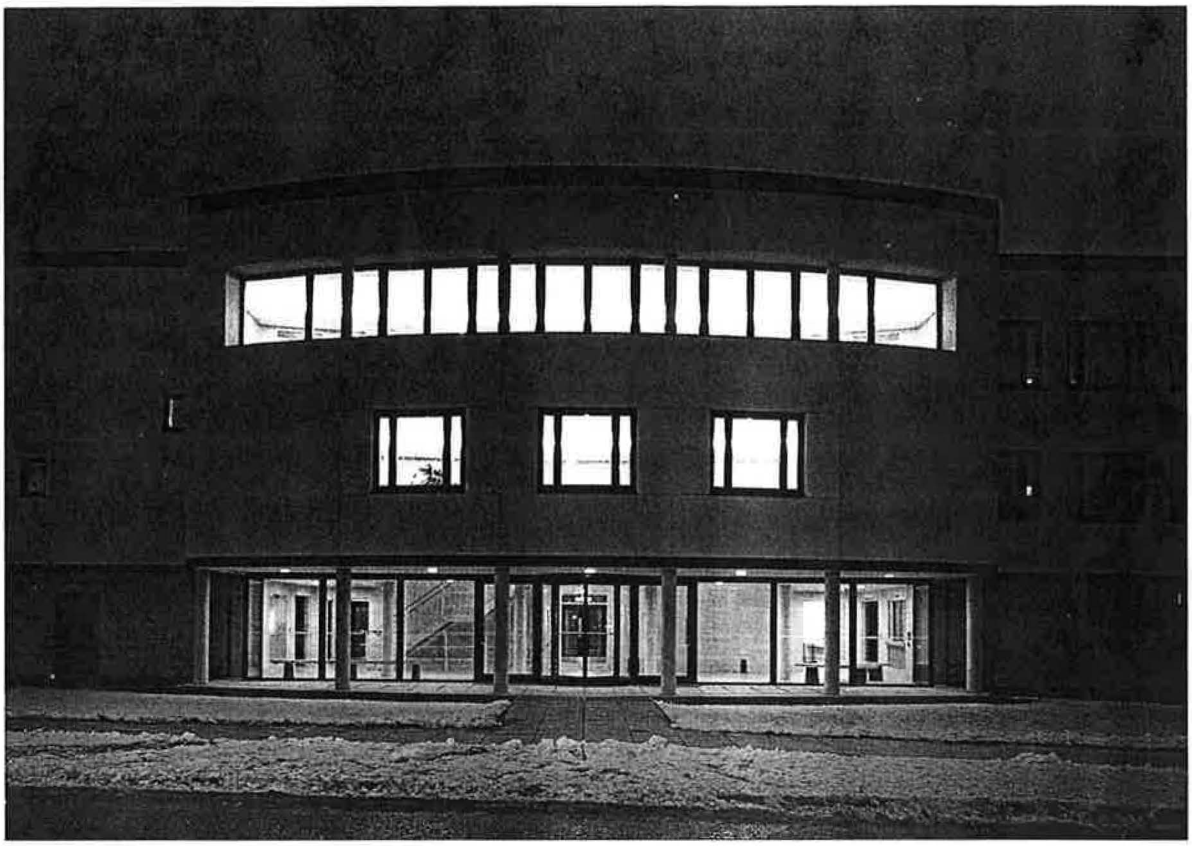


Teaching low energy

The UK's second building installed with the Termodeck passive cooling system has just been completed at the University of East Anglia. Roderic Bunn explains how this Swedish idea is helping clients achieve very low running costs.

The pressing need to reduce carbon dioxide emissions is at least having one benefit – helping the sales message of low energy architecture. Although it has taken the rather extreme prospect of a shrinking Arctic circle to focus attention, at least clients are beginning to realise there is more to a building than its initial cost.

None are more keen on energy-saving architecture than the University of East Anglia (UEA). For its latest academic building, the UEA has enthusiastically imported Scandinavian construction principles lock, stock and Smörgåsbord.

The four-storey Elizabeth Fry Building completes the University's development of teaching and student accommodation. Tucked away at the western end of the UEA campus, it lies cheek by jowl with other low energy buildings, notably the award winning student residences by architects Rick Mather Associates and the School of Occupational and Physiotherapy by John Miller & Partners, which gained the RIBA National Award in 1994.

Following the success of the latter building, the UEA appointed the same architect, John Miller & Partners, and the same services engineer, the Fulcrum Engineering Partnership, to design the Elizabeth Fry Building. The brief was for a 3250 m² facility incorporating offices, seminar rooms and 130-person lecture theatres, nominally to serve the School of Social Work but also to provide an overspill facility for other University departments.

The rectangular building is essentially split-level, with the site sloping from north to south by the extent of one storey. The curved main entrance is off-centre, forming a small atrium containing the main circulation stairs.

In terms of layout, the lecture theatres are located on the lowest level, along with the boiler room and four air handling plant rooms.

The upper ground floor level is devoted to seminar and lecture rooms together with a general arrivals area. Two dining facilities have also been provided together with a kitchen. The upper two floors house offices for the School of Social Work, along with tutorial and seminar rooms (bookable by any university department) administration rooms, a common room and post-graduate accommodation.

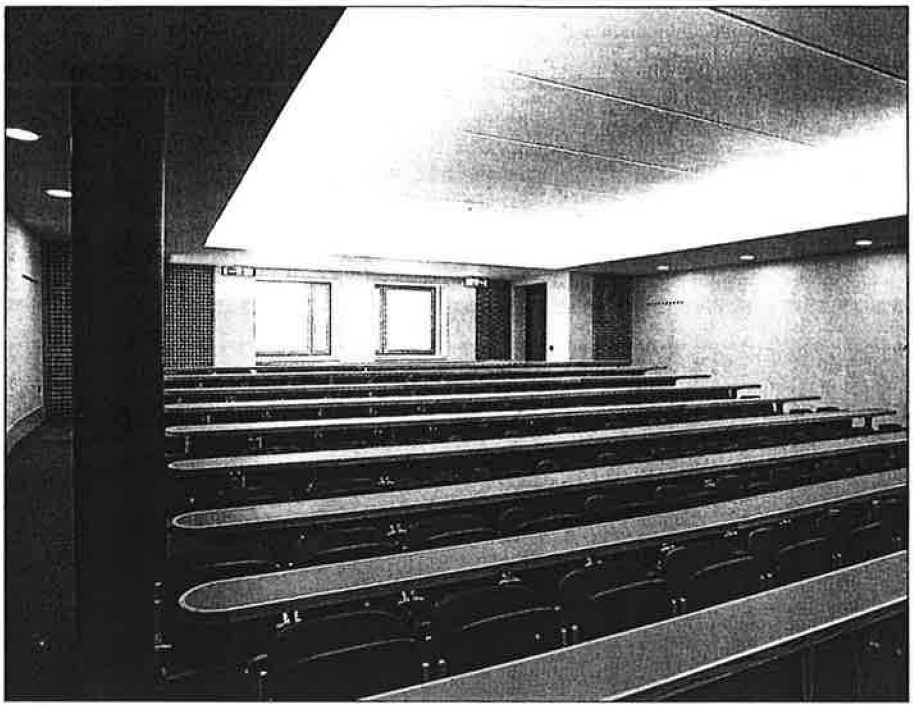
The designers target was to better the energy performance of the BRE low energy building. Inevitably this meant avoiding mechanical refrigeration, a decision which immediately forced reliance on the building's thermal mass to maintain internal comfort conditions, and the use of very high levels of insulation to reduce fabric heat loss.

Scandinavia is the place to turn to for ideas. In Sweden particularly, a combination of severe winter temperatures and a lack of fossil fuels has placed strong emphasis on high insulation and low infiltration regularly results in buildings with wall values of 0·15 W/m²K and infiltration rates below one air change per hour (ac/h).

The designers started out with an *in situ* reinforced concrete frame. To achieve wall U-values of 0·2 W/m²K, the architect opted for 200 mm of Rockwool and a heavyweight concrete inner leaf. Low emissivity-coated triple-glazed (2+1) windows and roof lights were imported from Sweden by virtue of their mid-pane U-value of 1·3 W/m²K.

The design team appointed an energy consultant, David Olivier, to advise on insulation and airtightness. Indeed, with specific attention to edge details (particularly sealing around window frames) and by using high quality dampers in the ventilation extract, the building has achieved a remarkable level of airtightness.

In David Olivier's estimation the Elizabeth Fry Building is probably the most airtight in the



One of the 130-seat lecture rooms. 100% fresh air is supplied through displacement terminals at the rear of the room and extracted at high level at the front.

UK. Tests by the BSRIA on the completed building demonstrated 0·02 ac/h at 50 Pa – and amazingly that was achieved while work was still being carried out.

The floors are constructed of interconnecting, precast concrete hollowcore slabs. These slabs perform more than a structural function, being the primary route for supply air into the building. This technique – Termodeck – has been used in Sweden since the late 1970's as a way of optimising the contribution of the building structure to control internal temperature. In the UK, the first Termodeck building is already demonstrating good energy performance (see box opposite).

Of course, Termodeck can't do it all. Being a mechanical ventilation system, energy efficiency depends on keeping down fan power and maintaining high levels of heat recovery.

Swedish-designed Regenair air handling units (ahus) were installed, incorporating heat recuperators capable of efficiencies in excess of 85%. These units are equipped with dampers which modulate every 15 seconds or so to switch the extract and supply streams back and forth between two heat accumulators.

The ahus are configured to run during preset occupation times, the actual run-time dependent on sensors strategically located in the building. Temperature sensors have been placed on the supply and extract ducts for each ahu, in the hollowcores and in the rooms. A single external sensor on the north face of the building provides the external benchmark.

A central ventilation control panel in each plantroom operates each ahu according to the temperature sensors, while the air quality sensors are dedicated to a particular ahu.

To keep a lid on fan power consumption, Fulcrum's Andrew Ford wisely opted for 3-speed fan controls for the two ahus serving the offices and seminar rooms, while the two ahus serving the lecture rooms are equipped with modulating dampers and variable speed drives scheduled off CO_2 detection.

While on the subject of the 130-seat lecture rooms, the ventilation system differs from the normal Termodeck practice simply because of the sheer volume of air required – the building will have continuously high levels of occupation and the lecture rooms will be occupied six days per week.

As the Termodeck can't be expected to handle the maximum design air volume, only a percentage of supply air passes through the Termodeck. The rest is supplied direct to an underfloor plenum where it is mixed with the Termodeck air prior to being supplied via displacement grilles at the rear of each lecture room. The extract air is removed at high level at the front of the rooms. Since waste heat is not always needed, the extract can operate on full bypass.

Elsewhere the ventilation system follows normal Termodeck practice. The 100% fresh air supply is pulled through an open builders' duct at the front of the building from where it is ducted to the other three ahus. A supply duct installed above the spine corridor on each floor enables tempered supply air to be injected into the Termodeck slabs on the north and south sides of the building (figure 1). The air then traverses up to three hollowcores, the length of run depending on the calculated room load. Air then enters

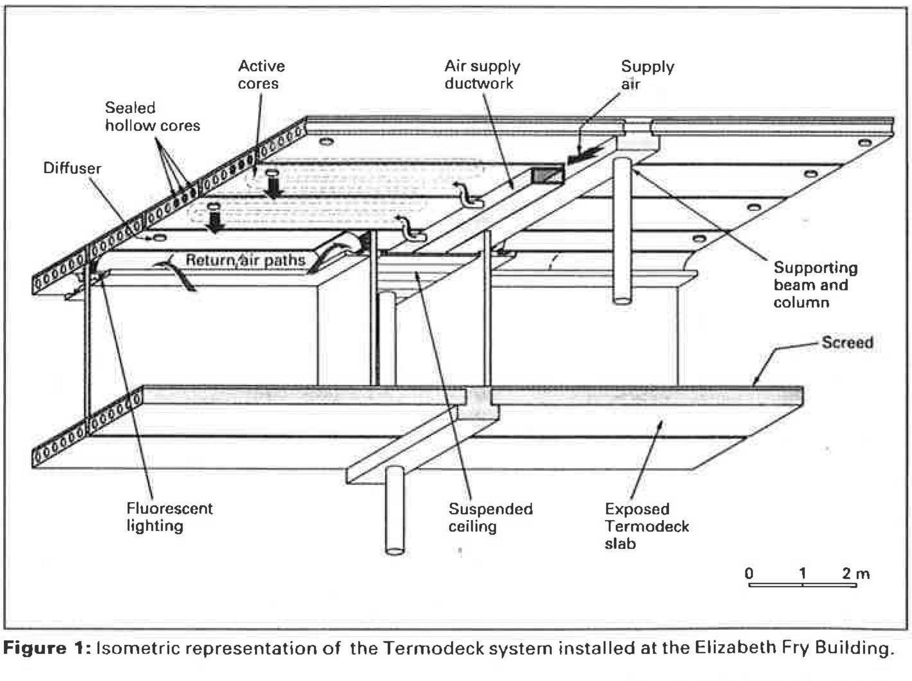
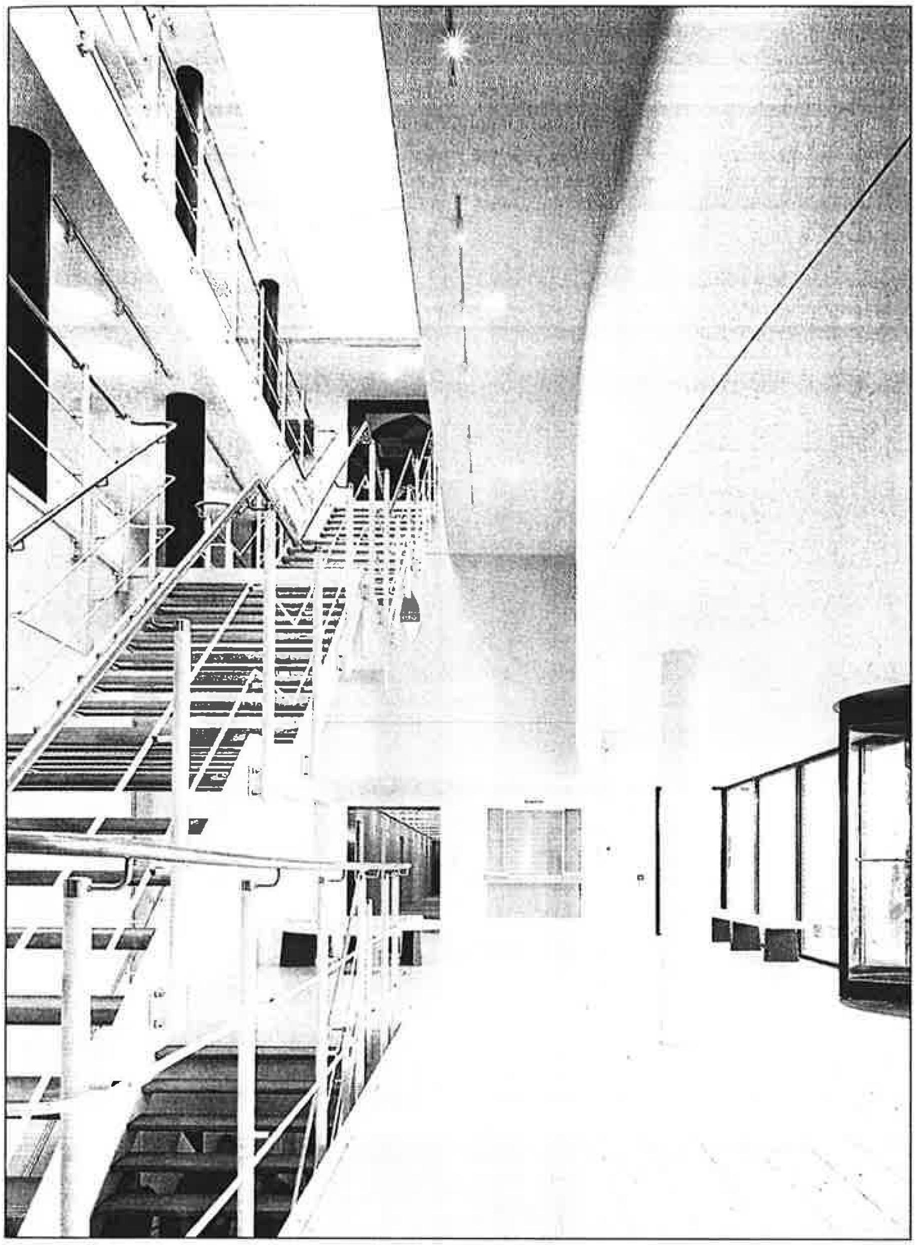


Figure 1: Isometric representation of the Termodeck system installed at the Elizabeth Fry Building.



The main entrance on the north elevation is effectively a narrow-plan atrium which contains the main circulation stairs to the building's four floors. The lecture rooms can be entered from the south side.

Feedback from Termodeck in use

Operational experience of Termodeck buildings in Sweden shows an energy consumption for heat and ventilation of between 30-50 kWh/m²/y, compared to over 200 kWh/m²/y for typical existing UK offices, *writes Robert Winwood.*

The first building to be equipped with Termodeck in the UK is following this trend. E A Technology and UMIST have been monitoring Weidmuller Klippon Microsystems' UK headquarters at West Malling in Kent during the building's initial six months of occupation. Data collected so far reveals that the building is extraordinarily resilient to variations in occupancy levels, control strategy and ambient air temperature.

In the coldest winter week, 1 January to the 7 January, the average ambient temperature was 0·8°C, ±2·2°C. As this coincided with the New Year bank holiday and followed the Christmas break, a combination of minimum ambient temperature and minimum levels of occupancy would be expected to give fabric storage buildings their severest test. However, the Weidmuller building came through with flying colours, maintaining an average space temperature of 20·9°C, ±0·7°C while using only night-time heating.

Monitoring has so far proved that Termodeck, when properly applied, can be a very effective system for winter operation – not surprising given its Swedish origins. We must now wait and see if it will perform equally well during summer.

Robert Winwood is a research associate at E A Technology.

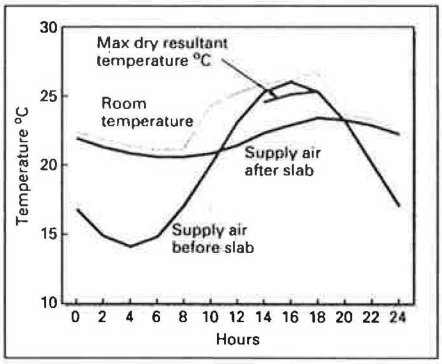


Figure 2: Computer simulation of the performance of a south-facing seminar room in July with air supply at 630 m³/h, lighting at 300 W and 1750 W of occupancy gains.

each room via a simple diffuser and extracted via a ceiling architrave. This not only hides the extract plenum but also the high frequency fluorescent uplighting. Any heat generated by the lighting and computer equipment is imparted to the extract air and recovered by the heat recuperators.

The control strategy for the first floor was complicated by higher occupancy loads that will occur in the large seminar rooms on the south side. The answer was to have separate supply ducts for the north and south sides. As it is possible that only one side will have a cooling or heating demand, each supply duct can be closed automatically and the supply and extract fan speeds reduced accordingly.

Fresh air supply air rates vary between 20-38 litres/s for north-facing offices, while the larger seminar rooms on the south elevation are run at 40 litres/s. Dampers in the stub-ducts control the air supply volumes.

Seasonal operation

During winter nights the ahus are scheduled to put heat into the hollowcores when room temperature falls below 18°C, a value measured in two sample rooms allocated to each ahu. At night the system will work on 100% recirculation, with the heater batteries raising the supply air to 35°C. The system throttles back when the sample rooms reach 20°C.

In summer, the ahus work to provide night-time cooling of the structure, enabling it to be used as a heat sink the following day. The fans are scheduled to come on at 22.00 h when:

☐ external air temperature has exceeded 15°C during occupied hours that day;
☐ either of the sample rooms for a particular ahu has exceeded a set temperature of 23°C;
☐ outside ambient is more than 3°C below room temperature and not less than 8°C.

Even the general meeting and common rooms are well detailed. The windows are Swedhouse units with a mid-pane U-value of 1·3 W/m^{2}K. This is the room above the main entrance, where the ceiling architrave mimics the curved north-facing wall. Nice room, pity about the wall colour.

The fans will also throttle back to a background ventilation if any of the sensors in the hollowcore or the sample rooms fall below 21°C, or if outside air temperature falls 2°C below room temperature or below 7°C.

With such high levels of insulation, 85% heat recovery and low levels of infiltration, the building's total heat loss is very low, approximately 45 kW. This performance has meant that the heat demands of the 3250 m^2 four storey building can be met by three 24 kW domestic gas condensing boilers – and even then the system is technically oversized by one boiler. At £1000 a unit, it can hardly be considered a crime. The designers considered installing electric panel radiators in each room, but with negligible window losses they simply couldn't be justified, so there is no background heating whatsoever.

Specific attention was paid to getting the lighting load down to the lowest possible levels. In the offices and seminar rooms the lighting is predominantly high frequency fluorescent located in perimeter reflectors designed to provide even illumination with low power consumption. All the lamps are individually controlled by switches placed by the doors. In the lecture theatres dimming is available from controls mounted on the lecterns.

Calculating the storage potential

Computer modelling carried out by Termodeck's inventor, Loa Anderson, showed that even with an external temperature of 29°C, peak internal temperatures should not rise above 26°C, with the daily average room temperature being around 22°C (figure 2).

But just how reliable are these predictions? Without specific and reliable weather data, it is very difficult to model the response of thermal mass to sustained periods of hot weather. But it is reasonable to assume that, depending on the building and the loads to which it is subjected, the thermal flywheel may last several days. The statistical likelihood is that the weather will break long before the ΔT reduces to the point where the temperature of the mass matches the external ambient.

Furthermore, recent computer simulations of Termodeck reveal that heat transfer between the slab and the supply air is significant at the point of greatest air turbulence, which is the 180° junction between two hollowcores. On that basis it is reasonable to assume that Termodeck has a considerable reserve of cooling capacity.

There is also the radiant cooling effect of the exposed slabs to consider. While the radiant component was not modelled directly, calculations of environmental temperature showed that the mass would be a major factor in maintaining comfort conditions. In any case the Elizabeth Fry Building is equipped with openable windows, and the narrow plan of the building easily allows single-sided ventilation.

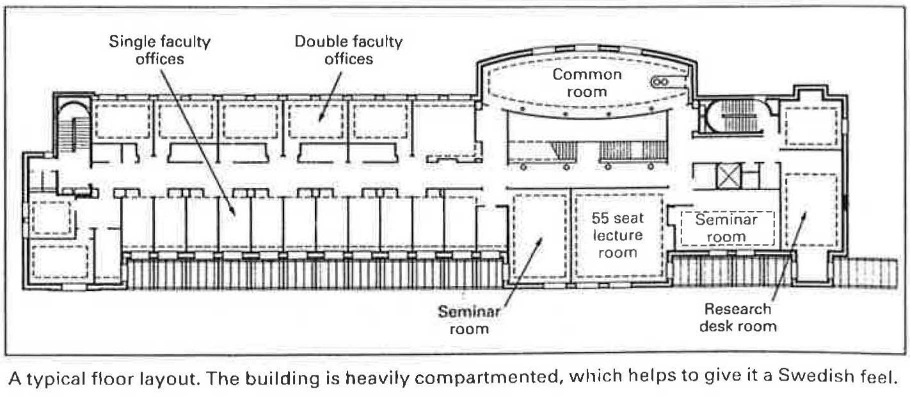
Although the building has an east-west axis, the architects avoided the use of external solar shading largely by choosing windows with an internal blind. By virtue of a covered walkway that doubles as a brise soleil, these blinds were omitted from the ground floor windows. Manually controlled Venetian blinds are provided within the triple glazing units in the lecture theatres and offices on the southern elevation. Those in the main foyer are automatically controlled to prevent overheating.

Overall impressions

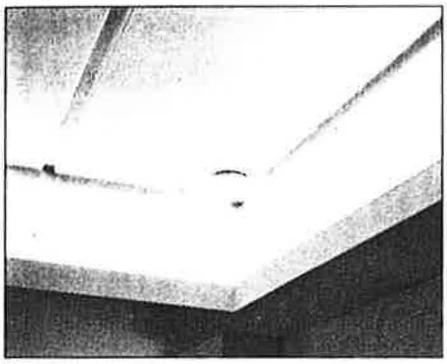
The Elizabeth Fry Building is as Scandinavian as Canary Wharf is North American. Whereas the latter style of architecture has become accepted as UK vernacular, the former is still a novelty, despite its virtues in meeting growing demands for low capital and running costs.

Academic accommodation by its very nature tends to be stripped of unnecessary frippery, and the Elizabeth Fry Building is no different in this respect. But its exposed internal structure, low energy lighting, high quality triple glazed windows, etc give a Swedish air of comfortable austerity.

It is a delightful building. Leaving aside its low energy virtues, the detailing is exceptionally high, particularly the stylish ceiling architrave that doubles as a location for the uplighters and



A typical floor layout. The building is heavily compartmented, which helps to give it a Swedish feel.



Most of the ceiling diffusers are ideally placed. For structural reasons, some are not.

a way of hiding the extract plenum. Then there is the light and airy atrium with beautifully elegant balustrading, and the simplicity of the recessed uplighters in the circulation areas – nothing more complicated than a bit of bent metal, but really well made.

Inevitably one or two things jar, particularly the awkward siting of some supply diffusers, forced by the beam which runs east-west through the building beam and the positioning of its structural reinforcement.

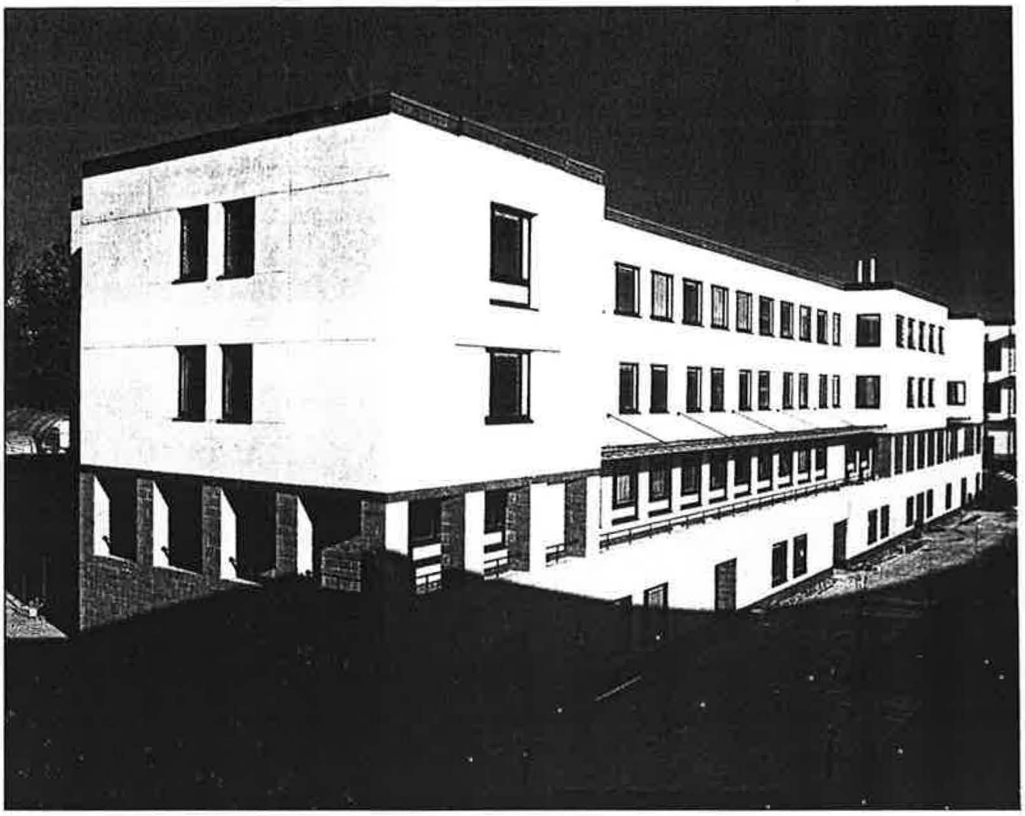
The structural engineers also insisted on columnar support. On the first floor, where the long seminar rooms force the spine corridor off-centre, these columns have ended up just inside the rooms and it looks a bit clumsy.

This off-centering also caused a problem where the Termodeck slabs on the north elevation stop short of the supply ducts, which have to run in the corridor ceiling space. So for the supply air to get to the slabs serving the south side, the supply stub-ducts are connected to the Termodeck slabs serving the north-facing rooms, the connecting cores linked through the upper portion of the beam which was constructed in two phases.

Similarly the extract from the south side also uses a short run of north side Termodeck before entering the extract plenum – a neat solution to a difficult problem.

Bearing in mind the performance of the Weidmuller Klippon building the energy targets look achievable, particularly as the fans are under speed control. The building's energy performance will be monitored by the BRE and Eastern Electricity, and *Building Services* will report the findings in due course.

In the meantime the services design for the next Termodeck building – a new learning resource centre at De Montfort University – is being carried out by consultants atelier 10.



The Elizabeth Fry Building is a descendent of the adjacent student residences which have large windows. Some windows on the new building's south side have semi-translucent sections to reduce solar gain.

Elizabeth Fry Building, University of East Anglia, Norwich, Norfolk

Client
University of East Anglia
Deputy buildings officer
Peter Yorke
Architect
John Miller & Partners
M&E consulting engineer
Fulcrum Engineering Partnership
Energy consultant
David Olivier of Energy Advisory Associates
Structural engineer
F J Samuely & Partners
Termodeck units
Hollowcore Systems
Quantity surveyor
Stockings & Clarke
Main contractor
Willmott Dixon Eastern
M&E contractor
Matthew Hall

Main suppliers
Boilers: Stelrad
Pumps: Grundfos
AHUs: Regenair
Motor control centres: Tour & Andersson
Kitchen hood: Spantile
Displacement units: Ventilation Jones
Grilles and diffusers: Halton, Waterloo
Main intake and lv switchgear: Dorman Smith
Spotlights: Concord
Recessed downlighters: Reggiani
Dampers: Halton
Gas water heaters: Stebel Eltron
Lighting controls: Powertron
Condensing gas water-heater: Chaudagaz
Variable speed drives: Alldrives
Windows: Swedhouse
Hydraulic lifts: Otis
Fire alarm system: Chubb

Loads
Calculated building heating requirement (ΔT 22°C): 15 W/m^2
Installed heating capacity: 22·5 W/m^2
Boiler capacity: 3 @ 24 kW
Installed fan power: 1·96 W/litre/s (5·3 W/m^2) maximum

Energy targets
Heating, hws, ventilation: 26 kWh/m^2/y
Small power: 8 kWh/m^2/y
Lighting: 16 kWh/m^2/y

Structural details
Termodeck slab thickness: 250 mm
Screed: 100 mm
Floor-to-ceiling: 2840 mm
Corridor ceiling zone: 440 mm

Comfort conditions
Scheduled supply air temp: 23°C
Room temp: 28·5°C Max
Winter night-time charge: 35°C
Recirculation: None (100% fresh air)
Building air tightness: 0·97 ac/h @ 50 pa

Ventilation
Primary air: 4 ahus at 8·7 m^3 max

U-values (W/m^{2}K)
Walls: 0·2
Floor: 0·16
Roof: 0·13
Glazing: 1·3 (with frame)

Distribution circuits
Constant temp: 60-50°C
Exhaust recovery
60% from lecture theatres
85% (average) from Regenair ahus

Electrical supply
3-phase 415 V supply

Lighting
Installed lighting: 12·2 W/m^2
Preset lighting load: 10 W/m^2 (75% in non-circulation spaces)
Lighting levels: 300-400 lux
Efficiency: 3 W/m^2/100 lux

Lifts
1 x 8 person @ 0·6 m/sec

Costs
Total gross area: 3250 m^2
Total cost: £820/m^2 (incl. fittings)
Mechanical services: £76/m^2
Electrical services: £69/m^2
Lifts: £12/m^2
Total m&e cost: £157/m^2 (19% of total)
Glazing: £39/m^2 (£200/m^2 window area)