# LORD OF THE FILES

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|---|---|---|---|
| Low velocity ventilation and borehole cooling could help deliver a total energy target of 90 kWh/m² ✓ | The use of triple glazing and innovative shading reduces solar gain to no more than 25 W/m² ✓ | Lighting predominantly relies on compact fluorescent lamps in uplighter fittings ✓ | Special side-acting sprinklers and flame detectors protect the fully glazed and planted courtyard ✓ |

Nearly 20 years after it was ordered by Parliament, the £230 million parliamentary building is ready to welcome its inmates: 200-odd constituency MPs and their staff. Does the building's controversial luxury extend to the engineering services?

BY RODERIC BUNN

**Let's get this clear right now.** The new parliamentary building has cost a small fortune. Its rather forbidding appearance makes the Bates' Motel look positively welcoming. Its spiralling costs have been pilloried by the media and public accounts committees in equal measure. Criticism has been aimed at every aspect of the building, from its Dickensian chimneys to its £150 000 fig trees imported from Florida.

Whether you like it or loath it, you and I paid for it. And what's more it's booked a place opposite Big Ben for the best part of 200 years, so we'd better get used to it. It's another matter whether it'll be habitable by then, given that the climate-challenged Thames is likely to burst its banks well before Sir Michael Hopkin's architecture reaches its sell-by date.

But that is then and this is now. And the big question is whether the mother of all Parliaments has acted with cavalier extravagance or Cromwellian austerity in creating a spanking new home for 210 lucky MPs. Oh, and 400 administrative staff – give or take.

There's no argument that Parliament needs the new accommodation. MPs are currently scattered among six buildings of varying degrees of dilapidation including, apparently, wooden huts atop the Palace of Westminster.

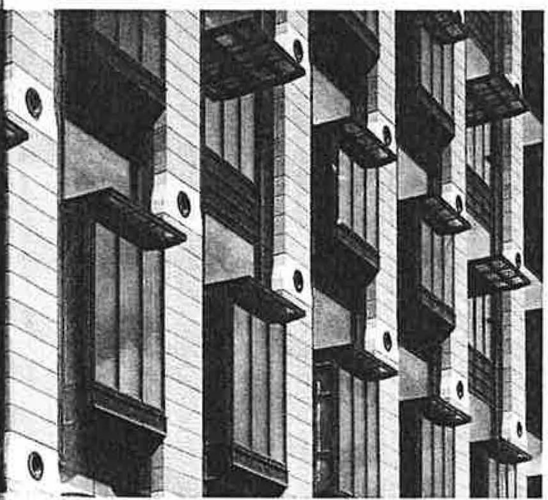
In January they will decant into this £230 million multi-storey, blast-proof building. Its seven floors of cellular offices are arranged around a central glazed courtyard, with the ground and first floors given over to four select committee rooms, nine meeting rooms, two multi-purpose conference rooms and two tv interview rooms.

## Early design

It's taken nearly two decades for Portcullis House to lumber from drawing board to fit-out. Architect Michael Hopkins began sketching the design in the early 1980s, with services consultant Ove Arup starting detailed work on the project in 1988. Tendering came some seven years later in 1995, and construction began on-site in January 1998 (although a great deal of off-site fabrication had already been completed).

Michael Hopkins' design pays overt homage to Norman Scott's Gothic architecture for the Houses of Parliament. And not just in appearance. Like Norman Scott, Hopkins was keen to integrate the services with the structure. In this Hopkins was inspired by the work of Italian civil engineer and architect Nervi (1891 – 1979), an early pioneer in the use of exposed concrete to

**LEFT: The building is either grim or perfectly suited to its context, depending on how you view it. It's better seen either from a distance or up close, BELOW, where the quality of the finishes demonstrates the value of off-site prefabrication. Note the external solar shades.**



PHOTOGRAPHS: ROBERT GRESHOFF

create an architectural aesthetic (see box 'Nottingham foray').

Hopkins' dislike of both suspended ceilings and flat, featureless soffits ultimately led to a waveform slab which, for quality reasons, begged to be pre-cast. Indeed the confined nature of the site, plus the long lead-in time caused by the reconstruction of Westminister tube station, prompted the almost entire prefabrication of Portcullis House. This included not just the slabs, but also the floors, the granite columns, the fenestration, the services risers and, to cap it all, the entire roof, including the plantrooms and services distribution.

Crown House Engineering (CHE) won the tender on the basis of its prefabrication skills. CHE translated the drawings generated by the consultants into a 3D Sonata model. The contractor then co-ordinated the off-site prefabrication of the services – along with key elements of the building structure – with the various specialist subcontractors.

The result was high quality, ease of commissioning, and parallel design and construction. Any minor tolerance problems – and it is extremely tight in many places – were solved by CHE on-site by reducing the depth of insulation.

The rooftop plantrooms are more akin to the servicing of a submarine than a building. "When we started out with this we spoke to Flakt's marine engineering division in Gothenburg about how to deal with space and access," said Arup's John Berry. "What they taught us is that what appears confined can actually be very accessible as long as you lay it out properly."

## Integrated engineering and architecture

Ove Arup & Partners not only set out to provide an ultra-low energy building, but also took great advantage of Hopkins' desire for an integrated solution. For a start, maintaining thermal conditions relies far more on the building fabric than it does on active m&e servicing. Second, where possible the architecture incorporates services routes. As a consequence, large elements of the building fabric and services – most notably the roof – were designed, prefabricated and craned to site as single items

Curiously for a concrete building it is not particularly heavyweight. Indeed, with the exception of the structural columns which plunge into the Alienesque world of Westminster tube station, the building is more of a lightweight structure. Not that this matters – a building which relies on the thermal capacity on a daily basis only needs the first 50 mm of dense material, and the 100 mm thick waveform shell slab easily provides this without adding significantly to the building's weight.

The fenestration consists of highly insulated (and blast resistant) glazing consisting of triple panes with a ventilated cavity. The outer double glazed unit is filled with argon and has a low emissivity coating, while the inner cavity contains retractable louvre blinds designed to maximise short wave solar absorption and minimise long wave heat loss.

This arrangement is claimed to transmit less than 25 W/m² solar heat gain across the floor area of the 4·5 m deep offices. The shading performance is said to be comparable with external shading, but in energy efficient terms is claimed to exceed it because of its role in recovering solar heat.

Avoiding the need for mechanical refrigeration rested on three factors: reducing solar gains, limiting internal loads and providing enough thermal capacity to deal with heat gains from lighting, equipment, and occupants.

The designers still had to hit the client's target room temperature of 22±2°C. Doing this by passive means needed an in-depth understanding of how heat would flow in and out of the rooms. The facade's high thermal resistance means that most of the daytime heat is retained, so the designers had to provide enough mass to absorb both radiated and convective heat.

Design iterations led to a barrel-vaulted concrete ceiling with dense raised floor tiles and architect-designed 50 mm pre-cast wall panels. The high thermal capacity of the room surfaces are claimed to possess a density range between 50 kg/m² and 200 kg/m² for around 2·5 m² per m² of room floor area.

In winter, heat recovered from the extract air, plus lthw radiant panels either side of the windows, maintain comfort levels. (Finned tube heaters were considered, but convective heat from them would be too easily entrained into the extract path through the fenestration).

In summer, some means of cooling the ventilation air was required. This is done by extracting groundwater from two boreholes sunk 150 m into a chalk aquifer. Water is extracted at 13·5°C, stored in two 165 000 litre buffer tanks

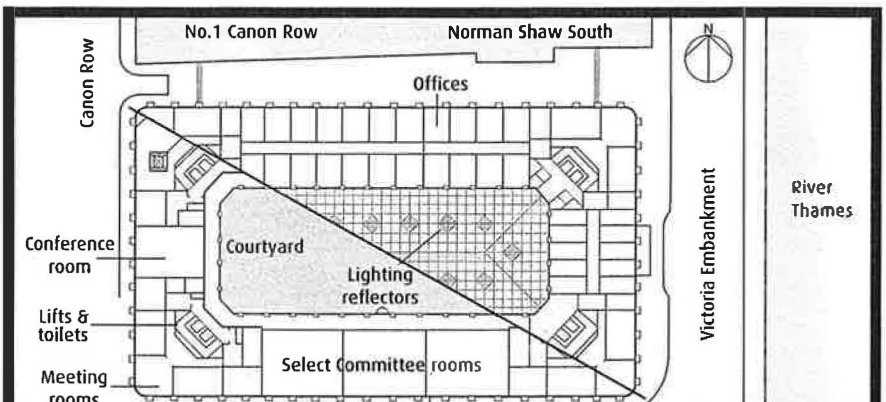
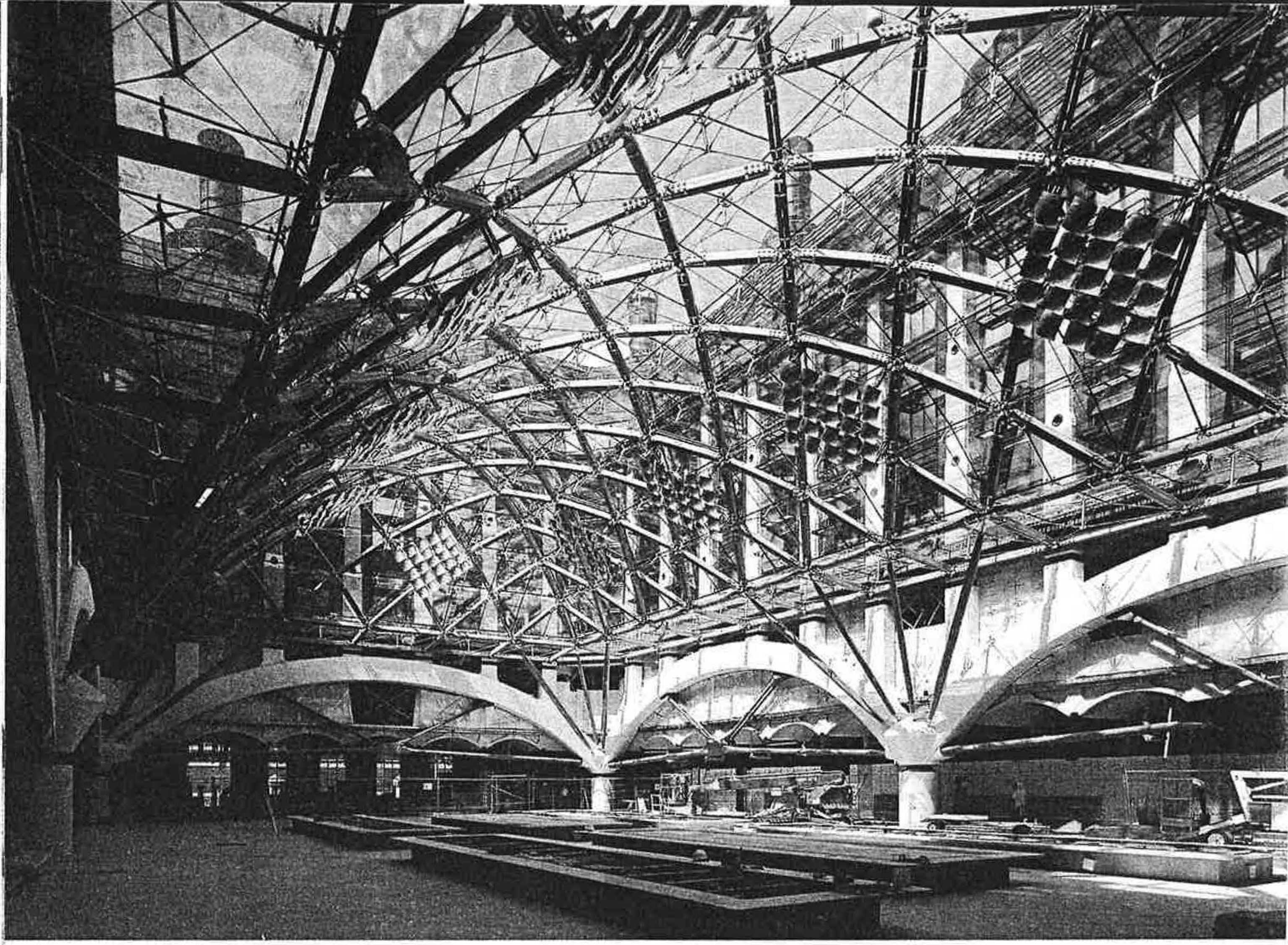



**FIGURE 1: A split 2D drawing showing the ground floor conference and committee room layout, with the office arrangement for the upper floors superimposed. The red lines delineate the fire zones.**



**ABOVE: The courtyard is naturally ventilated, with rooftop vents. Note the diamond-shaped reflectors designed to bounce the light emitted from perimeter-mounted metal halide spotlights. The 21 m-span transfer beams are connected to the foundation columns which rise up from Westminster tube station.**

in the basement, then pumped through heat exchangers connected to the ahu secondary water circuits. The dx fan coils added for the select committee and conference rooms also discharge their heat into this circuit.

Groundwater is stored in a greywater tank for toilet flushing, with any excess discharging to the sewer. (Arup had permission to dump it into the Thames, but obtaining a legal right of access across Victoria Embankment proved difficult).

The resulting energy targets are certainly impressive: Arup aimed for 90 kWh/m$^2$ for gas and electricity with the gas-fired heating and hot water alone accounting for 51 kWh/m$^2$.

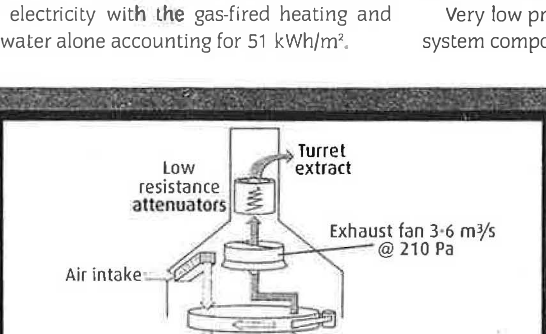
## Ventilation

The low velocity mechanical ventilation system pumps 100% outside air into the floor plates. Air is first drawn through the thermal wheels in each of the 14 ventilation turrets, humidified, filtered and cooled as required in the ahus, and then drawn down the outside of the building through sandwiched supply and extract ducts – 16 per turret. These structural bronze ducts, which run either side of the office windows, pump air into the floor void and thence through two displacement grilles in each office.

Very low pressure loss air handling and duct system components were selected to try and hit a specific fan power of 1 W/litre/s. The designers avoided long duct runs and minimised bends, duct expansions and control dampers.

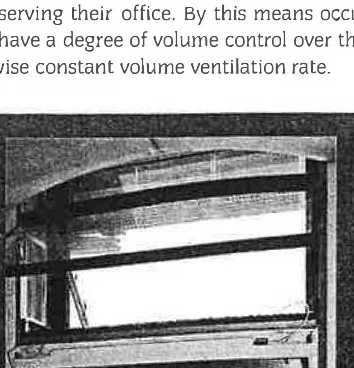
The total pressure generated by the supply and extract fans is claimed to be only 640 Pa, with a combined fan efficiency (fan, motor and inverter) of 65%. Typically the ahu face velocities are 1·20 m/s, with 0·65 m/s across the filters.

Although the entire floor plenum is pressurised, the occupants will be able to modulate a motorised damper in one of the two supply ducts serving their office. By this means occupants have a degree of volume control over the otherwise constant volume ventilation rate.




**LEFT, FIGURE 2: Schematic of the low velocity ventilation system at Portcullis House.**

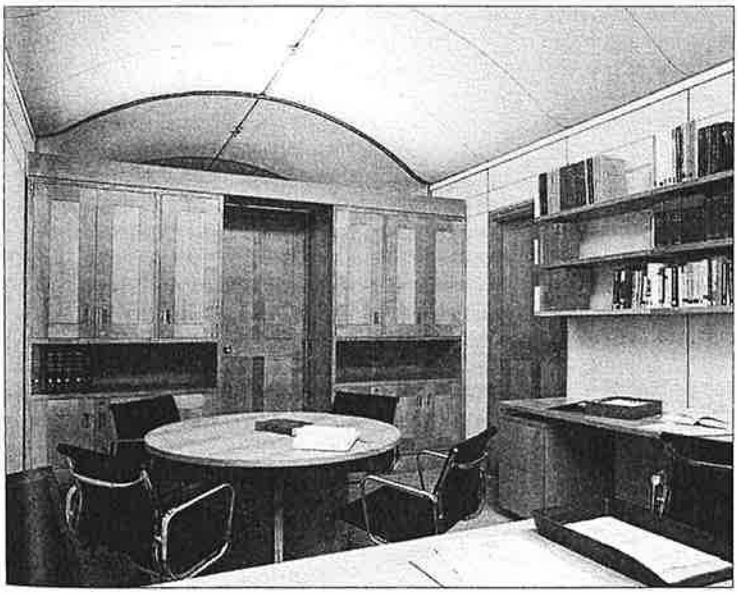
**RIGHT: The window arrangement uses a lightshelf to preserve room daylighting when the blinds are lowered to combat solar glare. This permits a larger glazed area because, without heat gain from electric lighting, the room can cope with more solar gain. This lightshelf has a corrugated reflective surface designed to maximise high altitude diffuse skylight reflections, while rejecting the lower altitude direct short wave radiation.**



Extract air is entrained into the outer of the two sandwiched ducts via a slot above the clerestory window, and back up to the rotary heat recuperator. There is no recirculation.

Conventional gas-fired condensing boilers handle the heating requirements in the offices and the underfloor heating circuit beneath the courtyard. A 70°C flow and 50°C return water flow regime is followed to ensure that the boilers remain in condensing mode. Of course, another advantage of a 20°C drop in temperature is it almost halves the amount of water needed to be circulated, and coupled with normal pipe sizes, lowers the pressure loss by a factor of four.

This also means that the head pressure required for the perimeter heating pumps is only 40 kPa, with a peak energy consumption of 450 W for each of the two duty pumps. The low pressure head also allows the 2-port valves to operate with a 1°C proportional band without the need for pressure reducing valves on each branch.



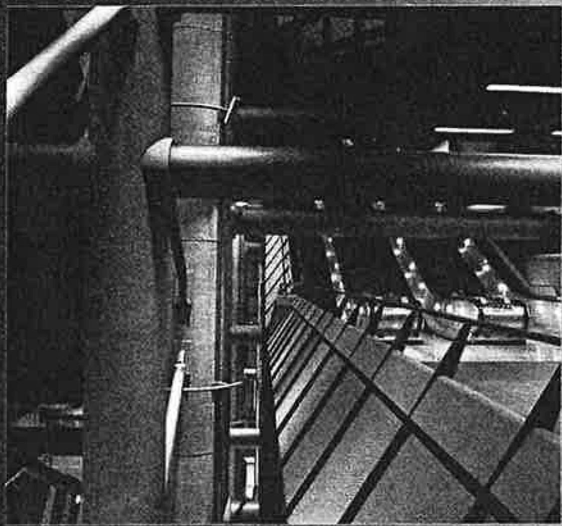
PHOTOGRAPH: RICHARD DAVIES

**A typical MPs office showing the pre-cast waveform slab. The manual controls for the occupants are extensive. Switches in the window reveal give control over the blinds, lighting levels, ventilation supply, and control over a two-port valve on a lthw radiant panel. Oak panelling is used extensively in the offices and corridors.**

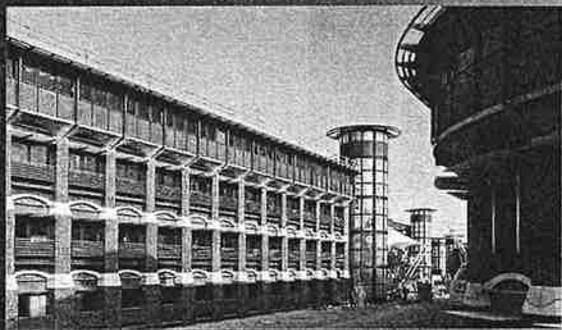
## Electrical services

As befitting a building with relatively simple m&e, the primary electrical servicing is straightforward. The same cannot be said of the IT systems which grew immensely during the contract.

Two 11 kV incomers provide power to two cast-resin 1000 kVA transformers. LV cables then run up the building's north-west core and secondary busbar riser, loop round the rooftop plantroom and then feed three other risers in each corner of the building. General power and lighting distribution boards feed three other busbars on each floor. Cabling then runs around



**ABOVE: The foundations for Portcullis House drop through the new ticket hall for Westminster tube station. Here, Hopkins' skeletal concrete frame combines with mezzanines, escalators and stark foot tunnels to create an Alienesque maze.**



### Nottingham foray

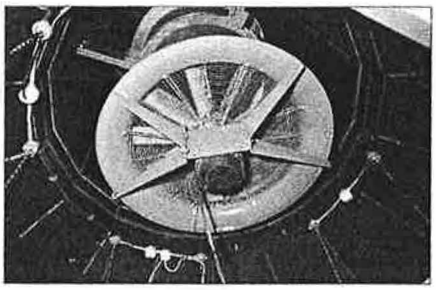
The architect and services consultant for Portcullis House have collaborated before, most notably on six headquarters buildings for the Inland Revenue in Nottingham. Completed over five years ago, the buildings were a testing ground for many of the ideas Michael Hopkins and Ove Arup were developing for Portcullis House.

"When we started out designing Portcullis House, we knew we wanted high quality finishes, materials and tolerances, and that prefabrication was a way of getting it," said Arup's director on the project, John Thornton. "Inland Revenue was really a test bed," he added. "In fact, the concept of prefabricating the stone piers for Portcullis House stemmed from experience at the Inland Revenue, where the brick piers were made at the same place the slabs were pre-cast."

The Inland Revenue hq also taught the designers the importance of cool radiant surfaces in improving occupants' perception of thermal comfort. While lower floors are heavyweight, the top floor is a lightweight steel structure.

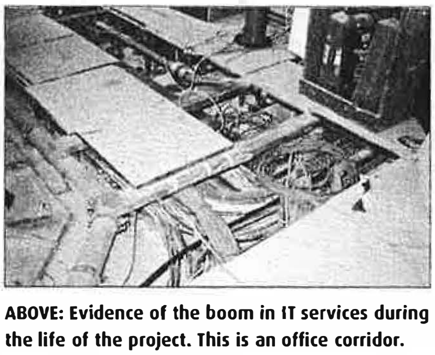
During the summer of 1996, temperatures on the top floor of Yorke House exceeded 27°C for 25 h, compared to 13 h on the second floor[1]. With no cool radiant surfaces to counteract the higher temperatures, occupants' on the top floor expressed far greater levels of thermal discomfort. As a consequence the designers of Portcullis House have provided concrete infill panels in the walls, along with exposed slabs and high mass floor tiles.

[1] *New Practice case study 114: The Inland Revenue headquarters*, BRECSU, March 2000.



**ABOVE: One of the 13 extract fans immediately above a 2·9 m diameter thermal wheel.**

**ABOVE: Michael Hopkins' architecture was designed to be in sympathy with that of Norman Scott, who designed the Houses of Parliament.**



**ABOVE: Evidence of the boom in IT services during the life of the project. This is an office corridor.**

a composite services racetrack beneath the corridor.

Given the absence of suspended ceilings, the trays not only carry the small power and lighting plug-in busbars, and security and communications cables, but also the heating and sprinkler pipework. Spur trays then branch off into the offices, the majority of the services making use of the 800 mm troughs created by the waveform slab.

Much data communications, sound and television cabling was added by specialist contractors, including the BBC, whose systems for the select committee rooms doubled the previous lighting and equipment loads. The trays in the floor voids, particularly in the corridors and committee rooms, are now packed to the brim.

The offices are served with conventional floor boxes set into the raised floor, and skirting mounted accessories which can be readily interchanged and relocated.

The burgeoning of security and data communications systems filled the cable containment, adding to power supplies. This included an extensive electronic signage and annunciation system to keep MPs alert of proceedings in the two Houses, an Intellikey electronic locking system for the MPs doors, and an extensive communications network for the televising of Select Committee meetings.

All these additions were incorporated into design sketches by Arup engineers, and then issued to Crown House Engineering and Kvaerner Rashleigh Weatherfoil, which imported the changes into the Sonata building model. 3D plots confirmed the services co-ordination.

The prefabricated double-skin facade created a tricky co-ordination issue for the lightning protection. The main conduction path is down the post-tensioning rods in the stonework, but where the latter connects to the slab, continuity is broken by insulating bushes and other measures incorporated to prevent bi-metallic corrosion. The engineers used braided connections to bridge insulated connections and bonded the lighting protection down the building.

## Lighting

Most of the lighting in the offices and public areas was designed for the architect by the Austrian firm Christian Bartenbach, with Ove Arup & Partners designing the circuits, emergency fittings and controls, and lighting in the catering and ancillary areas.

Lighting in the offices is indirect to the slab, with fluorescent fittings within the internal lightshelf by the window and in the joinery above the doors. By lighting the rooms in this way, the designer has got pretty close to the patterns produced by daylight.

The light sources are mostly compact fluorescents lamps (cfl), with two 55 W units and one 36 W unit in the light shelf. (Metal halide was initially proposed, but would not have been controllable). The cfl lamps are progressively dimmed by a Delmatic system as daylight levels increase, but the user has full manual override from a panel in the window reveal. This also gives control over the blinds, the radiant heating panel, and the supply air rate.

Lighting in the courtyard is worthy of special mention. Special diamond shaped prismatic deflectors are suspended in groups from the timber courtyard roof. These reflect and scatter the light from six 2000 W metal halide projectors slung from the the concrete transfer arches supported off the building s structural columns.

Lighting in the conference rooms and select committee rooms is designed with the needs of television cameras in mind. This is mostly in the form of compact fluorescent lamps and metal halide lamps in pendant fittings to get the right balance between horizontal and vertical illumination. (Further details on the specialist lighting will be covered by a forthcoming issue of *BS/ s* sister magazine, *Light & Lighting*).

## Fire engineering

The fire engineering strategy is not particularly complicated, although the interfaces with other systems certainly are. While not a particularly large, tall or deep building, Portcullis House is heavily cellularised, and there are comprehensive catering, dining and storage spaces, all of which present a fire hazard.

As a result the building largely conforms to *Section 20* requirements. It is fully sprinklered along with a Surefire automatic fire detection and alarm system operating on a double knock strategy. With the exception of the catering spaces and the plantrooms, the entire building has been treated as one fire compartment.

Given that the void beneath the raised floors is a pressurised cavity for the ventilation system, a fire could cause smoke to invade all offices on a floor. To reduce this all floors are divided into six zones by underfloor fire barriers (see figure 1, page 24). Circulation spaces are kept largely free from doors, and where these are required in the cores they are held back by electromagnetic holders. Two of the four lift shafts are designed to fire-fighting standards.

Sprinklers are provided to all areas except the main switchrooms, diesel storage room, stairs and toilet areas. Generally they are of the exposed head type in the offices, dropped through the pre-cast ceiling panels. Again, the sprinklers are zoned to match the fire barriers in the floor void.

The courtyard is protected by motorised fire valves and long throw sprinklers, the latter operated by an infrared detection system based on flame detectors. As one might expect, the detection zones in the courtyard overlap. As a fire develops to a 100 kW size the threshold for the first knock detection it will tend to be more prominent in one of the courtyard s zones. Once the Cerberus system has decided which zone takes the initiative, it nominates which sprinklers will operate. These will flood the zone once the first knock period has been exceeded.

Tests by the designers showed that, even with a fire developing on the boundary of several zones, the sprinkler spray will extend beyond the boundary line. The system was designed for an 8 m throw, but witnessed experiments demonstrated a 10 m throw.

The designers had to find a way of covering areas which will be shaded by internal planting, particularly given the potential for dry leaves to be ignited by a cigarette butt or a carelessly discarded match. Modelling reassured the designers that tree foliage would not be too dense to prevent the operation of flame detectors. Though the water sprays would be interrupted by the plant canopy, preventing complete extinguishing, they should control the growth of a fire.

## Costs and conclusions

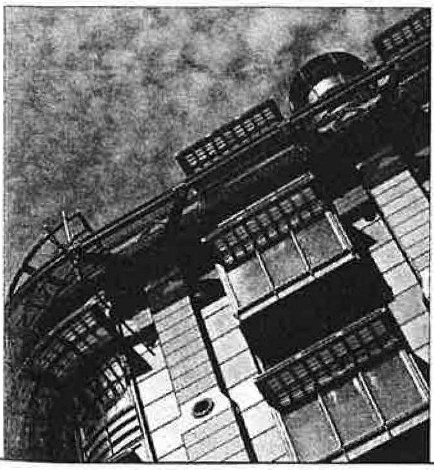
The project's cost overrun is a matter of public record. The House approved the scheme in 1993 at an estimated cost of £165 million. Once inflation was factored in the forecast came in somewhere around £216-227 million.

As of April 2000, the final cost stood at £230 million. About £4 million of this is due to client variations, and £10 million through the late completion of the Jubilee Line Extension and the rebuilding of Westminster tube station on which Portcullis House now sits. With political adroitness the client is therefore claiming a £15 million saving on the cost forecast.

At the time of writing the final costs had not been agreed – rumour hath it that the contractors have some major claims outstanding due to client variations. But if the tender costs are any yardstick, the direct building services costs for the building will only be 5-10% of the total. However, that does include a slice of the £30 million fenestration with its integrated ductwork and solar control devices.

The irrefutable fact is that each MPs office has cost the British taxpayer over £1 million. Whether this proves a wise investment depends on the life of the building, its maintenance costs and its energy performance. And, of course, whether you consider a stable democracy as something worth celebrating.

In many ways Portcullis House is a testament to the ingenuity of British architects and engineers. The need to lavish that on the egos of politicians does, however, stretch the credulity of this author just a tad.



## Portcullis House, Bridge Street, Westminster, London SW1

**Client**
Parliamentary Works Directorate
**Project manager**
Schal International Management
**Management contractor**
Laing Management
**Architect**
Michael Hopkins & Partners
**Structural and m&e consulting engineer**
Ove Arup & Partners
**Acoustic consultant**
Arup Acoustics
**Fire engineering**
Arup Fire
**Quantity surveyor**
Gardiner & Theobald
**Electrical contractor**
Kvaerner Rashleigh Weatherfoil
**Mechanical contractor**
Crown House Engineering
**Commissioning contractor**
CML

**Mechanical suppliers**
AHUs: Colt Holland
Boilers: Broag
Calorifiers: IMI Rother
Communications room cooling: Denco
Control valves: Landis & Staefa, Samson
Dampers: Actionair
Dry riser inlet: Norsen
Ductwork: Hargreaves
Extract fans: Colt Holland, Matthews & Yates
Fan coil units: Holland Heating, Energy Technique
Grilled tube: Kampmann
Heat exchangers: Cetatherm
Humidifiers: Stulz
Louvres: Royair
Pumps: Grundfos
Radiant panels: Comyn Ching
Raised floors: Durabella
Sound attenuation: Parr Acoustics
Underfloor heating: Warmafloor
Water heaters: Zip

**Electrical suppliers**
BEMS: Landis & Staefa
CCTV: Security Design Associates
Cable management: Arena
Controls: Landis & Staefa
Electrical distribution: Ellison, Barduct, Merlin Gerin
Electrical accessories: Wadsworth
Emergency lighting: Cooper Menvier
Escalators: Otis
Fire alarm/detection: Surefire
Floor boxes: Ackermann
HV switchgear: LEB
Lifts: Thyssen
Lighting controls: Delmatic
Luminaires: Concord, Erco, Sill, Creedlight, Crompton
LV switchgear: Ellison
Motor control centres: ISO Engineering
Power busbar: Barduct
Public address: Surefire
Standby generation: Cummins
Water leakage detection: JAM

**Engineering data**
Gross floor area (gfa): 23 000 $m^2$
Net usable area: 16 600 $m^2$
Plantrooms: 3000 $m^2$
Offices: 13 500 $m^2$
Amenity & dining: 300 $m^2$
Atrium (courtyard): 1600 $m^2$

**Contract details:**
Tender date: March 1995
Tender system: European open tender
Form of contract: PWD special trade contract
*Contract period*
☐ Off-site: 81 weeks
☐ On-site: 84 weeks
National Engineering Specification used: No

**Target energy use (gfa)**
Gas & electricity: 90 kWh/$m^2$/y (offices only)
$CO_2$ target: 750 tonnes/y
*Energy breakdown*
☐ Heating & hot water: 51 kWh/$m^2$/y
☐ Fans and pumps: 13 kWh/$m^2$/y
☐ Refrigeration: 0 kWh/$m^2$/y
☐ Lighting: 15 kWh/$m^2$/y
☐ Small power: 8 kWh/$m^2$/y
☐ Others systems: 3 kWh/$m^2$/y
Typical occupied hours: 50 h/week
BREEAM rating: No

**External design conditions**
Winter: -1°C/Sat
Summer (non a/c) 28°C db, 19°C wb

**Internal design conditions**
Winter: 20°C min, 30%rh min
Summer: 22°C ±2°C

**Primary air volumes**
Total fan power: 0·075 kW/$m^2$
Design air supply: 80 litres/s (4 litres/s/$m^2$)
*Primary air*
☐ Supply: 13 ahus at 5 $m^3$/s
☐ Extract: 13 ahus at 4·75 $m^3$/s
*Catering*
☐ Supply: 7·26 $m^3$/s
☐ Extract: 8·9 $m^3$/s

**Ventilation**
Scheduled supply air temperature: 20°C
Office temperatures: 20°C min, 24°C max
Fresh air: 100% min (4 litres/s/$m^2$)
Filtration: EU7

**U-values (W/$m^2$K)**
Walls: 0·27
Floor: 1·0
Roof: 1·0
External facade: 0·27
*Glazing*
☐ Lower triple pane: 1·5
☐ Upper triple clerestory: 1·2
☐ Triple bay window: 1·89

**Structural details**
Slab thickness: 125 mm (min)
Side wall thickness: 50 mm
Floor tiles: 40 mm (concrete filled)

**Occupancy**
Offices: 10 persons/$m^2$
Meeting rooms: 2·5 persons/$m^2$
Select committee rooms: 1·5 persons/$m^2$

**Noise levels**
Offices: NR 35
Meeting rooms: NR 30
Select committee rooms: NR 30
Toilet and circulation: NR 40

**Loads**
Installed heating load: 1440 MW
Installed cooling load: 1·1 MW (borehole system)
Fan power: 0·068 W/litre/s

**Distribution circuits**
LTHW: 70°C flow, 50°C return
DHWS: 65°C flow, 55°C return
Borehole storage: 330 000 litres
Bore water temperature: 13·4°C

**Electrical supply**
2 x 11 kVA transformers
500 kVA diesel standby

**Lighting**
Types: various compact fluorescent, metal halide
Courtyard indirect lighting: 6 x 2000 W metal halide
Lighting load: 260 kW
Offices lighting load: 16·6 W/$m^2$
Offices efficacy: 5·9 W/$m^2$/100 lux
*Lux levels*
☐ Offices: 350
☐ Conference: 300 (nominal)
☐ Kitchen: 500
☐ Toilets: 100
☐ Circulation: 150

**Lifts**
5 x 11 person @ 1·6 m/s
1 x 13 person @ 1·6 m/s
Fire-fighting: 2 x 11 person @ 1·6 m/s
2 x 630 kg kitchen lifts @ 0·63 m/s

**Costs**
Estimated total cost: £230 million

**M&E tender costs***
Mechanical services: £9 391 000
Electrical services: £3 083 261

*Prices are at the tender base date of December 1995 when the provisional building cost was £160 million. Naturally these sums will be subject to inflationary pressures, client variations and additional works.