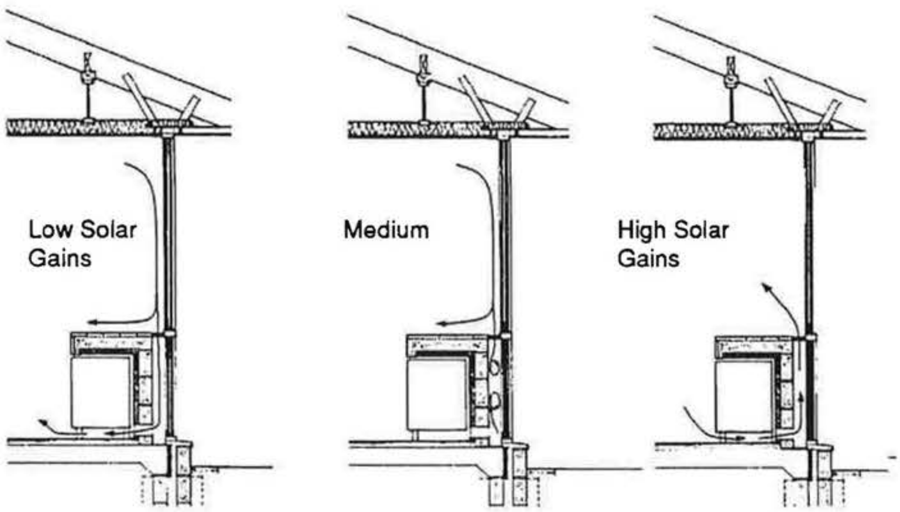


PERFORMANCE

With the exception of their control over air quality teachers were satisfied with the amount of control they had over environmental conditions in their classrooms.

PASSIVE SOLAR FEATURES

The Trombe bench was not liked by the teachers. This may be due less to the bench itself and more to conflicts between the bench and other features such as the venetian blinds and the sliding windows. While the Trombe bench could operate as intended it could not be considered a major contributor to the building's energy performance. In moderating solar gains to reduce peak temperatures, the bench's primary function, the bench's relatively small area and mass could account for only a small proportion of the total energy flow in the classroom. The energy collecting potential of the allied cavity was not realised. While air movement and temperature measurements indicated that warmed air circulation could occur on sunny days (as anticipated by the designer), they also showed that this could be easily disrupted by down-draughts from the large adjacent windows and by opening those windows. Furthermore, under periods of low solar irradiation, a reverse flow could occur, injecting cool air at floor level.



Bench Air Flows Under Different Conditions

In terms of utility, the bench worktop was not highly valued by the teachers. Whilst it could be used as a display surface, the positioning of the blinds at the inner edge of the worktop (so as not to disrupt the intended collection of energy by the bench top) was inconvenient as draughts, which occurred when the windows were opened, disrupted displays on the bench top. The bench's value as a safety barrier between the glazing and pupils was undisputed.

There was a notable response in the building's energy use to solar radiation, due largely to direct gains offsetting space heating. Allowing for variations in external temperature the useful solar gains represent, for an average week, 40% of the weekly space heating fuel (Solar Displaced Space Heating).

Occupant Control

Over the year, the teachers rated their ability to control or alleviate :-

Underheating	4
Glare	4
Overheating	3
Stuffiness and odour	2

5 = very satisfactory
1 = very unsatisfactory

Bench Temperatures

Mean external temp.	8°C
Peak room temp.	24°C
Mean room temp.	17°C
Peak bench surface temp.	25°C
Mean bench surface temp.	16°C
Peak collector cavity temp.	34°C
Mean collector cavity temp.	13°C

Solar Information

Average Weekly Solar Irradiance on Site

16.7 kWh/m²/week

Estimated Solar Displaced Space Heating Fuel

1778 kWh/week

Average Space Heating Fuel Use

4500 kWh/week

Solar Displaced Space Heating SDSH 40%

Solar Contribution SCON 26%

SDSH

Solar Displaced Space Heating

The amount of space heating displaced by solar gains. Expressed as :-

$$(SG/SH) * 100 \%$$

SCON

Solar Contribution

The relative contribution of solar gains to the overall heat input to the building. Expressed as :-

$$(SG/(SG+SH+IG)) * 100 \%$$

Teachers scored their environment as :-

The Classroom	Median
Its thermal comfort in winter	4
Its thermal comfort in summer	3
The ease with which temperatures can be controlled	2
The amount of daylight entering in winter	4
The amount of daylight entering in summer	4
Its decoration	4
Its character and 'atmosphere'	4
Its air quality	2
Its visual appearances inside	4
Its suitability for the job you do	4
Its layout and design	4
Its soundproofing from noise outside the building	4
Its soundproofing from noise inside the building	4
The extent of the view of outside from indoors	4
Its spaciousness	4
The classroom overall	4
The Building	
The standard of construction	4
Appearance of the *building* viewed from the rear	4
Appearance of the *building* viewed from the front	4
The *BUILDING* overall	4
(1 : very dissatisfied 5 : very satisfied)	n = 9

AMENITY

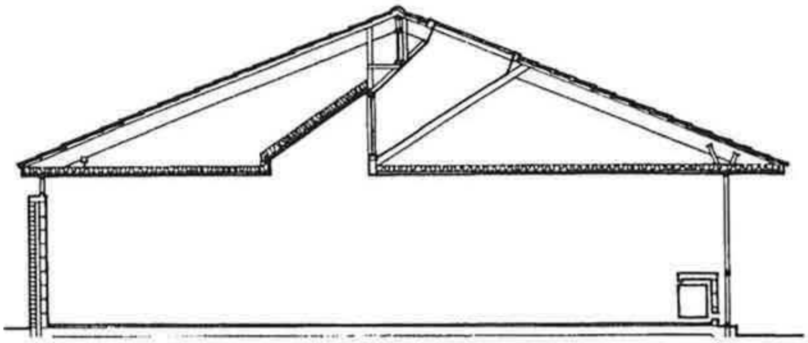
"One has a feeling of spaciousness, cleanliness and peacefulness. I have never worked in a school that has been so nicely situated and so nicely designed. It is very pleasant to work in indeed."

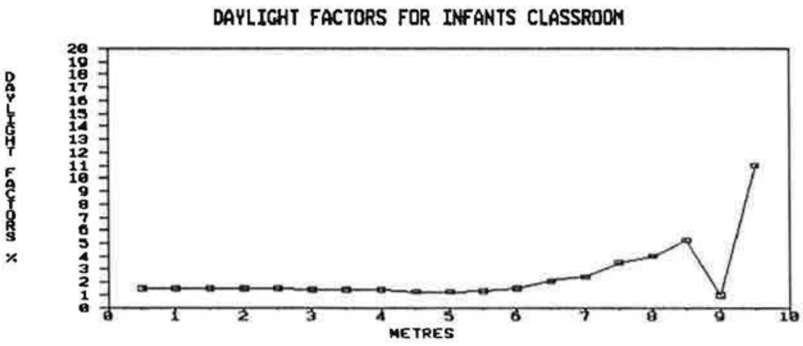
The staff were pleased with their building, regarding it as being well designed and admirably suited to the requirements of teaching. The building and classrooms were particularly liked for their visual appearances. The general ambience of the building was felt by the teachers to be a positive influence on the children's behaviour, inducing "pride" in their school and environment, "gentleness" and "concentration".

The caretaker found the building excellent to work with - a "caretaker's dream". He reported that it warmed up very quickly under most conditions, and retained its heat well after heating system shutdown. Whilst the staff made few major complaints about the building the caretaker's main concern was over the overheating in cloakroom areas (the workspace areas to the rear of the classrooms).

Daylighting, whilst pleasing in quality was not generally sufficient for teaching purposes and appeared to have little impact on the use of artificial lighting. Measurement showed that daylight levels fell off substantially away from the windows and that they were little affected by the rooflights in the rear of the infant classrooms.

No problems were reported with sound transmission between rooms or from outside the building.

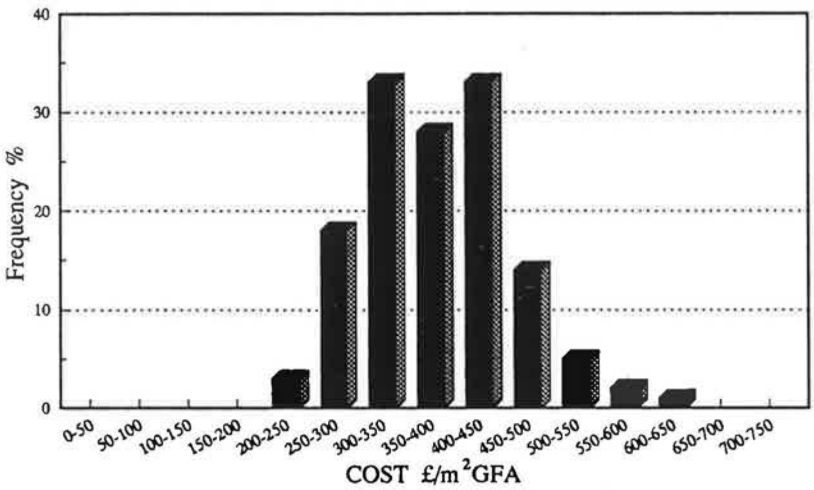




PERFORMANCE

BUILDING COST

The building is entirely new build. Adjusted to the second quarter 1986 and average UK site, the school has been costed at £417/m² gross floor area. This compares very favourably with the histogram of primary school costs.



Histogram of primary school costs (BCIS)
Normalised for time but not location

Minimal cost penalties can be related to orientation and reduced glazing on the northern facade. Some increase in costs can be identified in the specification of windows and insulation. The roof design in particular has accounted for some 17% of the total cost. In addition, in response to the highly exposed site, high quality materials and finishes have been chosen to minimise future maintenance costs, although this has increased the capital costs. Higher envelope costs have been offset in the services installation, where costs are lower than the norm and reflect savings made in the sizing of plant due to the energy saving measures taken.

EVALUATIONS

These star ratings are evaluations based on 12 months monitoring, interviews, questionnaires, and modelling studies brought together to give a comprehensive judgement of the building. Five stars indicate an excellent, three an average, and one a poor standard.

Energy ★★★★★

The building is operating efficiently. It has met and bettered all energy use targets. Of examples of monitored energy use in schools, including several recent examples of very "hi-tech" low energy design, it has been found to be one of the better examples.

Solar Design ★★★★

It has been estimated that 40% of the space heating requirement of the school (SDSH) is satisfied by solar gains. These would appear to be mainly from direct gains through the large south facing glazing areas. There is little evidence of a major contribution to displaced heating arising from the Trombe bench. The Trombe bench has not, however, degraded the overall energy performance of the building. There was some overheating, but this was not as severe as might be expected in a direct gain design. In thermal terms the most effective components of the solar design were the large south facing windows. The overhang, allied with the depth of the classroom and the thermally massive construction effectively controlled the solar gain, allowing an acceptable environment to be achieved. The heavyweight bench had some effect in moderating solar gains, but this was not thought to be particularly significant. The bench did succeed in distancing the classroom seating well away from the windows, so that the full benefit of the shading could be achieved. Daylight levels through the classrooms were not as great as initially might have been expected, given the amount of glazing and provision of rooflights etc.

Amenity ★★★★

Visually the school is highly regarded, both from the inside and outside. It is perceived as being a well designed and executed building. The building provides an excellent working environment for teachers and pupils. There is a considerable satisfaction with all major aspects of the building, apart from ventilation. Other than this and some complaints regarding overheating and the utility of the bench worktop, a maximum rating would have been given.

Cost ★★★★

As the costs for this building are average for a primary school, and as it has proved to both be energy efficient (i.e. promoting a saving in fuel costs), and of considerable amenity value to the staff and pupils, four stars have been awarded.

Composite ★★★★

This school is a quality, "low tech" direct gain passive solar building, which is loved by its occupants, and combines a pleasant working environment with low energy and maintenance costs.

ASSESSMENT

CONCLUSIONS

The School is deliberately centred around a simple direct gain passive solar strategy which represents only refinements of standard good building practice. The designer has attempted to provide the energy benefits of high insulation levels and extensive south elevation glazing, whilst maintaining thermal comfort and visual attractiveness. The demands of the highly exposed site, and a requirement for longevity and low maintenance, may have affected construction costs. The design aims have surely been fulfilled, as the building has both a good energy performance and is highly regarded by its' occupants. The building illustrates that passive solar design principles can be successfully translated to accommodate the needs of a primary school.

LESSONS and RECOMMENDATIONS

1. The designer diligently strove to strike a balance between the dual requirements of comfort and energy conservation. Whilst this has been achieved in many respects there remains, in the building, a conflict between the attempt to reduce the air change rate, to limit heat losses, and the needs for fresh air. Fine ventilation control for occupants might have been achieved through the provision of small openable windows or ventilators without substantially affecting the building's energy performance.

2. The Trombe bench was shown to be sensitive to the effects of cold down draughts from the adjacent large windows. This limited its usefulness as an energy device. The problem may possibly be solved by the addition of measures to stop cold down draughts entering the cavity whilst still allowing the free passage of warm air on those occasions when it is present. There is need for development work on this aspect of the bench.

3. There was a conflict between the Trombe bench's roles as an energy device and workbench. One way this conflict showed itself was in the positioning of venetian blinds on the classroom side of the bench, something that interfered in the placement and use of teaching material on the bench top. In the absence of an increase in the energy benefits derived from the bench, the device would be better suited as an amenity and hence the removal of the blinds to the window side of the bench.

4. The daylighting benefits derived from the rooflights in the infant classrooms appear to be minimal. It is doubtful whether these can be justified on a cost-benefit basis.

FURTHER INFORMATION

EPA Technical Report: Looe School 1990 ETSU Report 1163/1.

BUILDING, Issue 19 Volume 250, 9 May 1986, pp 43-50; "Building Dossier - Looe School". Building (Publishers) Ltd.

DESIGN NOTE 17 (1981), "Guidelines for Environmental Design and Fuel Conservation in Educational Buildings". Department of Education and Science.

"Passive Solar Design : Looe Primary School" AJ 13th December 1989, pp 55-61

"Monitoring Looe School". Buildings Services September 1989, pp 63-64

ETSU Renewable Energy Enquiries Bureau. Telephone : 0235 432450

Solar Building Studies are summary reports of the Energy Performance Assessment project. This is funded by the Department of Energy through its Energy Technology Support Unit at Harwell. The R&D is carried out by Databuild (Birmingham) and UWCC (Cardiff). The views contained in this document are those of the authors. The EPA of Looe Junior and Infants School was carried out by UWCC (Cardiff).

The co-operation and assistance of all those concerned with the building reported here is gratefully acknowledged : owners, operators, designers and occupants.

"This report is one in a series of
30 buildings being studied.
For further information on this
and the other buildings,
please write to: "

RENEWABLE ENERGY ENQUIRIES BUREAU
ETSU
BUILDING 156
HARWELL LABORATORY
OXFORDSHIRE OX11 0RA

Tel: 0235 (432450)
Fax: 0235 (433131)

HARWELL DESIGN STUDIO, UK, 8515B/91