REFLECTIONS ON MIXED MODE

The first Lincolnshire University building not only needed to be a landmark, but also highly functional, energy efficient and flexible for change of use. The solution: a mix of passive design, mixed mode services, full air conditioning and a covered street. How does it all stack up?

BY JOHN FIELD

Given the task of creating the University of Lincolnshire and Humberside's first building on a completely new site, multi-professional designer RMJM determined that it should be a model of energy efficiency. It should also be the focal point for the University's 1500 students, with inherent flexibility for future change of use.

Site constraints placed the 10 500 m² building on an east-west axis. A central east-west street atrium divides the building into north and south zones which are further subdivided into east, central and west zones. The southern elevation is sealed to protect it from noise from an adjacent railway line, but much of the building is naturally ventilated. The north elevation faces a large canal boating basin and has a fine view of Lincoln city centre.

The building comprises four storeys, save for the centre north section which is a full height, three-storey open area above restaurant and circulation zones.

Passive design principles are employed to minimise basic heating and cooling loads. The building has high insulation levels and exposed thermal mass. The south facade glazing incorporates mid-pane, permanently fixed angle venetian blinds designed to eliminate direct solar gain while providing some vision.

External motorised roller blinds are provided for the east and west facades where low sun angles make permanent horizontal or vertical shading ineffective. The north-facing glazing for the central circulation/restaurant area and administrative offices is clear and unshaded, providing an attractive view of the boating basin and city. The teaching rooms to the south are air conditioned, with displacement ventilation and cooling via chilled beams.

The north elevation up to the second floor has openable windows for natural ventilation of the north-facing administrative offices. The Learning Resource Centre on the top floor is air conditioned using fan coils.

Conditioning of the supply air is achieved by desiccant cooling systems in the roof-mounted air handling units. Commissioned in September 1996, this is understood to have been the first large desiccant system operating in the UK.

The briefing and design process was complicated by a change in the client's organisation which had wide repercussions. The developer, Lincoln University Company, was set

PHOTOGRAPHS: ROBERT GRESHOFF

up by local interests and with an academic partner, initially North Trent University.

The brief originated from this joint venture, and the design went out to tender in 1995. At this stage the academic partner was changed to the University of Humberside and, around the time of signing the main contract, the brief was reviewed resulting in a number of significant design changes, although the planned opening date of September 1996 was retained.

The design changes included relocation of the Learning Resource Centre from the north east wings to the whole of the top floor (which had been planned as a naturally ventilated area). The planned 9 m-high lecture theatres were also no longer required, being replaced with two 4·5 m-high rooms. The main contract was also changed to include all of the fit-out rather than just 40% of it.

According to project engineer Barry Redman, RMJM's integrated design approach enabled these changes to be made "on the fly" without affecting the programme and with minimised knock-on or design problems. This stemmed from RMJM's enlightened view that integrated design means beneficial interaction between design team members, rather than highly interdependent design features which can so often result.

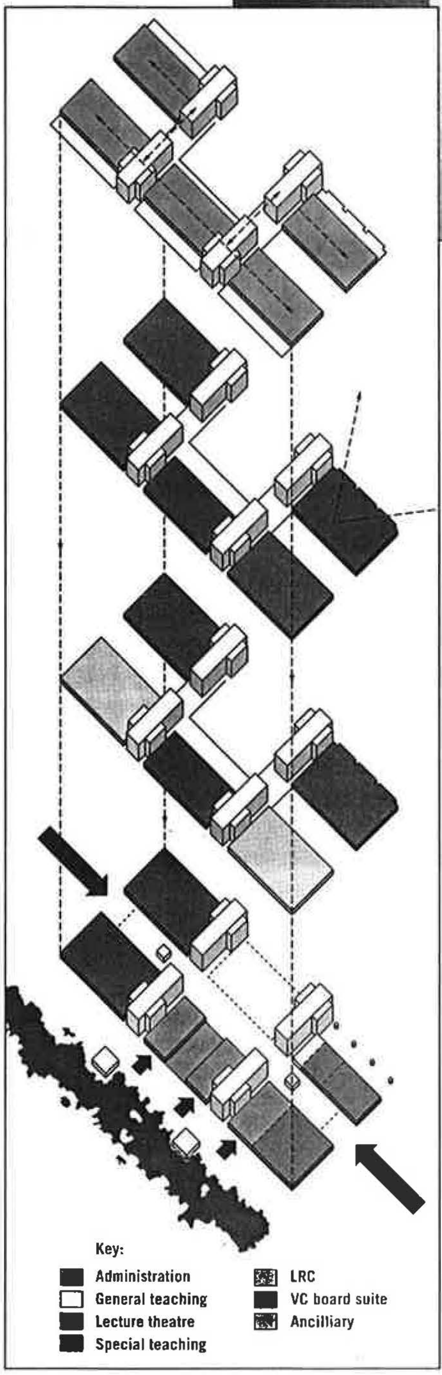
At the same time as these changes were made, the design team was novated to the main contractor, thus ending its direct responsibility to the client. While this arrangement provides the client with a single contact point at the contractor, possibly helping the objectives of rapid completion and cost control, the consultant has no recourse to the client if its view of design intent subsequently differs from the contractor's view.

This is of extra significance for building services, where the client may be highly dependent on the consultant's advice. Also, the novation continues into the defects liability period which neatly covers the crucial commissioning stage.

Air conditioned areas

Generic teaching space, mainly on the south side, has displacement ventilation and chilled beam cooling. Lighting/service beams alternate with chilled beams along the length of the exposed soffit. Ventilation air is distributed in ductwork under corridor floors and into a

RIGHT: The Learning Resource Centre on the top floor is air conditioned using fan coils situated on the roofs of the study rooms. The lightweight vaulted roof structure lacked both thermal mass and any means of support for chilled beams.



BELOW: Section through the four floors of the University. Teaching rooms to the south are air conditioned, with displacement ventilation and cooling provided by chilled beams.

supply plenum formed by the raised floor. Return is from a ceiling terminal housed in a somewhat quirky black-painted spigot which passes air into return air ductwork in the raised floor above.

Systems are designed to provide internal conditions at 15°C dewpoint. Supply air is nominally at 20°C winter and summer, but with some float up to temperatures of 22-23°C in hot conditions.

As originally planned, the building energy management system (bems) was to have been linked to a room booking system so that unoccupied rooms or areas would not be serviced. Isolation can be achieved by supply and return air dampers, with main duct dampers to control pressures in the distribution system. These should allow the volume of air to be significantly reduced at low occupancy so that advantages can be taken by the supply and extract fans, equipped with inverter drives.

Normally the chilled beams will not be operating, so with two-port operation and variable volume pumps with inverter control there is the potential for pump power savings.

One design alteration (stemming from the change of academic partner during the early contract stage) was the removal of the bems-linked booking system. As local controls were not generally specified, it is not surprising that nearly all spaces are now ventilated whether or not they are occupied. This certainly gives the potential for improvement in energy efficiency terms, given that the building is well below full occupancy this year.

That said, the estates department of the University of Lincolnshire and Humberside reports that by reducing fan and pump operating duties well below maximum levels, large savings have already been achieved in running costs compared to the initial months.

It is possible that by running the whole building at a low default level, comfort and efficiency are not far off what could be achieved by picking off individual spaces when unoccupied. This default-to-low-on operation may be less appropriate when the building is up to fuller occupancy. A PROBE-style investigation of energy consumption and occupant satisfaction against benchmarks would help to answer this question.

The change in academic partner also brought a different approach to building management. According to the University's estates department, the bems booking system was not included as it would depend on strict application of the booking system, at odds with the prevailing "walk-in-and-use" attitude.

Chilled beams are controlled to be on when the internal temperature is 24°C or higher. The thermal flywheel effect of the exposed concrete soffit should reduce the need for chilled beam cooling resulting from short duration/high occupancy use of rooms. The self-regulating characteristic of chilled beams coupled with the thermal flywheel of the soffit allows the stop-start control to be effective and allows savings from the two-port control valves, reducing chilled water flow volumes.

Lecture theatres are similarly serviced, although for much higher occupancy densities. The floor diffusers are located at the feet of the audience as they sit, and the designer says the system passes the "standard trouser test" to see if cold air from the diffusers produces a noticeable cold draft to the lower leg.

As mentioned, a fan coil system resulted from the relocation of the Learning Resource Centre to the top floor, originally intended for open-plan, naturally ventilated offices. The lightweight vaulted roof structure lacked both thermal mass and any means of support for chilled beams. The fan coils, located on the study room internal roofs, are deliberately oversized to operate off the chilled beam water circuit with its 14·5-17·5° C flow and return temperatures.

Study rooms on the top floor are free-standing internal structures provided with mechanical ventilation, but with no additional cooling.

Natural ventilation

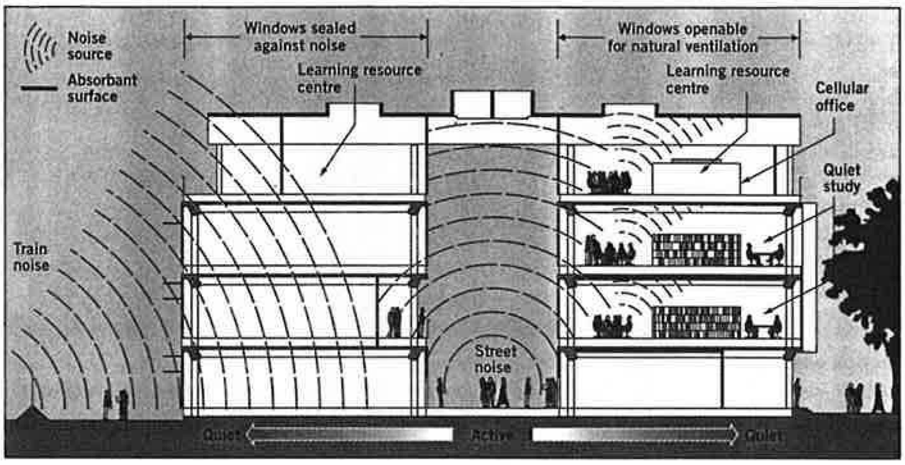
The administrative offices on the north side of the building are naturally ventilated with windows to the external and into the central street. Perimeter radiators have thermostatic radiator valves and weather compensation control. External roller blinds control solar gain and glare, and the exposed soffit helps reduce daytime peak temperatures. Some cellular offices adjoining the street have displacement ventilation fed from a special duct taken from the plantrooms.

The estates department reports that bringing the occupants up to speed on the natural ventilation operation of the building has been one of the trickier tasks. For example, staff in the naturally ventilated administrative offices did not appreciate that the internal street windows may be opened to add to ventilation.

These windows appear to have a significant effect in providing through ventilation. A feature contributing to confusion may be that around half of the building is air conditioned, while the naturally ventilated areas have a similar appearance with the exposed ceiling and custom light fittings (although without floor diffusers and chilled beams).

Lighting

Teaching and administrative areas are lit by 1200mm high-frequency fluorescent lamps in modified Zumtobel luminaires suspended in the exposed soffit grid. The luminaire was developed from the manufacturer's standard ZX range by perforating the side of the luminaire to provide an 11% indirect component. This indirect light onto the soffit is intended to avoid a cavernous appearance, and also aims



to reduce the dominant look of the suspended luminaire. It also reveals which lamps are lit. Perimeter compact fluorescent downlighters provide a wall-wash and, where near windows, some external lighting effect.

Dimmable lamps, coupled with illuminance detectors, provide maintained illuminance of 350 lux in general teaching areas and open-plan Learning Resource Centre areas where there is high usage of desk equipment.

Seminar rooms are illuminated to 500 lux. These lighting levels are achieved from a design maximum illuminance of (typically) 600-650 lux.

Lighting is controlled by a central ECS system with local momentary contact switches which provide override-on or override-off. The ECS system, which is not linked to the main bems, can provide time schedules, presence control (switching lighting on and off according to detected presence), absence control (switching lighting off, but occupants must switch it on), daylight linking, exit route linking and security lighting control. The system is configured so that initial wiring and rewiring costs are minimised, helping to offset system costs.

Some aspects of commissioning have been affected by the novation of the consultant to the main contractor, preventing full liaison on control needs and achievements. The lighting is intended to operate at 10% illuminance during absence times to prevent lamp life shortening from excessive switching, but this has not been implemented.

In addition, the building manager reports that occupants are used to turning lights on as they walk in, thus overriding the automatic control. Evidently, as with the natural ventilation, occupants need training on how to use such lighting controls.

Information systems

The Learning Resource Centre is extensively equipped with large display screen equipment for student use. Two communications rooms house communications hubs, servers and telephone switching, all using the category 5 unscreened twisted pair wiring.

Communications rooms are cooled by dedicated dx systems with 100% redundancy, and the power supply is backed up by a fifteen-minute 60kVA ups. Audio-visual equipment is included in the lecture rooms, which are linked so that information can be broadcast to any or all rooms. Video facilities in other areas are provided via a central system operated from a single video command room.

TOP: A railway line running adjacent to the University's southern elevation meant that this side of the building had to be sealed to protect it from noise ingress. However, much of the building is naturally ventilated.

ABOVE: While effectively cutting out direct sunlight, the fixed mid-pane venetian blinds on the south facade glazing have some non-specular reflectivity, producing a halo of glare in bright sunlight. This may require further preventative measures.

LEFT: Internal street windows may be opened for extra ventilation. Staff were not immediately aware of this, but an awareness exercise has now been carried out.

Central plant

Two plantrooms each span the roof laterally, serving the east and west parts of the building respectively. They are fully enclosed as a planning requirement as the roof forms the building's 'fifth elevation', visible from the nearby hill on which stands Lincoln's castle and cathedral.

The air plant has a desiccant cooling system using silica gel desiccant and return air evaporative cooling, with no auxiliary cooling coil. This plant provides dehumidified and cooled air. The designer's calculations show that it uses around one half the energy (expressed as associated CO_2 emissions) of an equivalently-performing dewpoint system.

Comparisons of energy use and cost are complicated by the change in energy source from electricity to gas (for heat to regenerate desiccant), and the need for the level of control of humidity offered by dewpoint plant.

Chilled water is provided for the chilled beam circuits by a conventional vapour compression refrigeration system, although the chilled water circuit temperatures at 14·5-17·5°C are higher than normal. The higher temperatures are put to good use by the inclusion of a free-cooling heat exchanger and control equipment to allow the chiller to be bypassed if the temperature of water from the condenser air heat exchangers is low enough.

The building shows evidence of a concerted attempt to provide appropriate comfort with energy efficiency: an appropriate mix of natural ventilation and air conditioning, measures to reduce solar gains and the introduction of thermal mass.

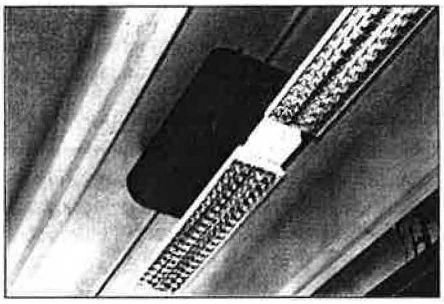
On the services side, the building relies on an innovative and highly efficient desiccant cooling system for the air supply, and highly controllable ventilation with variable speed inverter drives on fans and pumps.

The building had to be pushed through a rapid development and construction programme to meet the time and cost targets of its developers. As a side-effect, the designer has suffered from changes in the client's organisation with associated changes in approach and requirements. This came as the main contract was being let and from RMJM's novation to the main contractor which prevented closer interaction with the client.

The result is an apparently highly successful building which is probably not yet a low energy user. Once the systems are capable of being operated as intended this building could show dramatically low energy use.

John Field MA CEng MInstP is director of energy consultancy Target Energy Services.

The Lincoln University building's north elevation faces a large canal boating basin, allowing excellent views of the city's cathedral.



ABOVE: Ventilation air is distributed in ductwork under corridor floors, and into a supply plenum formed by the raised floor. Return is from a ceiling terminal housed in a quirky black-painted spigot, which passes air into return air ductwork in the raised floor above. High-frequency fluorescent lamps in modified Zumtobel luminaires are suspended in the exposed soffit grid.

BELOW: In the generic teaching areas, lighting and service beams alternate with chilled beams along the length of the exposed soffit.

University of Lincolnshire and Humberside, Brayford Pool, Lincoln

Client
University of Lincolnshire and Humberside
Employer's agent
Thornton Firkin & Partners
Architect, m&e consulting engineer, structural engineer
RMJM
Quantity surveyor
Gardiner & Theobald (pre-contract)
Main contractor
Balfour Beatty
M&E contractor
N G Bailey

Contract details
Tender date: January 1995
Tender system: Guaranteed maximum price (bespoke contract)
Form of contract: Design manage construct (DMC)
Contract period: 15 months (60% complete in 12 months)
National Engineering Specification: No

Mechanical suppliers
AHUs: Barkell
Boilers: Broag
Chilled beams: Klima-Therm (Distribution)
Chillers: York
Coolant: R22
Computer room ac: Stulz
Dry air cooler: York
Ductwork: Wright Favell
Extract fans: NuAire
Fan coil units: Diffusion
Floor grilles: Gilberts (Blackpool)
Flues: Rite Vent
Heat exchangers: IMI Rycroft
Humidifiers: Munters
Insulation (ductwork and pipework): Gill Insulation
Perimeter heating: Dunham-Bush
Pumps: Grundfos Pumps
Pressurisation: Grundfos Pumps
Radiators: Hudevad
Sound attenuation: Trox
Tanks: Brimar Plastic Fabrications
Toilet extract: NuAire
Underfloor heating: Multibeton
Water treatment: Liff Industries
Valves: Holmes Valves
Water heaters: Andrews Water Heaters and Boilers

Electrical suppliers
BEMS: Thorn Security
CCTV: Thorn Security
SMATV: TIS (Mansfield)
Cable management: Thorsmann & Co (UK)
Communications: BICC
Controls: Thorn Security
Electrical distribution and floor boxes: Crabtree
Electrical accessories: MEM
Fire alarm/detection: Cerberus
Lifts: Horizon Lifts
Lighting controls: ECS Lighting Controls
Luminaires: Zumtobel Lighting Systems, Concord Sylvania, Sill Lighting
Motor control centres: Thorn Security
Packaged hv substation: George Ellison
Power busbar: Barduct
Ring-main unit: Merlin Gerin

External design conditions
Winter: -3°C/sat
Summer (ac): 25°C db, 18°C wb

Internal design conditions
Winter: 20°C min
Summer (non ac): 27°C not exceeded for more than 2·5% of the time
Summer (ac): 25°C, 50% rh
Circulation and toilets: max not controlled, 20°C min

U-values (W/m²K)
Walls: 0·31
Floor: 0·18
Roof: 0·16
Glazing: 1·9

Structural details
Slab thickness: 700 mm o/a 550 mm beams
Clear floor void: 500 mm
Floor-to-underside of beam: 3800 mm/3500 mm
Ceiling zone: 0 mm
Net services zone: 500 mm
Live load: 5·0 KN/m²
Dead load: 6·36 KN/m²

Occupancy
Offices: 1 person/10 m²
Seminar rooms: 1 person/1·5 m²
Lecture theatres: 1 person/1·2 m²

Noise levels
Offices: NR38
Toilet and circulation: NR45
Lecture rooms: NR33

Energy targets (gfa)
Heating: 60 kWh/m²/y
Hot water: 9·0 kWh/m²/y
Fans and pumps: 17·0 kWh/m²/y
Ventilation: 12·5 kWh/m²/y (desiccant and winter heating)
Refigeration: 6·0 kWh/m²/y
Small power: 19·0 kWh/m²/y
Lighting: 19·4 kWh/m²/y
Lifts: 0·2 kWh/m²/y
*Gas: 84 kWh/m²/y
*Electricity: 66 kWh/m²/y
CO_2 emission target: 82 kg/m²/y
(occupancy times: 12 hours per day, 5 days per week)
(*includes kitchen)
BREEAM rating: No

Engineering data
Gross floor area (gfa): 10 500 m²
Net usable area: 7000 m²
Plantrooms: 670 m²
Communications room: 90 m²
Amenity and dining areas: 560 m²
Street: 460 m²

Loads
Calculated heating load: 0·6 MW
Installed heating load: 5 @ 0·15 MW
Calculated cooling load: 0·2 MW
Installed cooling load: 1 @ 0·2 MW
Fan power: 1·3 W/litre/s, 6·3 W/m²
Floor average: varies with space served
Equipment: 120 W/pc workstation
Lighting Load: 15 W/m²
Occupancy: 66 W/m² (max), 8 W/m² (min)
Shading coefficient of glazing: 0·24

Ventilation
Scheduled supply air temperature: 20°C
Room temp: 20°C min, 25°C max (comfort-cooled spaces)
Fresh air: 100 % min (10 litres/s/person)
Max recirculation: 0%

Primary air volumes
Primary air
1 ahu at 11·8 m³/s
1 ahu at 9·0 m³/s
1 ahu at 2·5 m³/s
Kitchen: 3·0 m³/s

Distribution circuits
LTHW: 80°C flow, 60°C return
DHWS: 60°C flow
Chilled water: 15·5°C

Refrigerant
Chillers: R22
Computer room: R22

Electrical supply
Supply: 1 MVA
UPS system: 60 kVA (for computer back-up)

Lighting
Types: linear fluorescent, compact fluorescent and metal arc
Lighting load: 136 kW
Efficiency: 2·3-3·5 W/m²/100 lux (depending on room type)

Lux levels
Office: 300-500
Conference: 400-500
Kitchen: 500
Computer: 300-500
Toilets: 200
Stairs: 200
Circulation areas: 200

Glare index: as CIBSE

Lifts
2 x 13 person hydraulic

Costs
Total net cost (£/m²): £1344

Mechanical services cost (£/m² gfa)
Sanitary appliances: £4.95
Hot and cold water services: £16.85
Heating, cooling and ventilation (including controls): £189.97
Drainage: £4.95

Electrical services (£/m² gfa)
Meter and switchgear, lighting and power installation: £156.55
Fire detection, fire alarms, security, earthing and bonding: £56.34
Telephone and data: £12.68
Lifts: £13.56