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A DISCUSSION OF THE NOVEL ENERGY SAVING DESIGN FEATURES OF THE NEW LEARNING RESOURCES CENTRE AT ANGLIA POLYTECHNIC UNIVERSITY.

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ABSTRACT

This paper describes and discusses the energy saving design features of the Learning Resources Centre at Anglia Polytechnic University. As part of the University's policy on environmental conservation, the design brief for this new Queen's Building specified a low energy passive design solution. The building, which has been occupied since September 1994, was awarded a THERMIE grant to demonstrate a 50% reduction in the annual energy related carbon dioxide emissions for a building of this type. Part of this grant supported a monitoring programme to ascertain the effectiveness of the chosen solution. The monitoring contract has been managed by ECD, the architects, and the work carried out by the University's own Building Performance Research Unit.

This investigation found that during 1995 the building consumed a total of 124 kWh/m^2 of energy which represents 48% of the 260 kWh/m^2 regarded by EEO as good practice (5). The top floor of the building is well daylit, the floor directly beneath the atria is also well daylit but this is poorly distributed to the surrounding floor space.

PROJECT BACKGROUND

Buildings have a major role to play in the management of energy and environmental conservation. UK industry and commerce spend over £10 billion each year on energy and are responsible for about 50% of all UK carbon dioxide (CO_2) emissions. Reducing the energy consumption of buildings and the associated greenhouse gas emissions must become a priority for all concerned with the design, production and maintenance of buildings. Saving energy not only saves money but is a cost effective method of helping to tackle the threat of global worming. This saving in energy and global environmental effects must not however be at the expense of comfort of the occupants using the building. What is required is a building that provides for the needs of the users at a low energy cost to the environment.

This was the approach adopted by Anglia Polytechnic University when in 1992 it was decided to relocate their headquarters from the town centre of Chelmsford, Essex to a 'Brown Field' (site formerly occupied by a ball bearing factory) at Rivermead adjacent to the River Chelmer. A masterplan was carried out for the 9 ha site with the first building being that of a Learning Resource Centre, now known as the Queen's Building.

As part of the University's policy on environmental conservation, the design brief for this first building specified a low energy passive design solution which would

- minimise the energy related carbon dioxide emissions from building operation
- minimise the running costs
- minimise the maintenance burden of the campus
- help reduce the ozone layer depletion by the elimination of the use of CFCS.

With the brief in mind, academic staff from the Faculty of the Built Environment Science and Technology approached the European Commission in October 1992 to obtain European Union funding to demonstrate the application of novel energy and environmental saving measures. ECD was appointed as architect on the project, with Ove Arup as environmental, structural and building services engineers, Bucknall Austin as quantity surveyors, and Esbensen of Denmark acting as independent energy consultants. Timothy Matthew Associates represented the University as project manager. A THERMIE grant was won and the building included in EC2000, an EU research project managed by ECD.

Following the appointment of the design team a week long multi-professional design workshop was held in early March 1993. This intensive workshop addressed the client's brief and planned to achieve the University's energy policy aims by:-

- avoiding the use of air conditioning
- using daylight efficiently
- utilising stack effect ventilation
- utilising low energy artificial lighting
- specifying condensing gas boilers.

A credible design solution was reached to provide a deep plan naturally ventilated and daylit space, comprising sidelighting with internal light shelves and two central atria for good daylighting. The daylight is supplemented by high efficiency background and task lighting. The central atria also provided a driving force to draw in air from the fenestration and remove it at high level through the atria windows by stack-effect buoyancy. The natural ventilation is controlled by the building's BEMS which mechanically opens and closes high level windows to suit the internal air conditions. The system also incorporates a night cooling strategy to cope with summer time overheating problems. The thermally heavyweight building is well insulated by current UK standards to provide a stable internally comfortable environment. The thermal energy is provided by low temperature heating distribution and condensing gas boilers.

The final design provides 6000m^2 floor area accommodating a library to seat up to 700 students, a media and education department with TV studio and production facilities, a graphics studio, computer teaching space and a dark room. A large presentation room, seminar rooms, offices and catering facilities are also provided. The building is located in Chelmsford Essex which is 60m above sea level, latitude 51.7^0 and longitude 0.55^0 E. The building is oriented in a south south-easterly direction encompassing mainly library space to the south four storey end with the office space located at the three storey north end. Further details of the building and its performance can be found in references 1, 2 & 4.

ENVIRONMENTALLY SAVING DESIGN FEATURES

Mechanically controlled Natural ventilation.

Air conditioning was avoided in this deep plan building by utilising a novel mechanically controlled natural ventilation system with night cooling. The perimeter windows comprise of a lower manually controlled main window with a smaller mechanically activated upper window. Each floor plan is divided up into a number of zones, with each zone having one air temperature sensor. When the air temperature for that zone exceeds a set-point figure, (currently set at 22^0 C) the BEMS mechanically opens the upper windows in that zone. The percentage opening of these upper windows depends on the degree of overheating so that if 22^0 C is exceeded by:

1.25^0 C, upper windows open by 25%
2.25^0 C, upper windows open by 50%
3.00^0 C, upper windows open by 75%
and 3.50^0 C, upper windows open by 100%

Thus during the day the fresh air brought in to each zone is temperature controlled.

The central atria windows are proportionally controlled by the BEMS such that the total opened area in the atria is equal to the sum of the perimeter windows openings. Thus an equal amount of air is drawn in by the perimeter windows to meet the needs of each zone and is expelled by the high level atria windows assisted by the natural buoyancy stack-effect. For the majority of the year, the day-time cooling mechanism can adequately control any unwanted temperature rise due to internal or solar gains.

During particular hot spells the building has an interesting night cooling system. The BEMS logs the amount the average internal air temperature exceeds a theoretical thermal mass set point of 22^{0} C in degree hours and should a threshold of 5 degree hours be exceeded at the end of occupancy, all windows are modulated to open until the building is cooled by incoming night air to match this preceding heat gain. At this point the windows are closed.

During the following day, should the average air temperature drift beyond set limits, the thermal mass set point is adjusted under the dictates of a self-learning algorithm which consults the preceding three day record in order to ensure continuous comfortable day-time air temperature conditions. A further sensor detects rain penetration into the building. If rain is registered, all atria windows are closed and the perimeter windows are proportionally closed to the 25% position. Minimum background ventilation is provided by trickle vent air bricks under each window. During the winter fresh air is drawn in through these vents and preheated by the perimeter heating system.

The kitchen, restaurant and the TV studio are mechanically ventilated by supply and extract fans serving displacement terminals. These are the only parts of the building which are not naturally ventilated.

Lighting Strategy

The building is generally heavily punctured with perimeter windows to maximise daylight penetration. This is designed to be further enhanced by twin internal reflective glass light shelves situated above each lower window. These internal light shelves have two functions, firstly they act as a solar control for the upper windows, permitting beneficial solar gain to the building whilst protecting the occupants from unwanted solar glare by reflecting it upwards onto the ceiling. Secondly, they have a design function to decrease the daylight levels adjacent to the window by reflecting daylight onto the ceiling enhancing the daylight deeper into the building. The lower windows have an integral blind system within the triple glazing which can be manually controlled by the occupants. These blinds are perforated such that even when fully closed the windows still permit daylight penetration.

In addition to the perimeter windows the daylight is further enhanced by the two central atria, providing very high levels of natural illumance deep within the building. The top floor is protected from excessive atria sunlight by internal sails mounted around the atria at high level. These are partially transparent permitting daylight to diffuse through to the occupied zones.

The daylight is supplemented by artificial lighting from single 36W tubes in luminaires with category 2 vdu louvres recessed into individual coffers on the exposed ceilings on each of the first three floors. In the seated library area this background illuminance of 150 lux can be enhanced by desk-mounted lamps providing additional local task lighting. Book shelves are illuminated by additional suspended fittings between each bookstack. On the top floor wire hung luminaires are suspended from the underside of the roof which contain pairs of 18W, 2L lamps. The overall installed lighting load is set at 13W/m^2. The central atrium have six additional 250W metal halide down lighters which are manually controlled.

The ceiling artificial lighting is controlled by a Thorn JEL system which is separate from the BEMS and incorporates timed and photocell control as well as passive infra-red detection and simple manual override. The photocell circuit is monitored every two hours and will switch off perimeter artificial lights when external illuminance exceeds a preset level.

Space Heating System

The building is heated by perimeter fin-tubed convectors positioned around the external walls. These are served by low temperature hot water from two gas-fired low NOx condensing boilers with a combined output of 746 kW and an efficiency of 86%. Hot water is provided by two 500 litre storage cylinders using a water to water heat exchanger sourced by the central boilers. The boilers are sequence controlled by the BEMS when activated by an optimum start switch at the beginning of occupancy. The flow temperatures are proportionally controlled such that when the external temperature is lower than or equal to -1^0 C the flow temperature will be 70° C and the return temperature 50^0 C. Incoming mains water is preheated using waste heat from the condenser of the restaurant bar cooler.

Building Form and Fabric

The building has a massive heavyweight concrete structure with waffle-slab concrete floors and is clad with a brick/insulation block external skin punctuated with mainly triple-glazed low emissivity glazed wooden-framed windows.

The timber-framed roof has concrete infill panels adding extra thermal mass and is held in place by a steel supporting frame.

The building has the following U Values

Element	U Value W/m$^{2\circ}$ C
External Walls	0.3
Ground Floor	0.25
Roof	0.3
Windows	1.5

The south facade has a projecting black aluminium powder coated timber bay unit encompassing protruding horizontal shading fins, to shield the occupants from excessive solar glare, as well as providing an architectural feature.

BUILDING PERFORMANCE

Energy Consumption

The total gas consumption for space heating and hot water for 1995 was 570990 kWh. The treated floor area is 5700 m^2 so the annual gas consumption per m^2 of floor area is 100 kWh/m^2.

The total electrical consumption for lighting and small power was 135071 kWh for 1995 giving 24 kWh/m^2. Both figures exclude kitchen and restaurant use.

This is summarised in table 1.

Table 1

Annual energy consumption 1995. $kWh/m^2/year$		Energy/m^2 floor area	Energy related * CO_2 emissions kg/m^2
Gas	570990	100	20
Electricity	135071	24	19
Total	706061	124	39

* Conversion factor 0.2 for gas
0.80 for electricity

No correction has been made for weather or occupancy patterns.
These figures compare very favourably with the UK Energy Efficiency Office EEO guidelines on energy consumption and CO_2 emissions.

They provide the following benchmarks for University buildings (5)

Table 2

University Academic Buildings Consumption per year	Low Consumption Less than (kWh/m^2)	High Consumption Greater than (kWh/m^2)
Fossil Fuels	185	220
Electricity	75	85
Total (kWh)	260	305
Total CO^2 (kg/m^2)	90	105

The Queen's Building energy total of 124 kWh/m^2 is less than half that regarded as good practice by EEO for this type of building. The energy related co_2 is only 43% of EEO good practice.

Even if the Queen's Building is compared with EEO Energy Consumption Guide 19 for offices (6) the building still compares well. Most buildings of this type would be normally air conditioned in the UK and a Type 3 air conditioned open plan office is regarded as good practice if consuming less than 232 kWh/m^2. The Type 2 non air conditioned open plan office (usually shallow plan) is regarded by EEO as low energy if consuming less than 156 kWh/m^2. This is still greater than the 124 kWh/m^2 per year for the Queen's Building. Guide 19 assumes 9am to 5pm occupancy 5 days per week. The Queen's Building is occupied 8.30am to 9.30pm weekdays and 9am to 5pm at weekends.

Daylight Performance

A daylight factor survey of the south atria which houses the main library has been conducted using a megatron daylight factor light meter. An effective assessment of the daylight performance has been achieved by simultaneously measuring internal and external illuminances by this single meter connected to one internal cell placed at desk height on a 2m floor grid, and one external cell placed above the roof profile on an extendible mast. This provides more accurate daylight factor information than other methods such as using two meters with a radio link between operators. Measurements were taken when the sky condition was cloudy but bright.

Table 3 provides a summary of some of the results.

Table 3

Location	Daylight Criteria
Top floor, south atrium south zone Blinds open	Average daylight factor 4.9% Minimum daylight factor 1.2% Uniformity ratio Min / Average = 0.24 % > 2% = 92%
Top floor, south atrium south zone Blinds closed	Average daylight factor 3.5% Minimum daylight factor 0.8% Uniformity ratio = 0.23 % > 2% = 72%

For the east and west sides the daylight reduces slightly from these figures. For example the average daylight factor reduces to 3.7% and the % > 2% reduces to 80%. However, for the whole of this floor the daylight is perceived to be well daylit by the occupants which is what you would expect with such a high average and minimum values. (3). This top floor represents 29% of the total treated floor area.

Lower floors do not perform as well, with the worst results recorded on the ground floor. The first floor has an average daylight factor of 1.8% with only 30% of the working place reaching the 2% minimum. However, the seated desk areas on this floor, which are located near the windows, have averages over 3% with 50% > 2% minimum. The central atrium on the ground floor has an impressive average daylight factor of 9.5%, minimum 5.7%, and UR = 0.6. The distribution of this excellent central core of daylight is, however, very poor, with daylight levels quickly dropping down to less than 1% just 2m in from the atrium. Architects need to address this poor distribution if they are going to fully utilise the core atrium daylight.

Conclusions

The Queen's Building at Anglia Polytechnic University is a low energy passive design solution accommodating a library, mini tv studio, a conference facility, offices and a cafeteria/bar area. Early monitoring of its environmental performance has demonstrated a 50% reduction in the annual energy consumption and energy related carbon dioxide emissions. The daylighting performance is a partial success with excellent daylight provided on the top floor with disappointing performances on the lower floors. The excellent central atria daylight is not effectively distributed to other parts of the building.

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