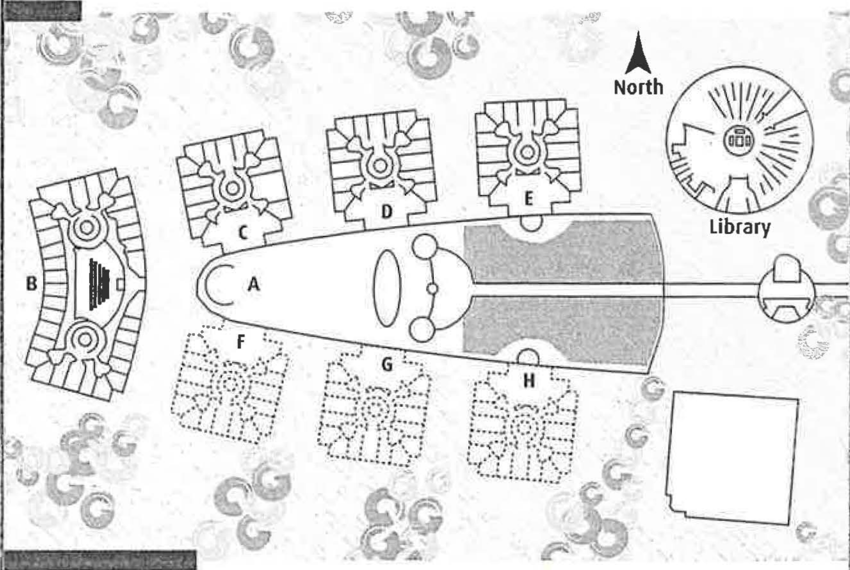
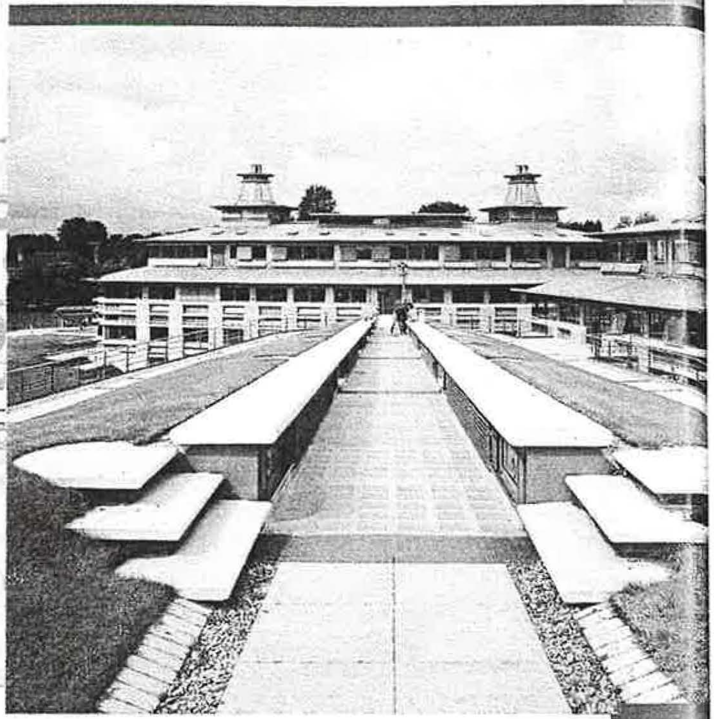
A predominantly naturally ventilated project, but with comfort cooling by chilled beams ✓

Thermal modelling suggests that offices can cope with loads of up to 230 W before temperatures rise ✓

The buildings are interesting examples of bems-controlled motorised night ventilation ✓





Cool and calculating

The design of mixed-mode ventilation and comfort cooling systems have taken another step forward with the construction of the Centre for Mathematical Sciences in Cambridge – the new home for the mathematical genius Stephen Hawking. But how energy efficient are the buildings likely to be?

BY JOHN FIELD

Resolving issues of the cosmos and advanced mathematics requires a clear head and a quiet environment, says the Centre for Mathematical Sciences' faculty client. Neighbouring residents agreed with the latter point and also didn't want to see too much of the ten building site.

With restrictions on noise, height and visual impact, the design team – and services engineers Roger Preston and Partners in particular – were set a severe test. But has this development for Cambridge University made the grade?

Site issues

The site was previously a field surrounded largely by detached suburban residences and the faculty's existing Newton Institute building occupying one corner. Planning negotiations produced a clear need to reduce visual impact and noise.

The central block, building A, is oriented east – west and will be bordered by seven pavilions: the double pavilion block B to the west, pavilions C, D and E to the north and pavilions F, G and H to the south, which are yet to be built. A, a science and technology library is being constructed to the north-east. The existing Newton Institute building is to the south-east (see illustration above).

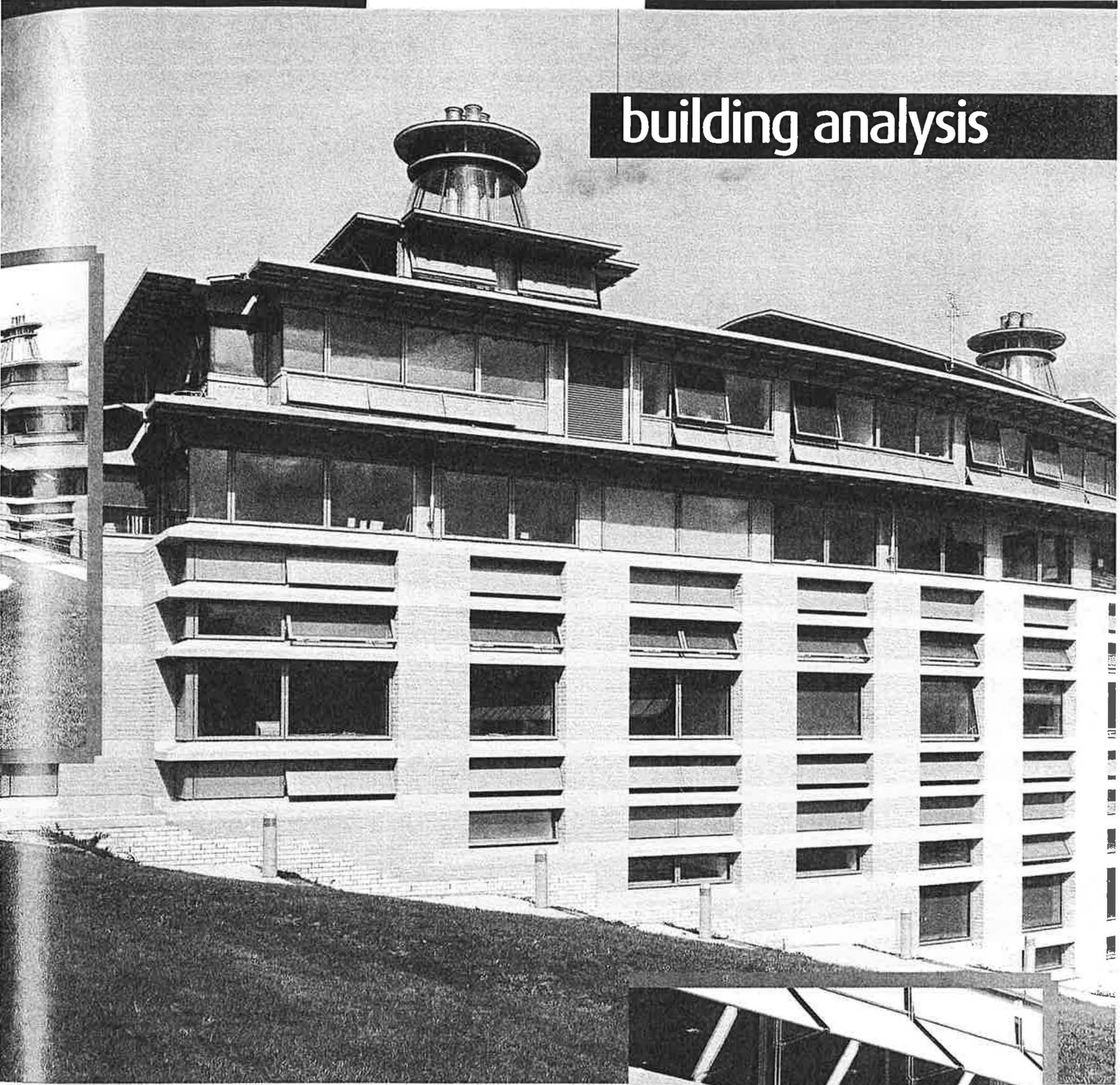
Phase 1 contractor Laing is completing buildings A, B, C and D, and all these are now occupied. McAlpine is the contractor for the library and pavilion E. Phase 2 has not yet started on-site but will complete pavilions F, G and H and a further laminar flow laboratory. The architects and services engineers are the same for all the contract phases.

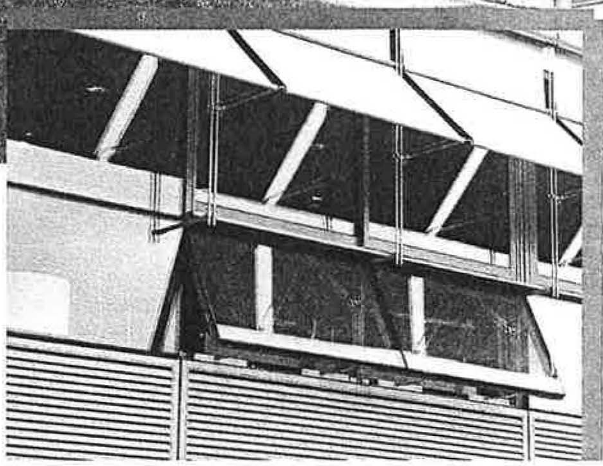
The faculty had wanted quiet buildings and not sealed boxes, so full air conditioning was inappropriate. The accommodation requirements for mainly cellular offices around staircase/lift cores led to the development of the pavilion arrangement, opening the way to natural ventilation strategies.

However, the relatively low proportion of space requiring cooling still produces a substantial cooling demand. This demand has required an impressive underground, attenuated chiller plantroom with 740 kW of cooling capacity, plus space for another 740 kW.

As overall height was critical to the visual impact, the central part of the site was lowered by almost a floor, and determined efforts were made to reduce floor to ceiling heights of the upper floors. Also, the central building was given a curved roof covered with a "lightweight mud" and grassed over to reduce visual impact.

This helps to hide the buildings from eye while the site lacks the three pavilions along the south flank. In the longer term the grass roofs





PHOTOGRAPHS: TONY WELLER, ARCHIMAGE

ABOVE: Pavilion B. The upper vents are glazed window lights, while the lower vents are insulated panels.
INSET, LEFT: The glazed walkway along the middle of the grassed roof provides daylight to the restaurant.
RIGHT: Solar shading to the central block.

will still hide the pavilions in the gaps between the buildings. Similarly, light nuisance to neighbours has been addressed with outward facing windows on upper floors having opaque blinds linked to the building energy management system (bems).

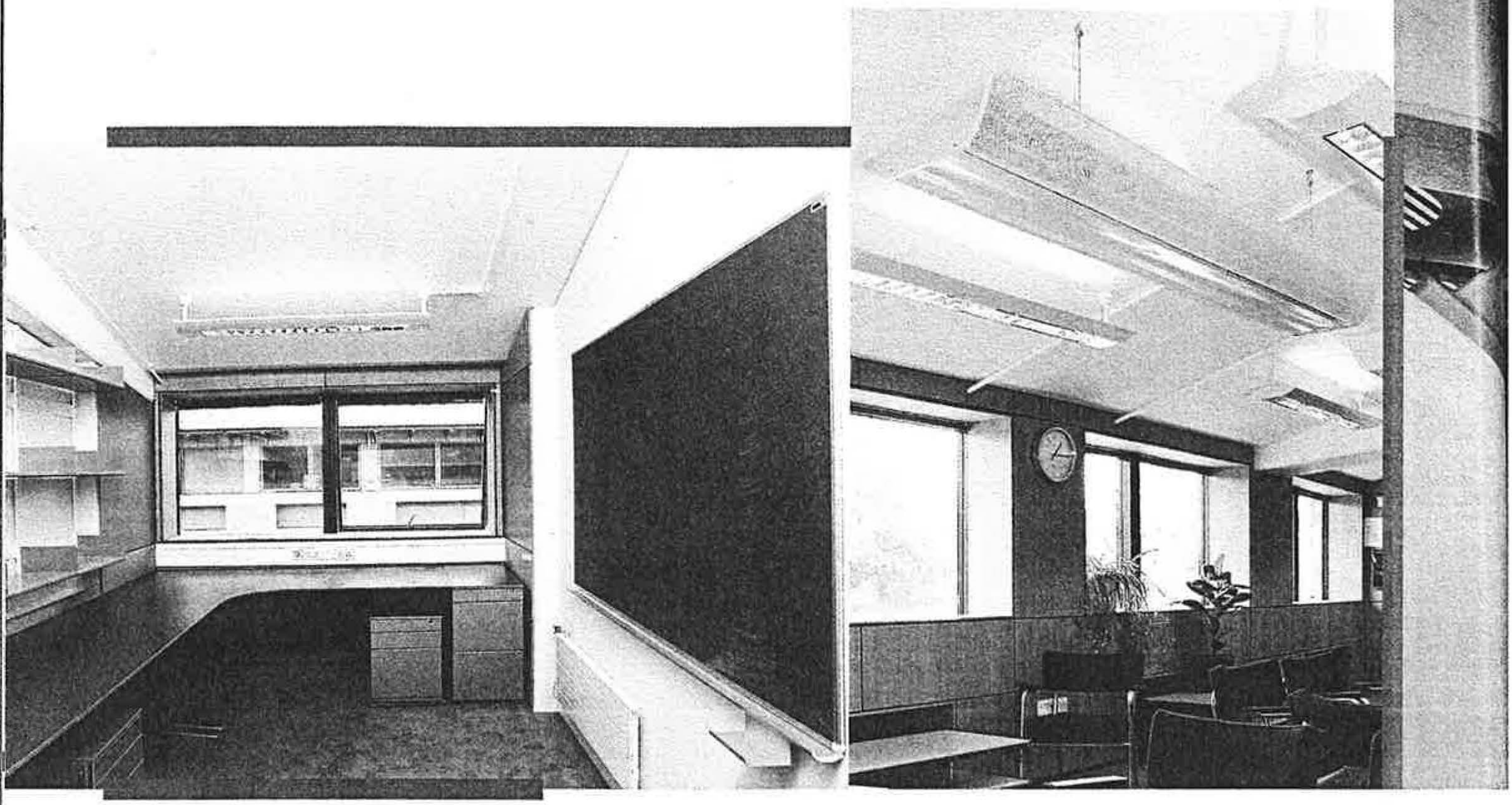
Natural ventilation

The design team looked at various passive and mixed mode options, including passive ventilation stacks and using the structure for thermal storage. A Termodeck-type approach was considered but did not seem well suited to the circular pavilion layout with central core staircases. For the cellular offices it was decided to go for a mainly single-sided natural ventilation with contingency to add chilled beam cooling. This decision was made with the help of dynamic modelling using Tas, and presentations to the client on the frequency of exceeding specified internal temperatures.

Exceptions to the natural ventilation strategy are deep plan rooms with comfort cooling and minimum fresh air, such as the Graduate Studies room, and the lecture theatres on the lower ground floor of the central building (A).

The cellular offices are generally of a standard floor area of around 13 m^2. These rooms may be occupied by a senior academic with relatively modest IT equipment, or in principle up to three researchers in some cases with exceptional needs of up to 500 W of power for computers and peripherals.

The thermal modelling showed that the proposed designs could handle up to two researchers with 230 W per workstation. Where



LEFT: One of the cellular offices, and RIGHT, an open plan area. Passive infrared presence detectors fitted to the inner lights can be set up to control the lamps, but this has not proved popular.

these criteria are exceeded, occupants would expect to experience higher temperatures. The option exists for chilled beams to be installed, but the occupants would have to shoulder the cost.

The chilled water system is designed to handle cooling needs in the lower ground floor, lecture theatres and laboratory areas, with additional plant capacity for adding cooling and fresh air for up to six rooms per pavilion.

The larger (180-seat) lecture theatre has displacement ventilation while the smaller theatres have constant volume systems. Passive ventilation of the large lecture theatre was considered, with the theatre raised on stilts, but the

The need to reduce room heights, while maintaining high and low level vents in each room, has required some ingenious solutions

extra height and cost were not acceptable.

The central building A has automatic blinds and windows, and opening vents along the roof spine, which is a glazed walkway along the middle of the grassed roof. Blinds are provided for all windows so that blackout can be enabled for presentations in the upper floor cafe/presentation space.

Room provision

Limiting summer temperatures is achieved by overhangs and blinds to reduce solar gain, exposed concrete soffits to absorb daytime heat gains, and vents at high and low level which can be used for night ventilation.

All floors have an overhang of 1·2 m, which provides shading for south-facing rooms in summer, but not necessarily in spring or autumn or for east/west facing rooms at any time of year. Rooms have 98% opaque roller blinds, which are manually controlled except where automatic operation is required to limit light pollution from the perimeter.

Vents above and below the window glazing are motorised and controlled by the building energy management system (bems) with full manual override, (which is returned to automatic control at the end of each day). Upper vents are glazed window lights and lower vents are insulated panels. Manual override to open is prevented at times of rain or high wind. Automatic actuation of the vents opens the top vent first in three steps, then the bottom vent.

As timing rather than position sensing controls opening extent, the vents have to return to the closed position to reopen to another partially open setting. This has caused some confusion with occupants and has meant that some of the planned operating times have been removed.

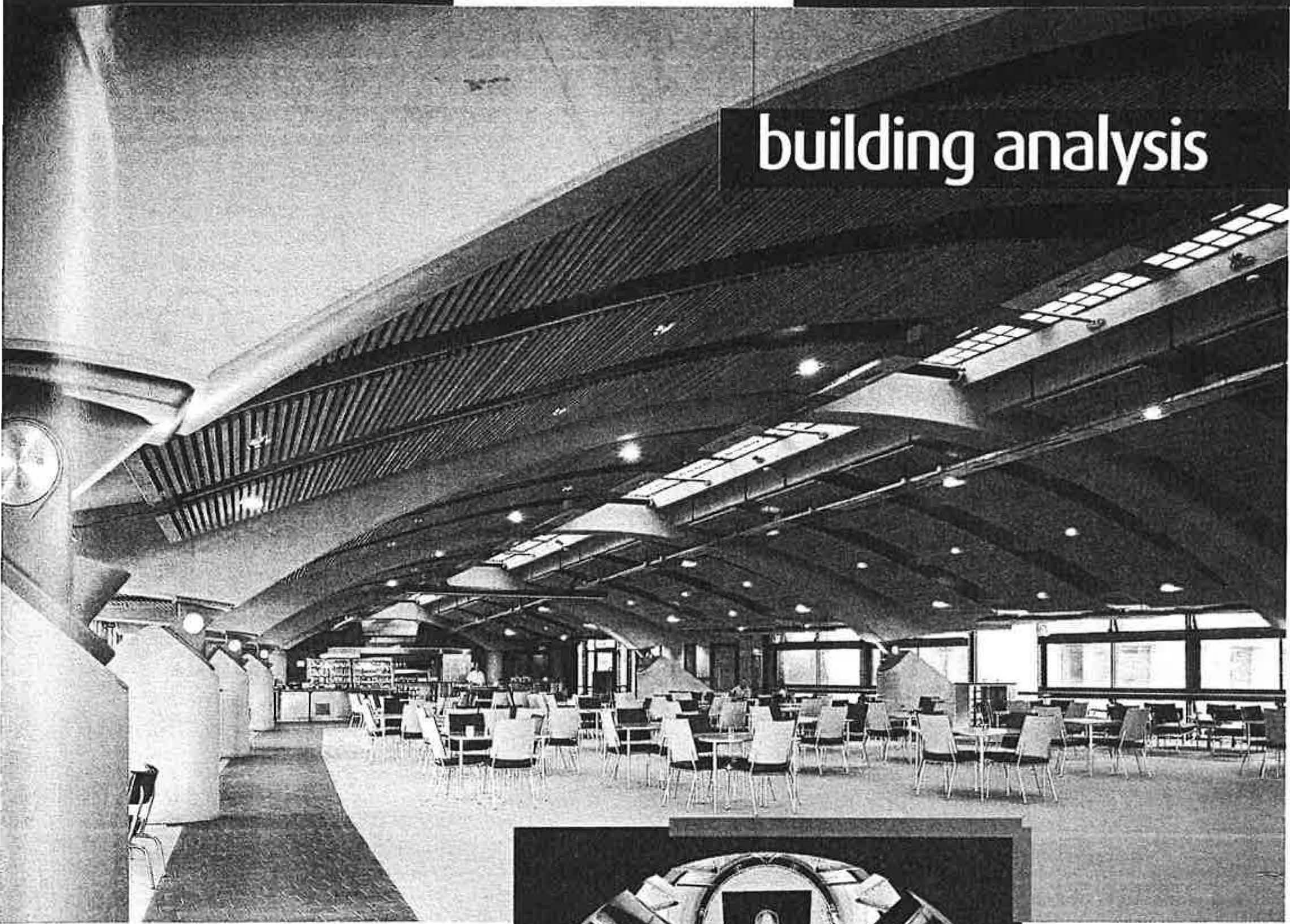
Night ventilation is achieved by opening the vents under control of the bems. Vent opening is linked to the lighting control system to prevent opening while lights are on which would attract insects. Night ventilation originally used upper and lower level vents, but currently uses only upper level vents for security reasons.

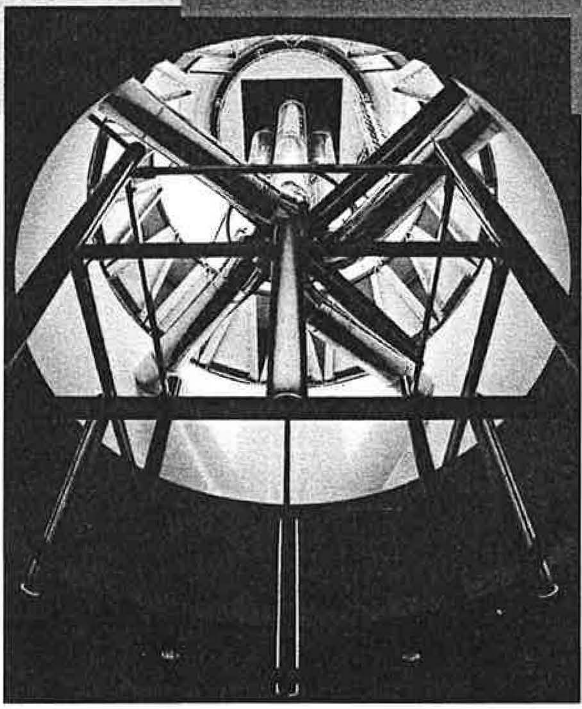
The chilled beam systems provide minimum fresh air when activated, and are interlocked with the vents to prevent the chilled beams operating with the vents open, as the air needs to be dehumidified to run the beams without problems with condensation. The fresh air provision is modest so large ductwork is not required, and vertical builders ducts are provided for fresh air and chilled water services.

The vent opening controls have three buttons (override, open and close) for both the upper and the lower level vents in each room. These seem fairly straightforward to operate. The vent actuators have their own control system, which is interfaced to the bems. This interface has caused problems contributing to a delay in commissioning the bems, so that some of the natural ventilation features have been disabled or introduced gradually.

The need to reduce room heights while maintaining high and low level vents in each room has required some ingenious solutions. The top floor is recessed from the plan of lower floors, and the first floor roof thus exposed drops down to the top of the first floor glazing to reduce facade height, which leaves no room for upper vents.

The upper vent in the first floor rooms is provided via a short vertical duct in the concrete ceiling that goes to a vent in the lower vents for second floor rooms. Upper ventilation in the second floor is provided by Velux windows.





ABOVE: The barrel-vaulted restaurant which runs between the north and south pavilions – a pleasing mixture of concrete and timber panelling.
LEFT: Inside one of the lanterns showing the boiler flues, wc vent ducts and a modicum of daylighting.

Electrical and data services

A typical room has two twin 28 W T5 fluorescent lamp fittings suspended from the ceiling with 15% backlight providing a ceiling wash. Passive infrared presence detectors fitted onto the inner lights can be set up to control the lights but this has proved to be unpopular. Corridor lighting is generally of compact fluorescent downlighters.

The lighting management system keeps circulation lighting on in a pavilion if any occupants are present, and for half an hour after the last office is occupied.

Wiring to a typical room comprises three double data/comms sockets and three double power sockets. There is no central uninterruptible power supply or standby generation, as individual users are expected to make their own arrangements. Central IT services are limited to a server room in pavilion D, while pavilion B contains the site's hub for the university fibre network Granta backbone.

Lanterns

The glazed pavilion roof lanterns could have provided light and ventilation to the central stair cores and ventilation to the top floor rooms, but in practice these functions have not been fully realised. While they do provide light to the stair/lift cores, the effect is limited by the lift structure, which reduces the light transmitted down, especially to levels below the top floor.

Use of the lanterns to provide natural ventilation to upper floor rooms produced a service bottleneck. This was due to the restrictions on ceiling height and the need for highly effective cross-talk attenuation in the very quiet working environment. This attenuation also compromises natural ventilation flows. These problems were not resolvable so Velux windows are fitted for high-level ventilation to second-storey rooms. The lanterns include boiler flues with lookalike wc vent ducts and soil vents.

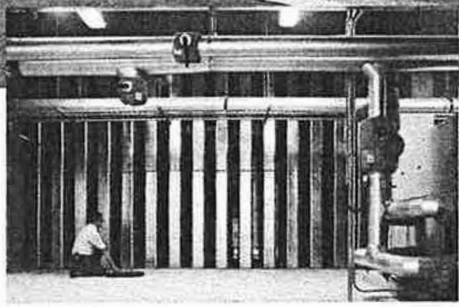
Other services

Room heating is provided by radiators fitted with thermostatic valves. Non-condensing gas-fired boilers are provided in most buildings but not, for example, in pavilion C, where the lower ground floor space is at a premium to accommodate a fluid dynamics laboratory which extends from the lower floor of building A.

The chiller installation appears very generous for what is predominantly a naturally ventilated site, but it is difficult to see what else could have been done. The cooling needs of the lower ground floor rooms and laboratories are supplemented by allowances for individual offices.

The stringent noise and visual impact criteria preclude a rooftop installation, so the chiller plantroom was fitted at lower ground floor level between two pavilions. The chillers are heavily attenuated in a cathedral-like hall (see photograph, overleaf) and they reject air vertically upward from a ductwell to ground level. Chillers use zero ozone-depleting R407c. The chilled water circuits are designed to operate efficiently at low duty with variable speed drive pumps.

Air handling plant contained in the basement of the pavilions is sized for the known loads to the lower ground floor rooms and also for up to six cellular rooms which may require chilled beams with fresh air. The units include run-around heat recovery coils that provide



ABOVE: The central block contains the main plant and staff restaurant. RIGHT: The chillers are heavily attenuated in a cathedral-like hall.

reheat in summer during dehumidification (required for chilled beam operation), thus allowing the boiler plant to be held off.

Looking forwards

Will the building work as intended? From the viewpoint of environmental servicing, a key indicator is the percentage of cellular rooms that have the chilled beam comfort cooling after, say, five years. But building and services design only plays a part of this: other issues that will dictate the future adoption of mechanical cooling include:

☐ whether cooling becomes a status symbol – hopefully a nicely operating office without cooling should be the status symbol

☐ charging occupants for the operating costs of the extra servicing for cooling, as well as the initial costs – this would also provide an incentive for chilled beams to be disabled or removed when no longer needed

☐ a good relationship between building manager and occupants so that automatic lighting, vent and other controls (such as blinds) are seen as a plus – this will require effective use of building and lighting management systems plus skillful interpersonal relations

The designers have applied lateral thinking and detailed investigation to ensure that the building has the wherewithal to operate successfully, and an array of measures to deal with different conditions and operating needs.

It remains to be seen how the occupants and building managers are able to use these facilities to produce the environment they need.

John Field is director of Target Energy Services, www.targ.demon.co.uk

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Client
University of Cambridge
Project manager
Davis Langdon Management
Architect
Edward Cullinan Architects
M&E consulting engineer
Roger Preston & Partners
Structural & civil engineer
Buro Happold
Quantity surveyor
Northcroft
Landscape Architect
Livingston Eyre Associates
Main contractor
Laings
Electrical contractor
T Clarke
Mechanical contractor
Kershaw Mechanical Services

Mechanical suppliers
AHUs: McQuay
Air curtains: Envirotec
Anti-vibration mounts: Engineering Appliances
Boilers: Hamworthy
Burners: Hamworthy
Ceiling diffusers: Gilberts Grilles
Chilled beams: Stifab Farex
Chillers: Delrac
Control valves: TA Hydronics
Computer room a/c: Delrac
Ductwork: Kershaw Mechanical Services
Extract fans: McQuay/Envirotec
Expansion bellows: Engineering Appliances
Fan coil units: Envirotec
Flues: Hamworthy
Gas boosters: Sekomat
Insulation system
☐ ductwork: Rockwool
☐ pipework: phenolic foam
Perimeter heating: Unilock HCP
Pumps & pressurisation: Holden & Brooke
Radiators: Zehnder
Sound attenuation: Allaway Acoustics
Strainers: TA Hydronics
Tanks: Brymar Plastics
Toilet extract: Envirotec
Water treatment: KJ Water Treatment
Valves: TA Hydronics
VAV boxes: Trox
Water boosters: Holden & Brooke
Water heaters: Heatrae Sadia

Electrical suppliers
BEMS: Siemens
CCTV: Philips
Cable management: Rehau
Communications: Grant & Taylor
Controls: Siemens
Electrical distribution: Group Schneider
Electrical accessories: MK
Fire alarm/detection: Defensor
Floor boxes: Simplex
HV switchgear: Merlin Gerin
Lifts: Quality Lifts
Lighting controls: ECS
Luminaires: Creed Lighting/specials
LV switchgear: Group Schneider
Motor control centres: Siemens
Power busbar: Barduct
Standby generation: S W Wilson
Trace heating and water leakage detection: Raychem

Engineering data
Gross floor area (gfa): 9150 m²
Net usable area: 6710 m²
Plant rooms: 494 m²
Offices: 3903 m²
Computer suite: 48 m²
Amenity & dining: 945 m²
Laboratory areas: 630 m²
Lecture theatres: 930 m²
Circulation areas: 2200 m²

Contract details
Tender system: Single stage competitive
Form of contract: JCT
Was National Engineering Specification used on this project: No

U-values (W/m²K)
Walls: 0·25
Floor: 0·25
Roof: 0·25
Glazing: 1·7 and 1·9

Structural details
Slab thickness: 275 mm
Floor to ceiling
☐ Lower ground floor: 4000 mm
☐ Typical: 3100 mm
Ceiling zone
☐ Lower ground floor: 800 mm
Live load
☐ Offices: 2·5 KN/m²
☐ Lecture theatres: 2·5 KN/m²
Dead load: 8·0 KN/m²

Occupancy
Offices: 70 People per pavilion

Noise levels
Offices: NR 35
Toilet & circulation: NR 40

External design conditions
Winter: -3°C/sat
Summer (non a/c): 29°C db, 20°C wb
Summer (a/c): 29°C db, 20°C wb

Internal design conditions
Winter: 19°C min
Summer (a/c): 22°C
Circulation & toilets: 20°C min

Target energy use (gfa) for a typical pavilion
Gas: 38 kWh/m²/y
Electricity: 112 kWh/m²/y
CO_2 target: 75 kg/m²/y
Energy breakdown
Heating: 38 kwh/m²/y
Hot water: 4·5 kWh/m²/y
Fans & pumps: 28 kWh/m²/y
Ventilation: 10 kWh/m²/y
Refrigeration: 2·5 kWh/m²/y
Small power: 18 kWh/m²/y
Lighting: 48 kWh/m²/y
BREEAM rating: No

Hours of occupation
Typical occupied hours:
24 h availability, 7 days/week
Fabric leakage: 5 m³/h/m² of fabric @ 50 pa

Loads
Calculated heating load: 1020 kW (Phase 1)
Installed heating load: 1400 kW (Phase 1) (includes allowances for future expanded loads)
Calculated cooling load: 850 kW (for the whole site, with current percentage cooling uptake)
Installed cooling load: 744 kW (modular central plant with an option of 1488 kW)
Equipment: 19·5 W/m² (typical cellular office)
Lighting: 12 W/m²
Installed lighting: 12 W/m²
Occupancy: 5·4 W/m²
Solar gain (winter): 6·6 W/m²
Solar gain (summer): 10·6 W/m²

Ventilation
Scheduled supply air temp: 20°C
Room temp: 18°C min, 25°C max
Fresh air: Full fresh air
Max recirculation: n/a (run-around coils)
Filtration EU category: EU 7

Primary air volumes
Total fan power: 0·072 kW/m²
Primary air: 2 ahus @ 1·2 m³/s typical per pavilion
Offices: 0·026 m³/s each (where comfort cooled)

Distribution circuits
LTHW: 82 °C flow, 71 °C return
Chilled water: 6°C
Refrigerant: R407c

Electrical supply
Transformers: 1250 kVA
Standby power: 40 kVA

Lighting
Types: T5 LG3 category 2
Lighting load:
2·15 W/m²/100 lux
Lux levels
Office: 400
Conference: 300
Kitchen: 300
Computer: 400
Toilets: 120

Lifts
8 person @ 0·5 m/s per pavilion

Costs (millions)
Total cost: £19.2 million
No building services cost breakdown was made available for this project.