Department of Education and Science
Architects and Building Branch

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Saving energy in schools

Three case studies in Nottinghamshire

Introduction

In 1986, local education authorities in England together spent £353 million on energy. Even a small percentage reduction would represent a significant saving in the running cost of educational buildings.

There is a wide range of energy saving measures available to local authorities for use in schools (see Figure 1). DES Architects and Building Branch Design Note 16[1] and Building Bulletin 55[2] describe a range of short payback measures including roof insulation and draught stripping. These have in many cases already been carried out. However, different measures can sometimes also be worthwhile. This Broadsheet discusses the main findings of a study which investigated the feasibility of three such measures.

The study was funded jointly by the Department of Education and Science and Nottinghamshire County Council and the research was carried out by the Environmental Design Unit of Leicester Polytechnic School of Architecture[3]

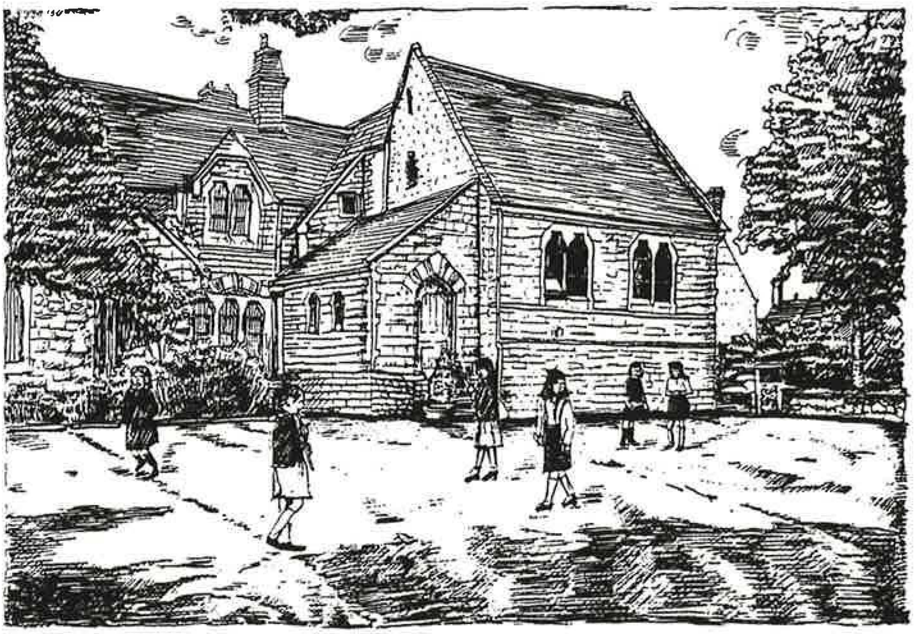
Energy consumption figures for 1976–1979 for all the schools in the Nottinghamshire area were first analysed. This showed that 84% of the schools in the area used more energy than the maximum annual

[1] *Energy conservation in two Oxfordshire schools*, Design Note 16, DES, 1978

[2] *Energy conservation in educational buildings*, Building Bulletin 55, HMSO, 1977

[3] A more detailed report on the research is also available and copies can be supplied on application to Architects and Building Branch of DES

Figure 1. Energy saving measures



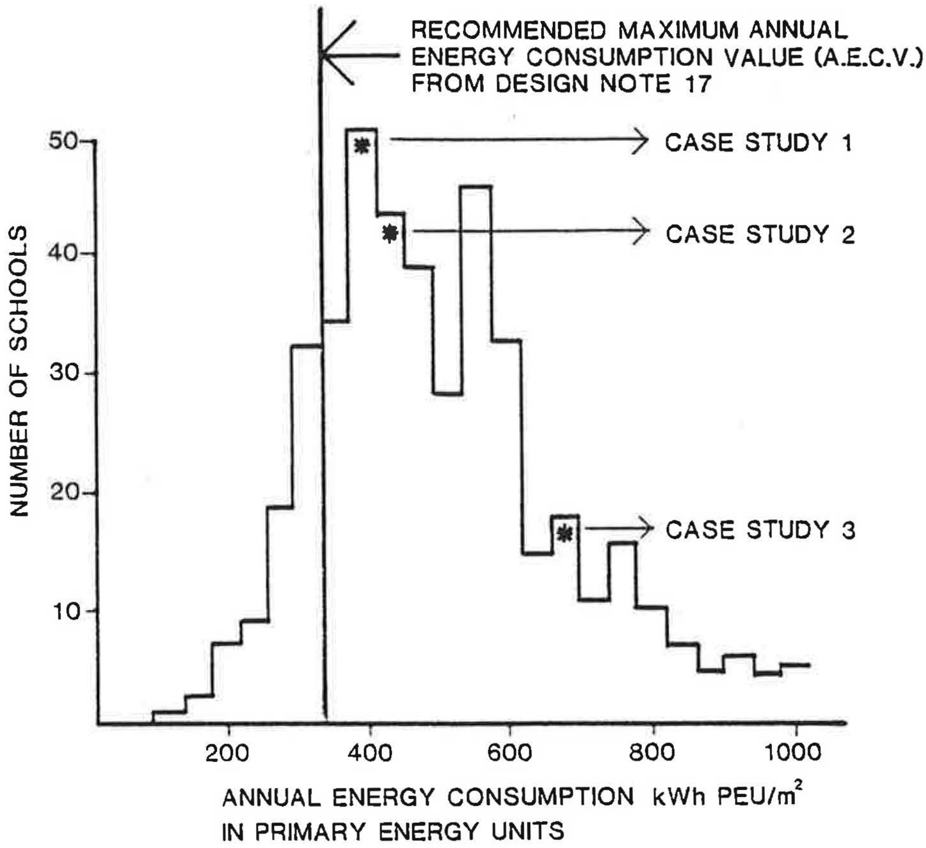
Short payback

1. Draught proofing
2. Loft insulation
3. Improvements in building management (eg turn off lights and shut doors)
4. Make greater use of thermostats and controls
5. Regularly test and maintain boiler combustion efficiency
6. Install optimiser/compensator heating system control

Longer payback

1. Install suspended ceiling
2. Reduce glazed areas
3. Improve 'U' value of walls and flat roofs
4. Incorporate passive solar features

Figure 2. Distribution of annual energy consumption in Nottinghamshire schools in primary energy units



energy consumption value (AECV) recommended in DES Design Note 17[1] for a typical primary school of 1000m^2 (see Figure 2). The schools chosen for the study were average energy consumers in Nottinghamshire (see Figure 2). The purpose of the study was to determine the effectiveness and cost benefit of the measures taken. In addition, the first two case studies illustrate how priorities of maintenance and energy conservation often coincide and how recognition of potential mutual benefits may enable authorities to pursue measures which otherwise would be less cost effective.

1 Addition of an insulated suspended ceiling to a Victorian school Lady Bay Infants School, West Bridgford

This building had high ceilings which were difficult to maintain and were thought not to provide a suitable scale for young children. Energy consumption and environmental conditions were monitored before and after the installation of the suspended ceiling. The suspended ceiling line was chosen to match the existing window and partition details, helping to make it unobstrusive from outside the building. The height varies between 3.1m and 3.5m which is in keeping with the scale of the rooms; to have adopted the minimum allowable height of 2.4m would have hindered the daylighting of the school. In order to further improve lighting and ventilation, the ceiling is flared up in places at 45° to meet the window heads (see Figure 3). This feature increased the cost but allowed for the provision of natural ventilation from the existing upper windows without the security risk from the use of the lower sash windows.

The new ceilings consist of acoustic tiles with 100mm mineral fibre insulation, giving an overall 'U' value of 0.31 Wm^{-2}C^{-1}. On sloping areas the insulation roll is pinned at the upper edge to convenient woodwork and allowed to drape against the tiles. The opportunity was taken to replace the original lighting system with fluorescent fittings. Ventilation is provided above the new ceiling to prevent condensation and air is thus able to circulate freely between rooms. A safety film applied to the glazing above the ceiling prevents any broken glass from falling on to the insulation.

Findings

This scheme is an example of an integrated approach to maintenance and energy conservation that provided:

- ☐ 15–25% reduction in energy use
- ☐ reduction in wall area requiring decoration
- ☐ better environmental conditions including improved lighting and acoustics.

After the ceiling was installed room temperatures were

[1] *Guidelines for environmental design and fuel conservation in educational buildings*, Design Note 17, DES, 1981

found to be 3–4°C above the desired level. It was calculated that the elimination of this excess temperature by the addition of a heating system controller (as described in case study 3) would produce a further 20% energy saving giving a typical combined energy saving from ceiling installation and temperature regulation of 35–40%.

The overall savings in energy and decoration costs arising from the installation of the ceiling together with a heating system controller would provide a payback period on the initial investment of between four and six years. This calculation excludes the additional benefits of optimised start-up and programmed shutdown usually provided by optimiser/compensator control which would further increase energy savings for the building as a whole.

2 External insulation to a flat roof Alderman Pounder Infants School, Nursery Block, Chilwell

This building constructed in the CLASP Mk V system was completed in the early 1970's. The existing roof had very limited insulation with a calculated overall value of 0.55 W/m²°C. It was in need of upgrading due to the risk of interstitial condensation. The additional insulation of the roof was seen as contributing to preventive maintenance that would be necessary in any case.

The roof consisted of a galvanised corrugated steel deck, overlayed with a vapour barrier, 12mm of fibreboard, three layers of felt and (before the insulation was applied) bonded chippings. The ceiling comprised 12mm mineral fibre tiles and a glassfibre quilt about 40mm thick; there was no vapour barrier. The roof specification was therefore similar to 'F' in Table 1 of Design Note 46.[1]

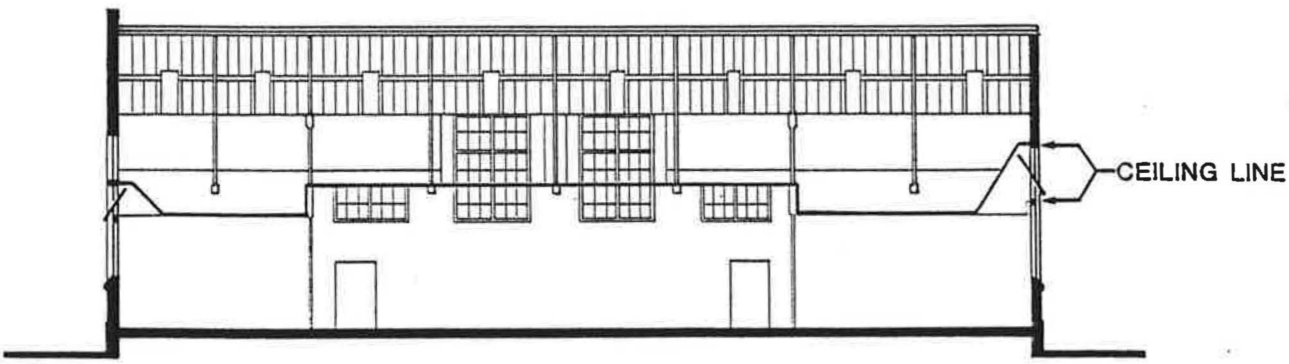
A range of materials are available to upgrade an existing roof not requiring major structural repairs. These include:

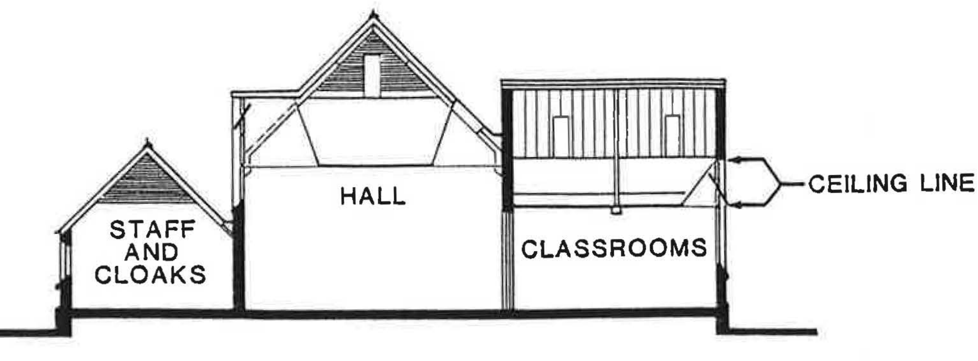
- insulation slabs. These are lightweight and usually bonded to the deck with bitumen, so avoiding the need for heavy ballast. A top weathering surface of a different material is applied separately
- tapering cork insulation slabs, with a top surface of a different weatherproof material
- roll-on insulation in the form of segmented sheets bonded to rolls of roofing felt
- spray-on rigid polyurethane foam with either an elastomeric polyurethane coating or an asphalt and chippings finish.

For this project, polyurethane foam was selected. This was light in weight and suitable for application to an existing roof which had so far not suffered serious deterioration.

[1] *Maintenance and renewal in educational buildings. Flat roofs: criteria and methods of assessment, repair and replacement.* Design Note 46, DES, 1985

Figure 3. Lady Bay Infants School elevations showing ceiling installation





Monitoring before the application of roof insulation showed that heat losses through the existing glass silk insulation on the heating pipes were significant and exceeded the heat flow upwards from the heated spaces. The insulation of the pipes in the roof void was therefore upgraded after the roof insulation had been applied.

A comparison was made of the heat losses through the roof both before and after the pipe and roof insulation. (See Figure 4.)

Findings

The installation of roof deck and pipe insulation was shown to achieve an overall saving of some 20%. In view of the relatively high capital cost and long payback period, these measures if applied to an otherwise sound roof would not be considered economically viable in themselves. Where, as in this case, the roof is due for major repair, the cost of extra insulation would generally be more than met by energy savings over a short period. The effectiveness of such expenditure in a particular case may be evaluated using investment appraisal techniques. (See Appendix 1 in Design Note 46.)

The insulation is easily applied from the outside of a building without disrupting the activities inside. In the case study the elastomeric waterproof coating was found to be not fully satisfactory with some uncured patches and pinholes. The alternative finishing layer of asphalt and chippings might, therefore, be preferred, although in this case the additional loading would need to be considered.

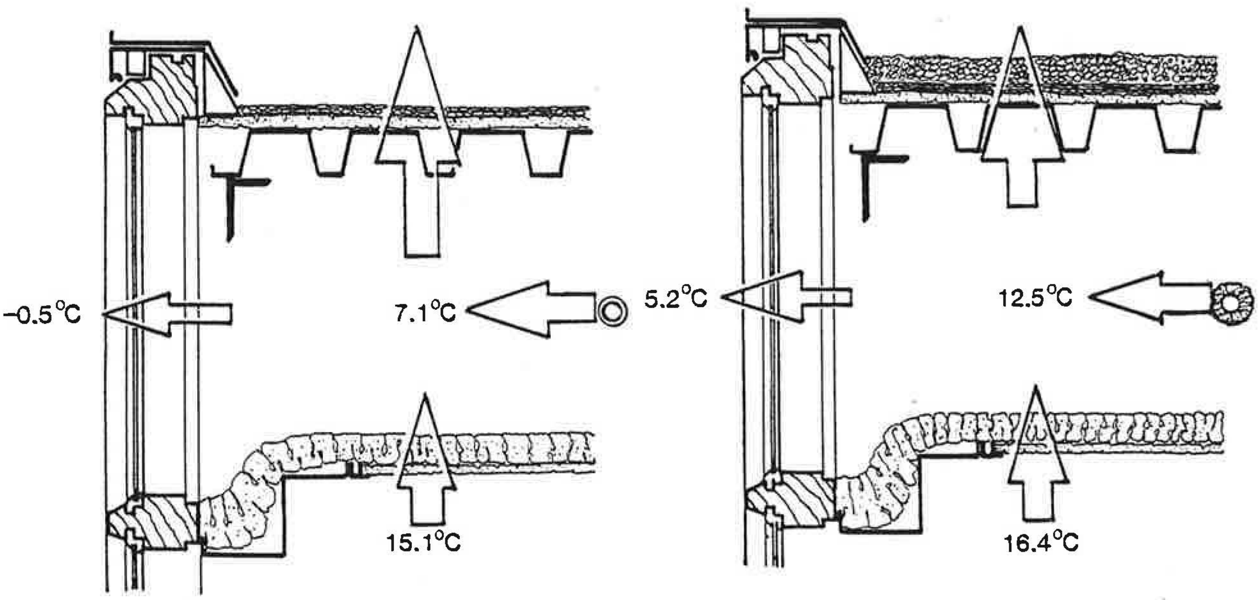
3 Use of a heating system controller Rosslyn Infants School, Aspley

This school, built in 1930, of traditional brick construction with pitched roofs was chosen for the study of the optimiser/compensator control of a coal-fired heating system. This device is more generally applied to gas-fired plants which are easier to control. However, if proved successful, there would be wide scope for its use in Nottinghamshire, where the majority of school heating systems are coal fired, and also in other coal producing areas.

For the purposes of this study, one classroom in the school was isolated from the heating system and heated by electric radiators and convectors. A computer was used to emulate the existing system, controlling the electric heaters via a triac circuit. A second identical classroom was used as a control to establish the warming and cooling time constants and power output characteristics of the solid fuel heating system. The electric heating enabled the interaction of the optimiser with the building to be studied in a realistic and reproducible way which was unaffected by the way in which the solid fuel boiler was operated.

The original gravity fed heating system had been previously converted to a pumped system. The stoking rate was originally under the manual control of a caretaker. After the installation of a controller the system would be operated at a fixed stoking rate throughout the day, regulation being achieved by on/off control of the underfeed stoker. Manual adjustment of the stoking rate would then only be necessary to cope with seasonal or fuel changes.

Figure 4. Energy balance for the roof structure



TOTAL HEAT LOSS 62 kWh

Before the deck and pipe insulation retrofits

TOTAL HEAT LOSS 24 kWh

After both retrofits

Findings

This measure yielded a fuel saving of up to 40% with a short payback period of between two and three years. These results support the introduction of such a device in similar schools with slow response coal-fired heating systems serving medium to heavyweight buildings where there is no secondary control of the heat emitters (eg thermostatic radiator valves).

Notes on selection and installation of heating controllers

In the three years since the case study was started, heating controls have advanced and they now vary considerably both in cost and in the control functions provided. The following notes provide additional background information to help in the selection and installation of heating controllers.

For considering the performance requirements for such a system the following aspects should be considered:

- ☐ type of fuel
- ☐ heating and burner controls
- ☐ ease of programming
- ☐ compatibility with any regional energy management system.

Temperature sensors

The resultant temperature which is a measure of comfort and combines radiant temperature with air temperature is often lower than the air temperature. To compensate for this the desired room temperature thermostat setting can be increased (1°C should be enough). Alternatively, a black bulb resultant temperature sensor can be used.

The internal temperature sensor must be sited in a suitable position in an area typical of the heating standard required. The sensor should be away from direct sunlight, cold downdraughts and heat sources. Immersion or strap-on water temperature thermostats should have good thermal contact. External thermostats should be positioned on an open surface, in a position away from draughts, vents, windows, and the reflected heat from building or ground surfaces.

Compensator control

A compensator uses an outside temperature sensor and is programmed, at the commissioning stage, with a relationship between required flow temperature and outside ambient temperature. Control is usually by a mixing valve but can be directly on the boiler, replacing the operation of the boiler thermostat.

When a pump is added to a system that was originally designed for gravity circulation care must be taken to ensure that the flow temperature required by the compensation schedule in cold weather is achieved. This requires careful design of pipework alterations and recalculation and balancing of the system to produce a reduction in the flow rates.

Self-adaptation allows for the controller to correct for long-term changes in boiler output power caused by changes in calorific value, combustion conditions and feed (stoking) rate changes. It is therefore a particularly useful feature in solid-fuel installations.

Optimum start

The desired internal temperature should be achieved within 30 minutes of occupancy on at least 70% of heating starts. Generally, this is only possible by using an internal temperature sensor.

The simpler optimisers tend to base their calculation of required start time on one temperature sensor only. The more complicated ones use both an inside and an outside sensor. Recent work[1] indicates that the use of a single sensor can give rise to accurate prediction of required start time, provided that it is an inside sensor and not an outside sensor.

Self-adaptive optimisers are widely used. They simplify commissioning as they monitor the performance of the heating system and make alterations to the programme settings to allow for the different thermal inertias of building constructions and response of heating systems. However it should be remembered that they will also self-adapt to system faults with consequent increase in energy consumption.

Optimum stop

To effectively include standing losses from the heat emitters into the occupied period, the switch-off time needs to be at least two hours before the end of occupancy. With a large volume system, it is not possible to achieve this length of time if close control of room temperature during the day is required. If loose temperature control (with wide air temperature differential) is allowed it is possible to use optimum stop; however the thermal inertia in a large volume system makes the prediction of optimum off-time imprecise. Therefore in both these cases optimum stop is not a useful function and is best suppressed and a programmed off-time used instead.

[1] 'A value for money guide to optimiser selection'. V. Sharma, P. Hibbert and P. Archer in *Building services and environmental engineer*, September 1982.

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