A LOW ENERGY DESIGN FOR KING ALFRED SCHOOL, LONDON

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ABSTRACT. This paper describes the low energy design of a new 896m^2 passive solar re-development at King Alfred School, Hampstead, London. Environmental design input came from the Low Energy Architectural Research Unit (LEARN) to an original design by architects van Heyningen and Haward (vHH). The project consists of groups of steel framed and timber clad modular units allowing completion during one summer holiday period of nine weeks. Energy saving design features include: Daylighting optimization utilising rooflights with daylight insulation and automatic light switching, passive solar ventilation from a buffer space, direct gain with external shading, and improved insulation levels. Estimated savings for all the measures are 50% (£1165 per annum) compared to a conventional design to current UK building regulations, and overall payback time is 7 years. In the school context, daylighting and lighting control provided the largest savings, insulation levels being only moderately improved upon.

1.0 Project Description

The new lower school re-development replaces existing buildings with groups of steel framed and timber clad 150m^2 modular units to allow rapid completion during one summer holiday period of nine weeks, Figure 1. The frame will sit on a 100mm concrete raft foundation, chosen because of the unstable site conditions, with a floating timber floor, quick to install and unaffected by future cracking of the slab. The pre-painted steel frame, of 100mm hollow square section columns and 175mm x 100mm beams, is bolted together allowing the mill aluminium finish roofing system to be fixed, providing immediate weather cover. Wall construction is 150mm timber stud with red cedar tongue and groove boarding, all dimensions on a 610mm grid to aid rapid internal finishing with pre-painted plasterboard. A covered area at the front of the building has a triple skin polycarbonate sheet roof, with an opaque upper roof for shading. The addition of 'cafe style' concertina opening doors creates a buffer sunspace for pre-heat ventilation in the heating season which can fold completely back in the summer to prevent overheating.

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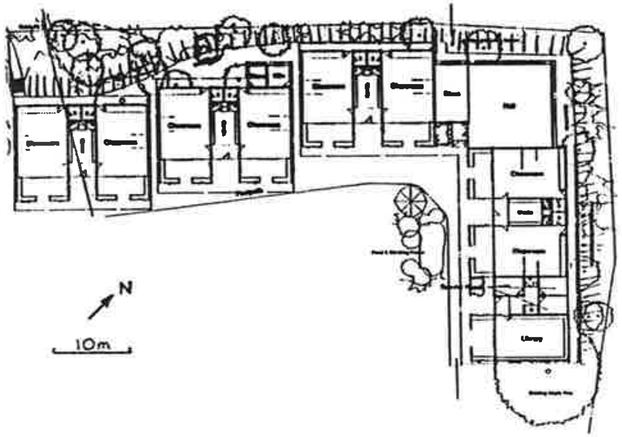


Figure 1. Site plan of King Alfred Lower School Re-development. The buildings are formed in an 'L' shape around an open playing field, the front facades being either SE or SW orientated, the rear overshadowed by trees

Mineral fibre insulation consists of 100mm in the walls, 100mm in the roof and 80mm under the floor, giving U-values of $0.37W/m^2K$, $0.41W/m^2K$ and $0.28W/m^2K$ ($0.49W/m^2K$ to ground temperature).

2. Environmental Design

Environmental studies focused primarily on a typical end classroom, as shown in Figure 2.

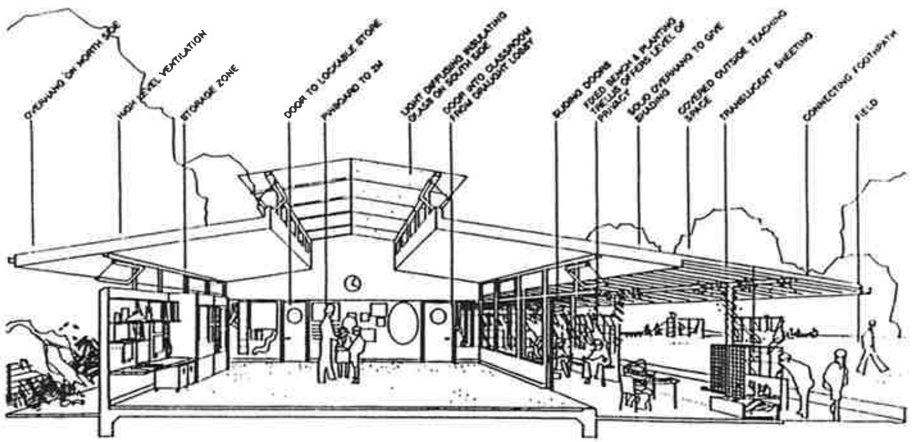
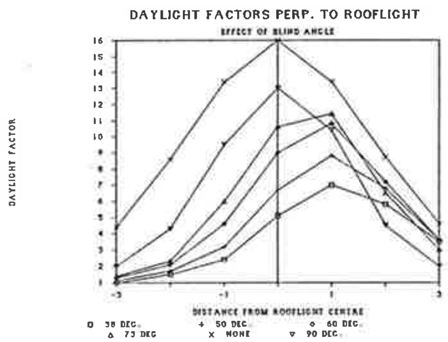


Figure 2. Sectional Perspective through a Typical Classroom. Rooflights have daylight insulation at the front and insulated panels at the rear; vertical lights are opening. Windows are plain double glazing.

2.1 DAYLIGHTING DESIGN

Computer daylight modelling of the original design indicated a poor daylight distribution, with high daylight levels near the front windows and under the rooflight but poor at the rear of the room. Electric lighting use will be based on the minimum daylight factor but will also be increased when daylighting is uneven. Using 1:20 physical scale models in an artificial sky, white venetian blinds were tested under the rooflight but did not increase daylight factors at the rear of the room, instead decreasing daylight factors under the rooflight, as seen in Figure 3. From the rear of the room the rear of the rooflight cannot be seen, has little effect on minimum daylight factor but adds to the unevenness of daylighting. Therefore insulated panels replace glazing at the rear of the skylight reducing thermal losses in areas where daylight is not useful with the resulting daylight distribution in Figure 4. Front window heights above 1.8m were found to provide little additional daylighting due to the shading overhang obstructing sky sight lines. Sill heights below 0.7m were also found to provide little daylighting benefit.



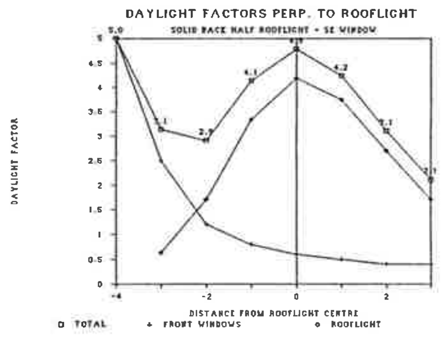


Figure 3. Effect of Blind Angle. Figure 4. Effect of Rooflight.

2.2 SHADING SYSTEMS

Simple venetian blinds could not exclude the sun, due to the non south facing orientation of the buildings, an 'egg crate' type solar shading device with a height to width ratio of 3:1 would be required. However such systems would reduce daylight levels and would give rise to problems and cost to keep clean. Light diffusing 'daylight insulation' double glazing was considered the best option for solar control in the rooflight. Using a 1:20 model of a classroom, the effectiveness of a 1.3m overhang was investigated. Excluding non-term time, the potential problem months for overheating are May, June and July. For these months the whole facade is shaded, for both

SE and SW at noon. The worst solar penetration occurs at 9-10am for SE and 3-4pm for SW, when the sun patch rises up to 1.0m in May. If overheating is a problem increasing sill height will therefore have an effect in solar exclusion.

3.0 Thermal Modelling with SERI-RES

The SERI-RES model was used to look into energy consumption of the building over the 185 day school year; term times 2/9-6/12, 8/1-27/3, 15/5-11/7. Using typical hourly weather data for Kew weather station, an annual simulation has been made based on 8am-4pm heating, 9am-4pm occupation (5 days a week) at 20°C for term times, with 5°C winter frost protection at other times. Economic appraisal aimed for a simple payback less than 11 years. The following aspects were investigated:

i. LIGHTING. Figure 5. shows the variation of electric lighting consumption with daylight.

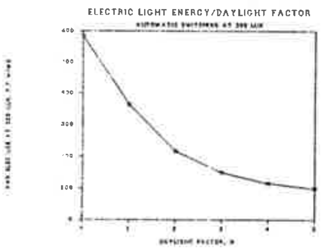


Figure 5. Electric Lighting vs. Min. Daylight Factor. It is clear to see that largest savings are made increasing DF from 0% to 2%. Automatic switching of 300lux lighting (7.7W/m^2) below 300lux daylight.

Automatic electric light switching is by Setsquare Liteminder automatic occupancy and daylight level switching at a unit cost of approximately £40. The units payback in less than one year, excluding installation costs.

ii. INSULATION OPTIMIZATION. Variation of insulation levels in 10mm increments has allowed a life cycle costing of various insulation thicknesses. Savings are based on gas heating at £0.02/kWh and mineral fibre insulation at £0.167/10mm thickness per m^2. This has yielded optimum economic insulation thicknesses for mineral fibre of: Roof 100mm, walls 100mm with the floor remaining at current UK building regulations of 80mm.

iii. WINDOWS. Sensitivity to increased front window area is for a small reduction in energy use due to the solar gain more than off-setting greater heat losses.

iv. DAYLIGHT INSULATION. Daylight insulation has been incorporated in the front half of the rooflights primarily as a means of solar control, in order to diffuse light and minimise glare. Due to the decreased solar transmission the use of 12mm daylight insulation actually increases annual energy consumption by £1.65 p.a. This measure improves comfort and obviates the requirement for further solar control devices,

such as blinds, which will require maintenance.

v. SOLAR VENTILATION PRE-HEAT. The required ventilation rate of 30m^3 per person per hour translates to 3.5 air changes per hour in each classroom. Assuming 3/4 of the ventilation air comes via vents to the buffer zone (2.625 ach, 467 m^3/hour) and 1/4 directly from outside (0.875 ach) an annual saving of 13.6kWh/m^2 (£0.27/m^2) is predicted. This measure is not cost effective unless the amenity value of a covered and glazed area for school activities is assumed to offset most if not all of the cost.

vi. SUMMER OVERHEATING. In order to see the effect on overheating, details of window area and overhang size were investigated, defining overheating as an air temperature of 25°C or more. In the original design the main front SE (or SW) facing windows have outside dimension 1.6m x 6.2m (sill height 0.7m, area 9.9m^2), with opening lights of 0.53m x 6.2m (3.3m^2) above. Venetian blinds were not considered appropriate in the context of a school, being expensive, requiring maintenance and being venerable to abuse by children. From this and the heliodon study the overhang of 1.3m is both effective and appropriately sized, reducing peak temperatures by 1.5-2.5°C. Given the loss of useful solar gain and daylighting penalty of smaller windows, a sill height of 0.7m has the greatest effect on overheating whilst having small effect on daylighting. The overall result of this will be at most 12 days where for one hour or more the temperature is 25°C or more, the maximum temperature being 30.9°C for the worst hour of the year.

4.2 OVERALL BUILDING PERFORMANCE

The energy balance for the heated areas is shown below in Figures 6 and 7.

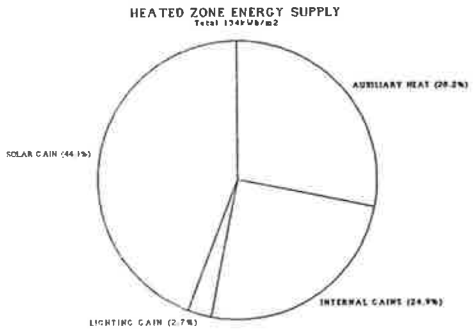


Figure 6. Energy Supply

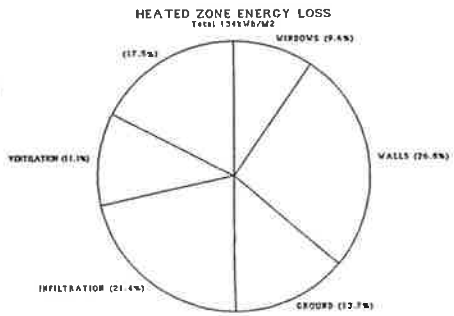


Figure 7. Energy Loss

The main factors giving rise to energy savings are:

i. Optimization of daylight design and use of efficient luminaires has led to lower electric lighting use. Annual electric lighting use is £224 (3.74kWh/m^2, £0.25/m^2) for 300 lux on the working plane at 7.7W/m^2 using high efficacy fluorescent lamps. This is a saving of up to £385 p.a.(£0.43/m^2), the figure compared to continuous lighting while occupied. Compared to present school practice of leaving lights on until approximately 9pm for cleaners, a further saving of up to £352 p.a. (5174kWh) is made, allowing half an hour for cleaning. Total lighting saving is in the order of £737 p.a. Had standard fluorescent lights been specified both running costs would be increased by approximately 42% (£94 p.a.).

ii. Despite the relatively short occupancy period of a school building, economic optimization of insulation thickness has resulted in greater than building regulation standards being used. Wall, roof and floor insulation thicknesses are 100mm, 100mm, and 80mm respectively, providing an annual saving of 2.4kWh/m^2 (£0.05/m^2) compared to UK Building Regulations.

iii. The use of solar ventilation pre-heat (SVP) from an attached glazed space has reduced the ventilation load, leading to heating net savings of £242 p.a. 13.6kWh/m^2 (£0.27/m^2).

iv. Orientation of main glazing to the SE or SW has allowed direct solar gain to contribute significantly. Simulated useful direct solar gain (term time, October-April) is 18kWh/m^2 for the heated zones in addition to indirect gains due to SVP and would be 24kWh/m^2 if the buffer were not in place.

4.0 Conclusions

Total annual heating and lighting energy use simulated for a similar west facing design to building regulations provides a reference of 83.4kWh/m^2, with a net running cost of £2.37/m^2. The chosen design has a predicted annual energy use of 42.4kWh/m^2 and a net running cost of £1.06/m^2, a saving of 55% on compared to building regulations. A more common reference for school energy use is primary energy units (PEU) used in Department of Education and Science design note 17, where ratios of 3.73 and 1.68 are applied to electricity and gas respectively. Allowing 2.6kWh/m^2 for hot water provision and 3W/m^2 for general electrical use, the proposed design has a total energy consumption of 48.0kWh/m^2, that is 95.8kWh/m^2 PEU. This is a 48% saving on the building regulations reference of 185.4kWh/m^2 PEU and a 66% saving on the DES recommended maximum of 280kWh/m^2 PEU for middle schools. On this basis gross running costs are £1.32/m^2 for the chosen design compared to £2.62/m^2 for the building regulations reference, a saving of 50%.

Total estimated net overcost for additional insulation, double glazing, transparent insulation, and controls, less plant saving, is £7,749. Estimated saving are £1165 per annum indicating a project payback of 6.7 years.