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Learning curve

by Roderic Bunn

One of the most important projects of the 1990s has just been completed – the naturally ventilated School of Engineering at De Montfort University in Leicester. Roderic Bunn reveals how it could influence a new breed of environmentally sensitive buildings.

There are buildings immediately recognisable as products of truly great architecture, landmarks that enter into the national psyche and retain their greatness as fashion and architectural styles change. Others come close, but for one reason or another fail to deliver, and are remembered only as brave attempts that somehow didn't quite work. Most buildings largely disappear without trace.

On the face of it, the new School of Engineering and Manufacture at De Montfort University may not be the stuff of greatness – for a start it's an academic establishment, it doesn't conform to any particular architectural style and it is certainly devoid of the corporate and architectural egomania so often associated with lauded commercial buildings.

Instead, this building is important for the way it tries to answer the crucial issues now facing the design professions, including the need for environmentally sensitive, flexible buildings which can perform without fuel-hungry m&e services and over-complex controls.

De Montfort University – formerly Leicester Polytechnic – had long wanted a new engineering school and was keen to find architects to design a 'green building'. This was fuelled by Leicester's 1992 role as Environment City, which motivated City institutions into embracing sustainable urban development.

Back in the late 1980s, the Leicester Polytechnic vice-chancellor asked the architect Short Ford Associates (formerly Peake Short) to propose a design which, alongside a financial appraisal, was presented to Government for funding approval. In the summer of 1989, the scheme was drawn up into its current form with the enthusiastic support of Leicester Council's chief planning officer.

The building doesn't follow earlier design rules for teaching spaces, and avoids the CLASP system of the 1960s which produced bland, deterministic and repetitive structures that defied the creative spirit of both teacher and pupil. Instead, the architects have combined good space planning with morale-boosting architecture that makes clever use of daylighting and, for the first time in the UK, applies stack-driven natural ventilation.

By 1990 this novel engineering approach was being assessed by an impressive list of advisers and researchers: Cambridge Architectural Research studied the effectiveness of the chimneys in inducing the stack effect, the Environmental Computer Aided Design and Performance Group (ECADAP) at De Montfort University was commissioned by ETSU to study the overall natural ventilation strategy, Professor Tom Lawson at Bristol University advised the architects on the building's air flow physics, and Max Fordham Associates was appointed services adviser.

Building layout

The School's as-built form is little different from Short Ford's original design, being a collection of quite narrow plan interconnected buildings on a NE-SW orientation comprising engineering and computer laboratories, classrooms, staff rooms, two auditoria and an open-plan drawing studio.

Two four storey laboratory wings extend to the NE, linked by a glazed connecting bridge at the far end. These are quite narrow-plan buildings, enabling a cross ventilation strategy to be adopted.

The main part of the building is the four storey central portion, which is divided by a full height concourse. The main entrance is between the two engineering laboratories, the concourse acting as the main circulation route with steel stairways linking all floors.

With the concourse essentially a long thin lightwell, winding between complicated structures like the two auditoria, the architects took a great deal of time determining daylight patterns. The result is a continually changing arena of light and shade, with daylight bouncing off reflective surfaces to strike deep into the building.

On the elevation facing Mill Lane, two 70-seat classrooms occupy the ground floor directly beneath two 150-seat auditoria. At third floor level the concourse opens out onto the open-plan drawing studio, with its copious amounts of daylight from glazed ventilators in the roof gables.

South east of the concourse a double-height, full-length m&e laboratory occupies the first and second floors with staff accommodation on the third floor. Classrooms on the first three floors occupy three short wings on the SE elevation.

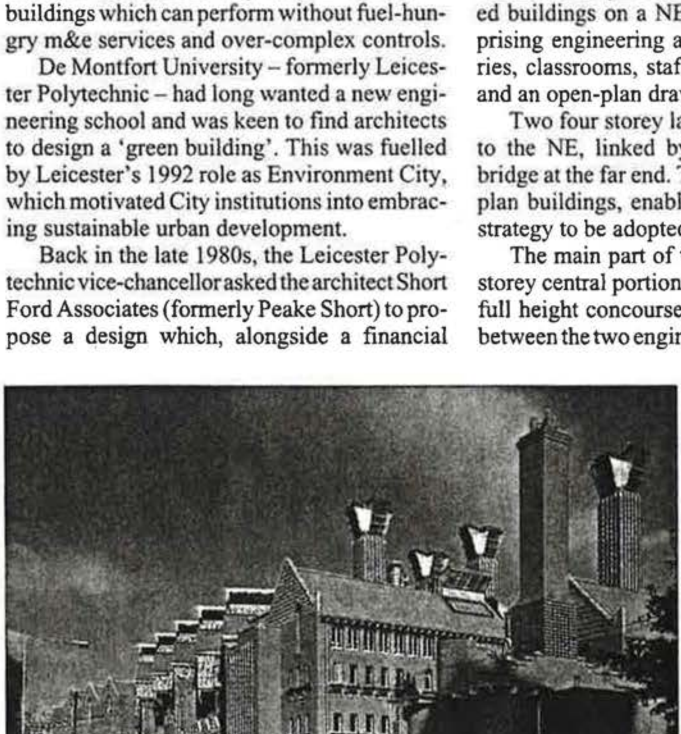
The remaining building – the mechanical engineering laboratory – is essentially a huge single-height machine hall that is fitted out with various pieces of automotive engineering test equipment.

Generally speaking the U values are better than those stated in the *Building Regulations*, with 100 mm Rockwall infill in place of the usual 50 mm. As the west elevation of the engineering hall faces dwellings, triple glazing offers good acoustical protection, but all other elevations are fitted with standard double-glazed windows.

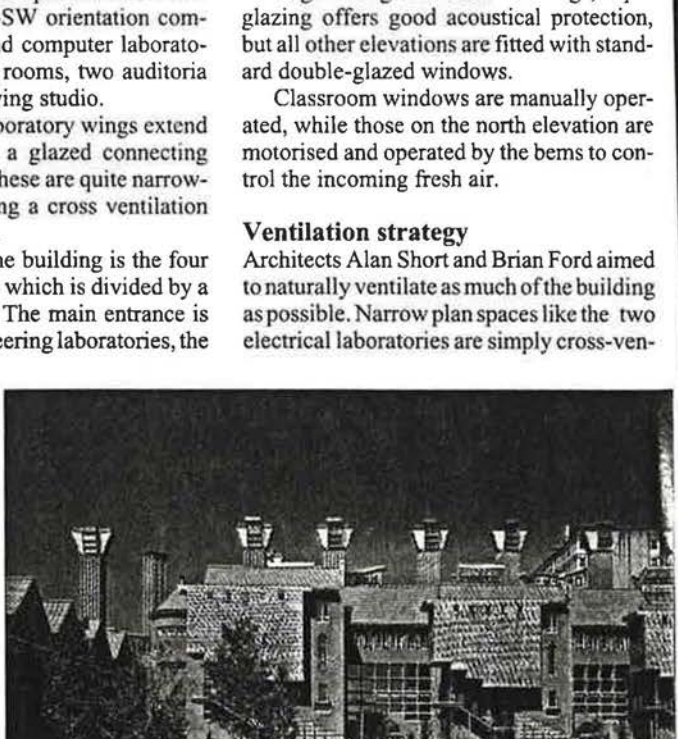
Classroom windows are manually operated, while those on the north elevation are motorised and operated by the bems to control the incoming fresh air.

Ventilation strategy

Architects Alan Short and Brian Ford aimed to naturally ventilate as much of the building as possible. Narrow plan spaces like the two electrical laboratories are simply cross-ven-



The NW elevation facing Mill Lane. Note the natural ventilation stacks and glazed ventilators in the roof gables.



The SE elevation. On the left is the large mechanical engineering hall, with the classroom wings in the centre. Note the extensive glazing.

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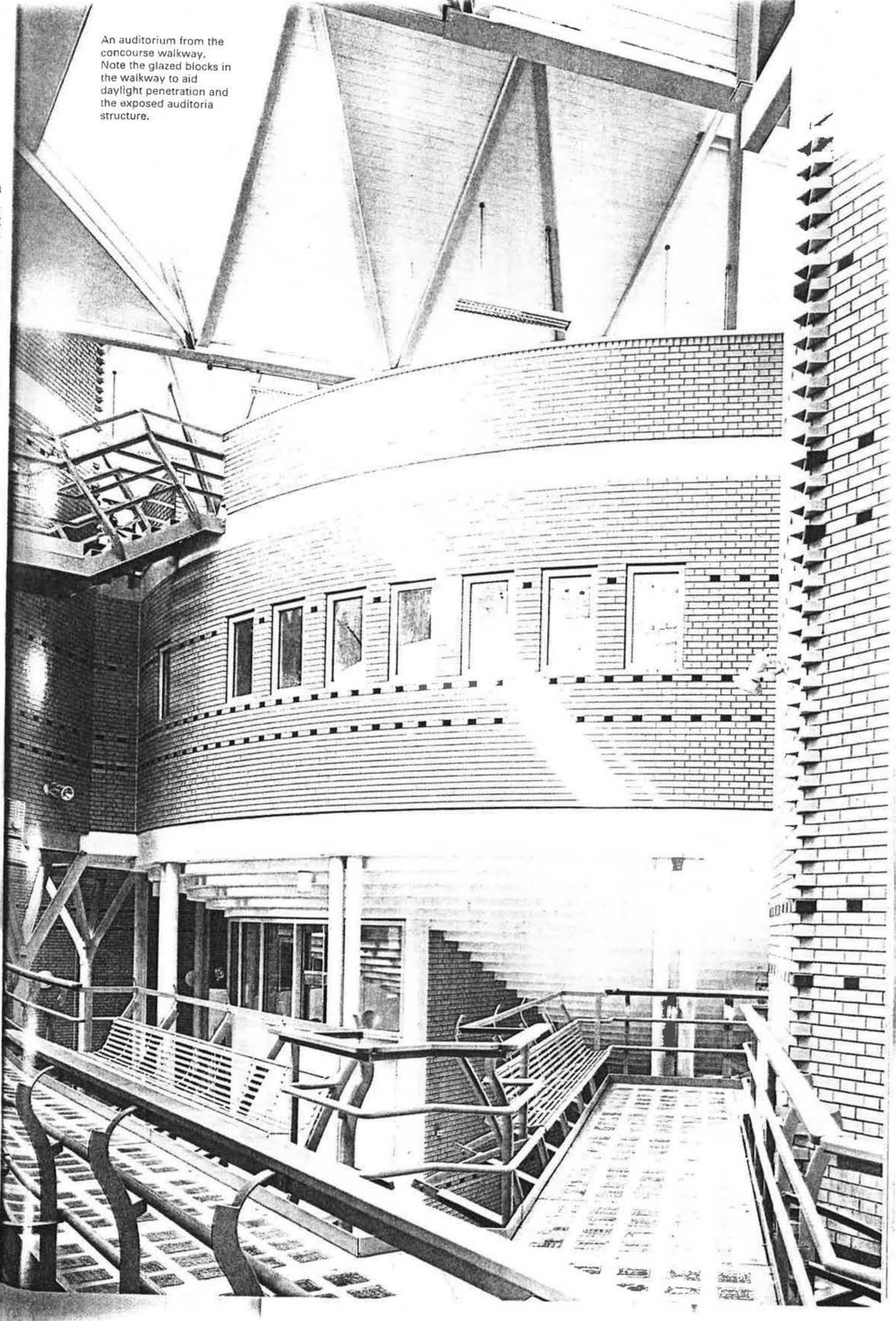


An auditorium from the concourse walkway. Note the glazed blocks in the walkway to aid daylight penetration and the exposed auditoria structure.

tilated, deeper zones being ventilated by low level air inlets with conventional motorised dampers scheduled to similar dampers in the extract stacks.

In the case of the narrow plan laboratories, more than 50% of the lightweight courtyard elevation can be opened to convect away internal heat gains.

Much effort was made with the deep plan zones to get daylight as deep into the building as possible, and to make the most of the thermal mass available for heat transfer. Hence most of the internal brickwork is exposed, as are the stepped soffits of the auditoria. There are no false ceilings in this building.

The large mechanical laboratory is naturally ventilated, incoming air entering on the west elevation via a builders' work duct and a 500 mm vertical gap between two offices, and via latticed brick buttresses on the east elevation. The 90-110 db engine test cells at the north end of the hall are mechanically ventilated, largely because to naturally ventilate them would have caused noise problems for adjacent housing.

Noise attentuation was a major issue for the engineering hall. On the west elevation noise breakout is limited by the placing of all ancillary offices along the west wall, which means the ventilation air has to traverse the space above the false ceilings. On the east elevation the buttresses are lined with acoustic quilt. The ridge ventilators also only face north and south, whereas elsewhere on the site they open on all four sides.

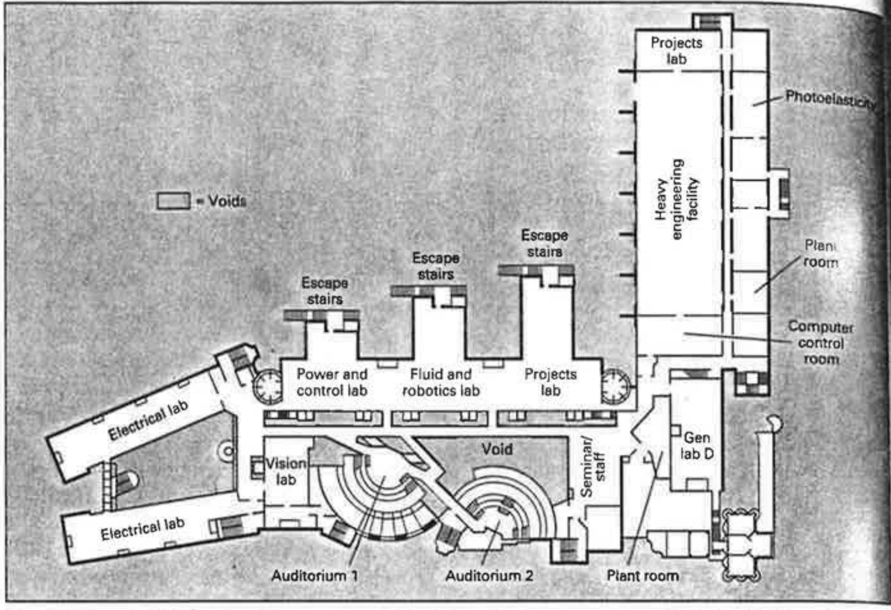
The central portion of the building is complicated in terms of its ventilation paths. Its depth precluded a cross-ventilation strategy, which led to the adoption of stack-effect chimneys to extract air from the laboratories, concourse and auditoria.

A row of chimneys exhausts air from the two auditoria, the concourse and the double-height engineering laboratory. The drawing studio is fed with air from the concourse which exits via gable vents, as does air from the third floor staff accommodation.

So how well will this strategy work? Max Fordham Associates and De Montfort University undertook studies using the ESP simulation model to see how well natural displacement ventilation would work, design calculations being based on an internal mean of 19°C, a minimum of 13°C and a peak of 25°C.

The research showed that a heavyweight fabric – coupled with night-time cooling in summer – would create an internal temperature no more than two or three degrees higher than external ambient in almost all cases.

Although a sustained heatwave could result in a gradual rise in fabric temperature, and thus reduce the potential for night-time purging, Max Fordham Associates believes it is highly unlikely that internal temperatures will ever climb higher than 28°C. The simulation predicted a significant number of hours over 25°C, but this was deemed acceptable for a naturally ventilated building which will have a low population in summer.



The first floor building plan. The narrow section laboratories are cross-ventilated, while the diamond shaped void adjacent to the left auditorium shows the position of the ventilation chimneys.

Ventilating the auditoria

The two auditoria are perhaps the most critical spaces in terms of ventilation effectiveness, and originally it was thought they would have to be mechanically ventilated.

In each auditorium air is supplied in a plenum under the raked seats and exhausted through two natural ventilation chimneys.

A key element for maintaining an acceptable thermal profile and good air quality was the size and position of the chimney extract. The opening had to be sized so that the boundary of the 1 m thick layer of hot polluted air was below the top lip of the extract opening, but above head height of the top row of seats.

Although small eddy currents might be expected to occur as the hot air cools in contact with the ceiling and walls of the auditorium, they should not be enough, say the designers, to invade the occupied zone.

The height and insulation factor of the chimneys was also important in as much as the top 5 m of chimney would be cooled by contact with the outside air, and thus cool the extract to the point where backflow might be a problem. To check this, the researchers at De Montfort University tested what would happen if the temperature of the entire 13·3 m chimney was at external ambient, and even then backward flow was not demonstrated.

The other major worry was whether or not a column of air in the chimney on a cold, damp, still winter morning would present too much inertia for the stack effect to work.

This is still a moot point, and the architects accept the possibility that mechanical assistance might prove necessary. As it is, the engineers wisely installed a punkah fan in one chimney in each auditorium to help air movement for the days when external wind speed will fall below 1·5 m/s at temperatures above 20°C. As Max Fordham's project engineer Edith Blennerhassett explained: "There was a lot of pressure not to have fans because no-one really wanted them in, but we felt that a fan costing £50 was reasonable for the three days of the year it might be needed."

The architects considered methods by which the chimneys could be heated by the sun to aid air movement, but the largest hole that could be made without adversely affecting their structural rigidity was around 500 mm – really not worthwhile. Conversely, the low level stacks serving the concourse and drawing studio are fully glazed.

One of the difficulties with this type of building is the paucity of natural ventilation products on the market. As bespoke solutions are expensive, the designers relied on adapting proprietary products where they could. Finding a natural ventilation damper that would seal under low pressure differences was a problem, the answer being to fit rubber seals to the lip of a standard product.

Lighting

As the building relies heavily on natural daylight, studies were undertaken to establish the effectiveness of the design.

A 1:50 scale model of the building was put in the artificial sky at De Montfort University, while illuminance and daylight factors were determined by running the design through the Radiance daylight simulation model.

The results of this work were encouraging despite significant differences in calculating daylight factors for the core areas, partly created by limitations in the scale model which prohibited detailed mapping of the spatial distribution of light. For example, the depths of the window reveal depended on the thickness of the modelling material which didn't match those used in practice.

Much attention was paid to the structural detailing to enable daylight to strike deep into the building. For example, the windows have very thin brick mullions backed up by slender steel sections, and the floors are cut back in

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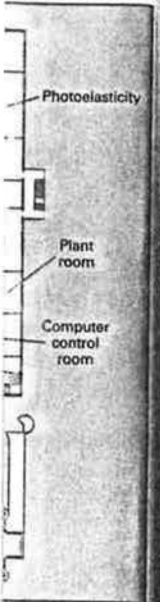

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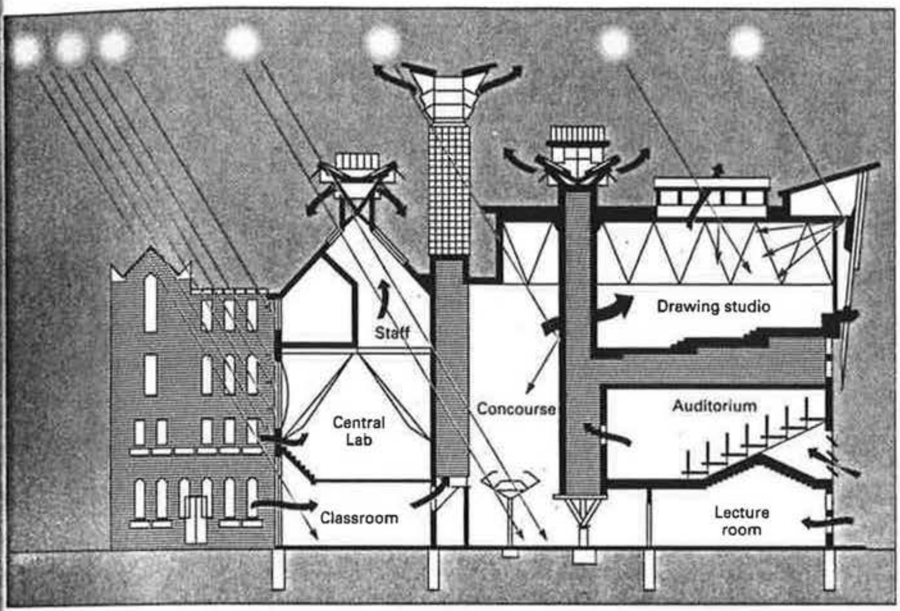

The principles of the natural ventilation strategy. With so much mass and so little solar gain the building should work well, although extract fans may be needed in the two auditoria.

Detail of the amazing roofscape with the natural ventilation chimneys. The louvres conceal motorised dampers controlled by the bems.

places to let light penetrate deep into the space.

Some lancet windows in the ground floor classrooms actually impinge on the ceiling slab in such a way that the pre-cast T-beam soffit in the electrical laboratory is punctured by stepped plinths. Not out of place here, but enough to inflict a heart attack on a letting agent obsessed with net to gross ratios.

Control of daylight was most crucial in the computer and electrical laboratories. Here, the perimeter workstations are protected by light shelves which serve to cut out direct sunlight while cocooning the academic computer users who, apparently, prefer to work on computers like troglodytes. The shelves also serve to redistribute daylight across the room by a small factor of 2%.

Artificial lighting relies on low energy lamps where possible, although there is a high concentration of fluorescent fittings and SON lamps in the engineering hall.

Fire safety issues

It is fair to say that the fire officer wasn't quite sure how the building would meet fire regulations. With smoke ventilation relying purely on convection currents and no active protection beyond standard smoke detection and addressable fire alarms, ease of access to a great many escape routes was very important.

A major issue was the drawing studio, ventilated via the concourse area and thus in danger of being invaded by smoke.

Three escape stairs on the north elevation serve the studios in addition to those available to the south, and with the motorised roof vents designed to open in a fire condition, the risk to life was considered small. The concourse itself is not a nominated fire escape route.

Will the building work?

The difficulty with analysing this building is that little of it conforms to established methods of m&e servicing, and so much of it is innovative that accurate analysis will have to wait until De Montfort University and the BRE publish results from their very extensive monitoring programme.

It is incontrovertibly a stunning building, and deserving of praise for setting a new vocabulary for naturally ventilated buildings. But what is vital – not just for the design team but for all professionals interested in natural ventilation – is that the building is proven to work. With so much intellectual input having been underwritten by powerful simulation tools, it has a very good chance of doing so. Its performance in practice, warts and all, should be awaited eagerly.

One question has been answered:\ how do services consultants get paid for this type of job? With so few m&e services installed, Max Fordham's fee was negotiated as a fixed sum based on the services cost, plus a sum to cover their input into the form and construction of the building. The way of the future?

Consultant's view

The School of Engineering and Manufacture is designed to be a low energy building, relying on high efficiency plant and controls. However, the primary strategy has been to engineer out the need for energy consuming services, particularly air conditioning and mechanical ventilation, *writes Bart Stevens.*

Instead, the central area of the building has been specifically designed to induce natural ventilation through openable windows and ventilation openings, with extract through chimneys which induce a draught, thus cooling the adjacent rooms.

This process is aided by the building's heavyweight construction, and the maximum possible exposure of the structural mass so that swings in internal temperature can be smoothed out. While this is fine in principle, the absence of mechanical cooling plant means there is no spare capacity that can be called upon or turned up. For the building to work correctly the control system must be relatively complex so that the optimum performance can be extracted from the natural ventilation.

The most appropriate control system is that of a computerised building management system, suitably complex in its functionality while also being flexible in terms of programming.

At De Montfort, we chose a BES system which can monitor and control around 900 points. One of its best features is that its control algorithms are written in plain English and can be easily altered by the user. This means that it is possible to continually fine-tune the controls; this is particularly important bearing in mind the radical design of the building for which there is little previous experience to fall back on. Moreover, the bems is also linked to Max Fordham Associates' office by a modem, so that monitoring and tuning of the controls can be undertaken .

The building will be monitored in detail for the first year of operation, initially to complete the commissioning of the controls, but later to assist in the fine tuning and to gain a greater insight into the operational principles of naturally ventilated buildings.

It will be useful that the building will be used as a teaching aid for the University's engineering students and, for this reason, a number of additional sensors were included. These enable temperatures within the structure, water and gas flow rates, internal and external lighting levels, electricity use and the power factor to be measured. In due course these will provide an extremely useful and also rare insight into the dynamic functioning of the building.

The building will be used at a wide variety of times throughout the day and during the year and it was therefore divided into ten zones to allow the maximum control over the space heating. If necessary, the building can be further sub-divided via the software routines, as the motorised valves are already in place.