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1 Finsbury Avenue, London: Phase 1

Arup Associates Group 2

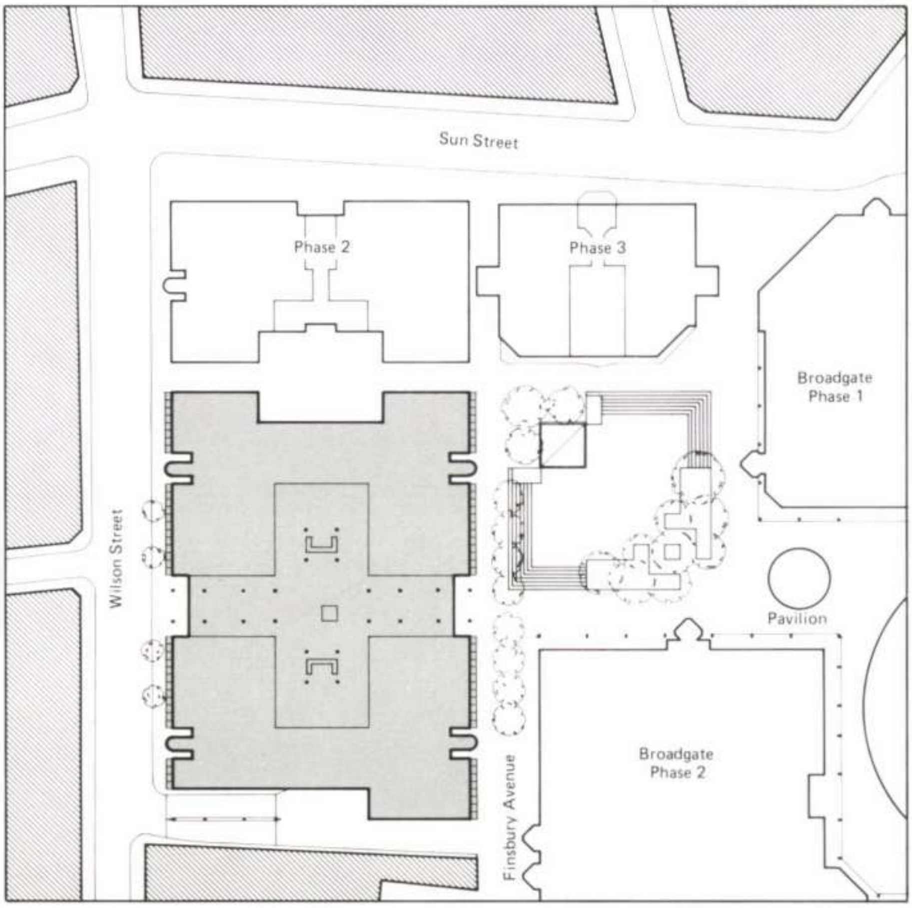
Speculative office buildings in Britain are usually horrors, planned for the meanest sort of 'efficiency' and brazen in their vulgar disregard for context.

One Finsbury Avenue is very different.

Though a huge 300,000 sq ft development, it nestles its eight-storey bulk remarkably gently into its smaller-scale surroundings on the eastern fringe of the City of London. Yet it is more than an exercise in shoe-horning in.

The design goes to considerable lengths to achieve a striking identity and sense of generous calm within; and the building is the first phase of a planned new urban place — or rather network of places.

Peter Buchanan,
The Architectural Review, May 1985



Location plan for Phase 1

One Finsbury Avenue is part of an office development in the City of London for Rosehaugh Greycoat Estates Ltd. which, when completed, will provide a total of 50,000m^2 of built space. It is designed to be constructed in three phases and has been planned to form two sides of a new city square. The other two sides will be contained by the buildings on the Broadgate site which are currently under construction.

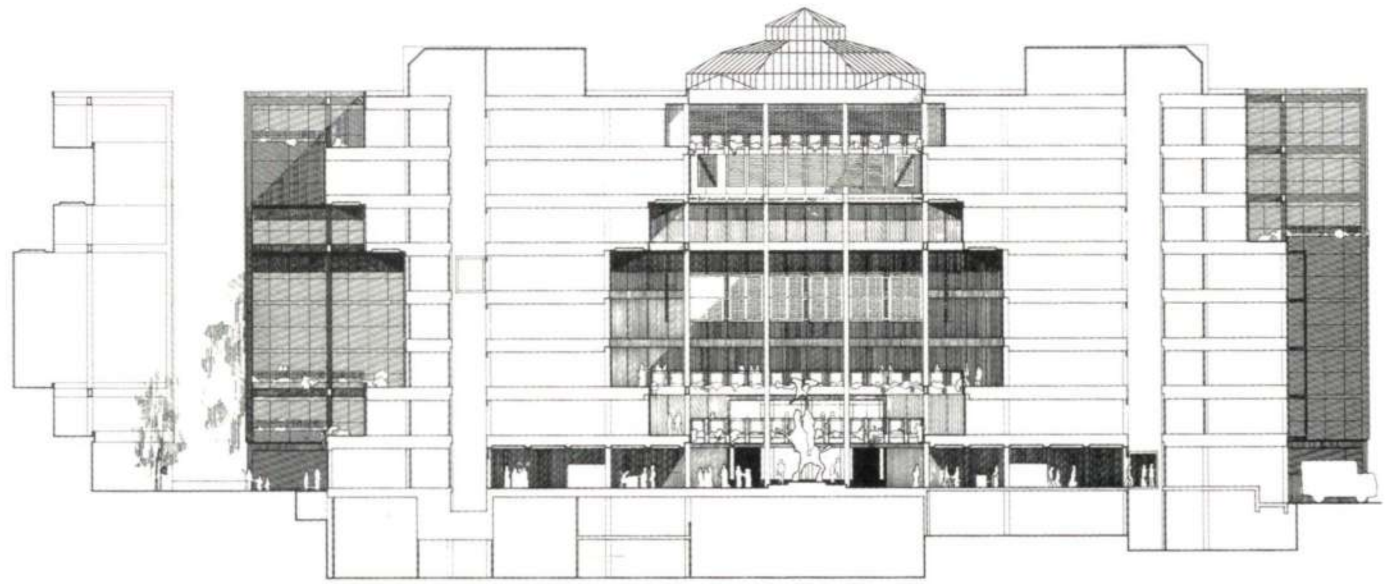
In addition to offices the total development will include shops, a restaurant, pubs and amenities. This first phase contains 25,000m^2 of rentable office space together with a small leisure centre with sports facilities which is planned in the basement.

Eight storeys high, with stepped back landscaped terraces at the fifth and sixth floor levels, the building is planned around a full height central atrium space capped with a large glazed dome and overhung with planted balconies. There are two major entrances, one from Wilson Street and one from the new pedestrian square which was created as an integral part of the project. Both entrances lead into the central atrium. Two circulation cores give access to the large office floor areas of over 3,000m^2 each. Generally, the building is designed to benefit as much as possible from natural daylight, while at the same time being very economical in its use of energy.

The client's brief required a design for a building which was efficiently planned, functional, cost-effective and of high quality to attract potential tenants in a highly competitive letting market. The building, which is air-conditioned using a variable air volume system, has a steel frame and metal deck structure supported on large diameter bored piles. The glazed curtain walling is heated by a patented method which circulates hot water through mullions and transomes. External shading devices protect the building from the effects of solar gain, and at the same time the bronze anodized aluminium sunscreens also provide maintenance access to the facades.

Part of the solution to the brief was the need for an assured early completion of the building, and the choice of steel as the material for the structural frame reflects this need. This frame was designed using rolled UB and UC sections in Grades 43B and 50B steel, and in order to achieve maximum economy the design was based on a simple rectilinear form with repetitive elements and simple bolted connections. Horizontal stability is achieved by diagonally braced frames in the core areas. Made up of a total of 1,500 tonnes of steel the structural frame was erected in 13 weeks.

The floor slab is 130mm thick overall, constructed on 1.1mm profiled steel sheeting spanning 3.0m and using a lightweight aggregate pumped concrete mix. The concrete slab acts compositely with the profiled steel sheeting as well as the frame beams.



1 Finsbury Avenue: North-south section

The staircases were fabricated off site in specially designed folded plate pans with 16mm thick flat stringers. Erected at the same time as the main frame, these provided access for construction operatives.

Within the internal air-conditioned office environment the steel frame has not been treated other than lightly cleaned before fabrication. Externally the building envelope steel was cased in concrete and wherever possible beams were pre-encased at the fabrication works. Fire protection above the suspended ceiling is provided by a sprayed vermiculite cement, whilst within the habitable areas it is protected by steel sheet faced board protection.

The atrium roof structure is an octagonal-sided dome of rectangular hollow section steelwork. The steelwork and glazing design were integrated so that all glazing bars are structural members. This allowed smaller sections to be used to create a spider's web effect. Maintenance of the underside of the roof is carried out from a rotating tubular steel gantry with mesh sides.

This gantry support can be wound around a circular rail by hand. The centre support hanger and two thrust bearings form a maintenance-free pivot.

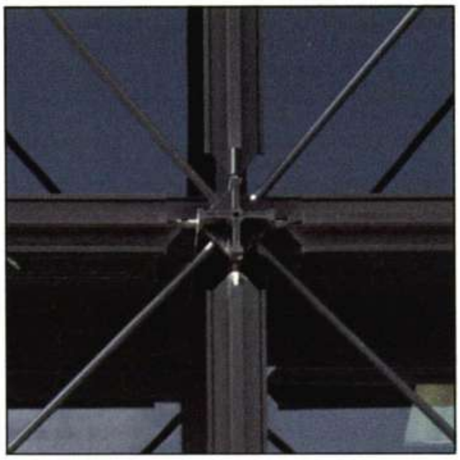
A subsequent phase of building is currently in detailed design and when all of the three future phases are constructed, an additional open 'atrium' will have been created to enhance the existing pedestrian route. This new area, typical of the spaces found in the City of London, will be surrounded by a variety of shops, restaurants and pubs which are included as a part of the development.

Arup Associates were appointed in late 1981, the scheme design was approved in March 1982 and construction began at the end of 1982.

The building was completed in September 1984 after a 21-month construction period at a total cost of approximately £20m.

This first phase of development at One Finsbury Avenue received the Structural Steel Design Award and the Financial Times Architecture at Work Award in 1985.

Credits
Client:
Rosehaugh Greycoat Estates Ltd.
Architects, engineers and quantity surveyors:
Arup Associates
Management contractor:
Laing Management Contracting Ltd.
Photos:
Peter Cook and Arup Associates




Patscenter

Ian Gardner

Architect: Richard Rogers & Partners

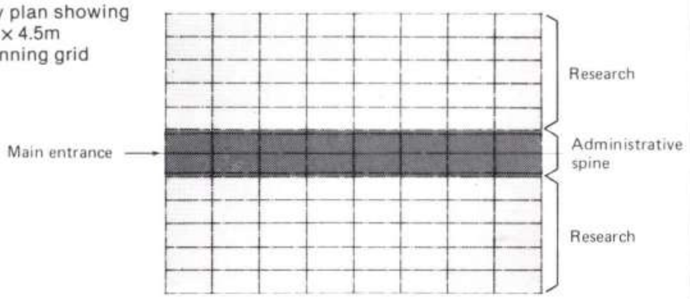
Introduction

Patscenter is a new research facility for PA Technology on the outskirts of Princeton, a university town which is close to the American eastern seaboard and approximately mid-way between New York and Washington. Early in 1982, management and technology consultants, PA Technology, were seeking to rationalize their American operations and while doing so gain a more distinctive image. They chose to achieve this by appointing the architect Richard Rogers to provide them with a laboratory and corporate facility with the potential for easy growth. Richard Rogers invited us to assist in the development of the building brief, planning and scheme design; providing both structural and building services engineering input.

Architects and consulting engineers require a state licence to practice in the USA. Neither ourselves nor Richard Rogers had the appropriate licences for the State of New Jersey and, as non-residents, we were not eligible to apply for them. For the architect this was overcome by Richard Rogers & Partners working in association with a small firm of New Jersey architects. For ourselves it was established that we should hand over the project to separate structural and building services engineers in New York once the scheme design and project budget had been approved by the client. Our involvement was therefore to end with the American engineers' acceptance of our scheme design.

The success of a building such as Patscenter with its highly expressed structure and services is very dependent on the quality and consistency of their detailing. This was recognized in our brief, which was extended beyond the basic scheme design to include the development in principle of the key engineering details.

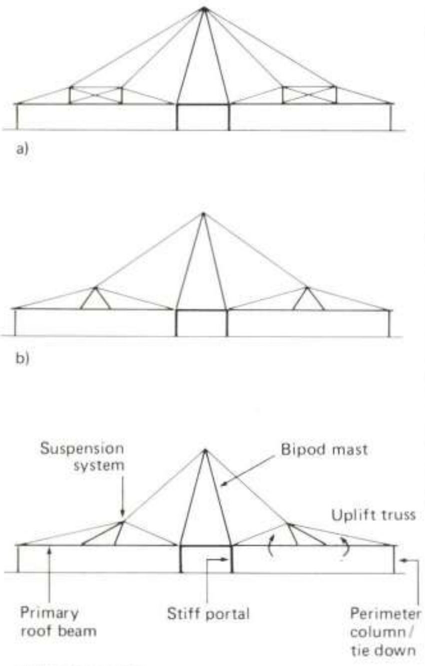
Key plan showing 9m x 4.5m planning grid



1.

2. New structure being assembled (Photo: Ram Ahronov, Project Architect)

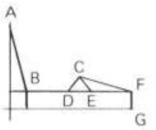
3. View of central spine (Photo: Otto Baitz)



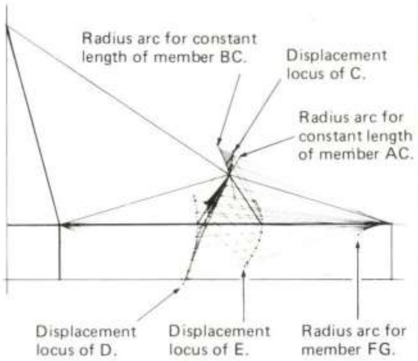
c) Final geometry

Evolution of structural frame

5.

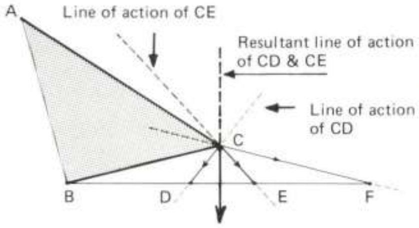


The members shown above remain fixed in length in the displacement locus shown below.

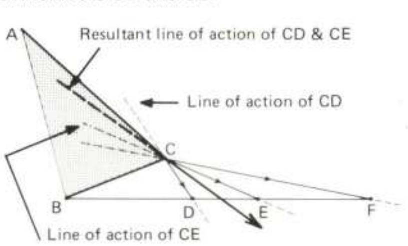


Plot of node displacements for one of the sub-assemblies considered. Shaded areas show that either member AC or member BC would need to increase in length.

6.



a) The lines of action of load-carrying members CD and CE are both outside the triangle enclosed by members AC and BC. The resultant line of action must consequently also be outside the enclosed triangle. It is therefore not possible for member BC to act in tension under the action of members CD and CE.



b) Although the lines of action of load-carrying members CD and CE are not both inside the triangle enclosed by members AC and BC, their resultant line of action is inside the enclosed triangle. Members AC and BC are therefore both tension members.

7.

4. Rooftop view showing external services plant (Photo: Otto Baitz)

Building layout and concept

The nature of the research projects which PA Technology are appointed to carry out varies considerably. Their work involves both desk-based studies and practical experimentation; both office areas and laboratories are therefore required. However, the mix of spaces and the layout of rooms needs to be adaptable to enable different combinations of research commissions to be undertaken.

Other less flexible areas are also required. Early during the briefing stage, specific areas were scheduled for central administration offices, computing, library, reception and conference facilities.

This combination of flexible research space and less flexible central facilities, together with the client's expressed desire that the building form should be readily extendable, determined the concept for the building's internal planning. The central facilities are located in a 9.0m wide spine which also duplicates as the principal circulation zone. On either side of this spine two large single-storey enclosures, each 72m long × 22.5m wide, provide the research space. To achieve the required flexibility these research areas are organized on a 9.0m × 4.5m planning grid and are column-free. All vertical structure is contained within the central spine, or is external to the building envelope.

The desired layouts of offices and laboratories have been formed by erecting free-standing demountable enclosures within the completed building. These subdivide the two large research spaces into combinations of rooms, generally using the discipline of the planning grid.

The resulting building plan is essentially linear with a dominant symmetry about the spine (Fig. 1). From the outset the architect was keen that this should be reflected in the building form. Richard Rogers felt that the building should be perceived as a series of slices, each representing a one bay module. Further slices could thus be added at a later date without impairing the concept and visual integrity of the building.

The structure is externally expressed to achieve the column-free research enclosures and, equally importantly, to provide the main architectural theme for the building. The large single-storey building, with its general roof level only 4.5m above ground level, is enlivened by the deliberately dramatic steelwork frame (Fig. 2). Major services plant is suspended above the central spine keeping it clear of the main building envelope. The building services also, therefore, contribute to the architectural image (Figs. 3 and 4).

Structural frame

The structure comprises a row of nine identical frames spaced at 9.0m intervals along the building length. Each frame has a stiff 7.5m wide portal within the central spine, above which extends a rigid 15m high bipod mast. Inclined tension members splay out symmetrically from the top of this mast to provide mid-span support for the main roof beams over the research enclosures.

Whilst the geometry of the bipod masts and their supporting portal was established early in the project, it took longer for the geometry of the tension system to be developed (Fig. 5). From the start we requested that the suspension system must incorporate a truss to resist wind uplift, and thus avoid the inefficiency of having to ballast the roof down with sufficient dead weight to maintain always a net downwards loading. The initial scheme (Fig. 5a) had twinned inclined hangers on each side of the mast connecting to the roof system at ⅓ span points. This was originally based on clear roof spans of 27m. However, for the 24m roof spans which emerged from the internal planning, this arrangement was considered over-elaborate and the outer hangers were found to be making very little contribution to the roof support.

A hanger with an inclination to the horizontal of less than about 30° does little to prevent vertical deflection of the roof and, at such a small inclination, the hanger tends to sag visibly under its own weight. Its axial stiffness, initially at any rate, is therefore that of a shallow catenary rather than a direct tension member. Also, with a central mast arrangement such as the Patscenter building, the horizontal component arising from the inclined hangers is resolved at roof level by the primary roof beams carrying compression forces back to the stiff spine. The outer hangers of small inclination tended to put an unacceptably high compression component into the main roof beams.

In scaling down the roof suspension system to one which seemed more appropriate for the 24m spans the outer hangers were removed (Fig. 5b). However, the very clear and symmetrical arrangement for the wind uplift truss over each roof span, which was liked by the architects at this stage, caused us further problems.

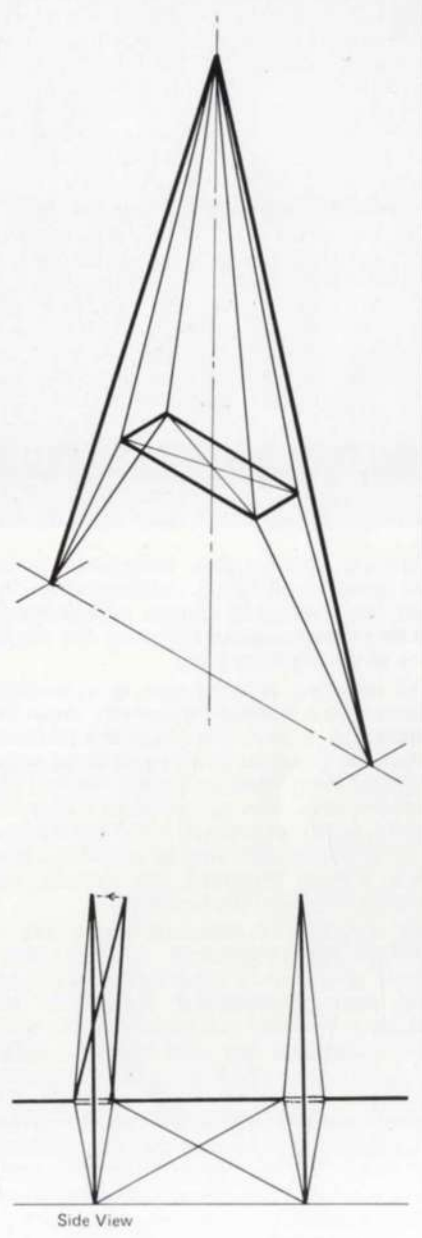
We approached this new geometry by first convincing ourselves that, even with pinned joints at the main roof beam suspension points, the system was not a mechanism — it would have been absurd to have the whole stayed-roof system dependent on the bending stiffness of the primary beams. Assessing whether a structure containing a high proportion of tension-only members is statically determinate is not always immediately obvious. We chose the simple graphical method of plotting the loci of node displacements for rigid sub-assemblies and then assessing whether the omitted tension members would have had to increase in length to follow these loci (Fig. 6). If a displacement locus was possible with all omitted tension members either maintaining or reducing their original length, then the system would clearly be a mechanism.

Although the system was not a mechanism it proved highly inefficient. To prevent lateral displacement of node C much of the tension in member AC had to continue as a tension in member CF. This both reduced the vertical upward reaction available at node C to take the roof loadings and put large compression loads into the roof beam at node F. Also member BC could only be prevented from going slack by enormously pre-tensioning member CF (Fig. 7a). Again since further tension in member CF resulted in increased compression in the roof beam, this would have been counter-productive.

Inclining the central triangle CDE simultaneously solved all of these problems (Fig. 7b) and provided the final as-built geometry (Fig. 5c). The main hanger became more steeply inclined, thus beneficially reducing its horizontal component. The resultant line

8. Side view of building at night (Photo: Otto Baitz)

9a) Platform support hangers
in the same plane as the mast



9b) Final mast
and platform support geometry

of action of members CD and CE fell within the enclosed triangle ABC, automatically keeping member BC taut. It also became possible to minimize the bending moments induced in the primary roof beam by initially setting the resultant of CD and CE just within the line of AC. Fine tuning is then achieved by controlling tension in member CF to pull the resultant further round.

The uplift wind truss, although possibly less clearly stated, is still provided by this final geometry. Members CD and CE are required to act as compression struts when there is a net uplift loading, but their lengths have not been greatly increased relative to the previous geometry. They therefore remain as sufficiently slender tubes for the overall tensile effect of the suspension system to prevail. In fact, the tensile effect tends to be enhanced by the asymmetry of triangle CDE with the system looking more taut, and the various members all appearing to have been drawn upwards towards the masthead.

Mast stability

Longitudinal stability of the row of nine bipod masts is provided indirectly by making use of the suspended services plant platforms and their support hangers. This has enabled the structure, when viewed from the side elevation, to appear relatively simple and uncluttered. The masts project upwards at 9.0m centres independently of one another, conveying the image of the building being segmental with a bay-by-bay add-on flexibility (Fig. 8).

Out of plane loadings on the masts and suspension systems are transmitted down to the main roof level via the structural chassis of the services platforms. All horizontal forces associated with the vertical support systems are then resolved at roof level and transferred to ground level through the combination of central portals and diagonal bracing at the ends and sides of the building.

This solution for the longitudinal stability was not immediately arrived at. We started by proposing diagonal cross-bracing between the masts along the building length, but the architects were keen to preserve the planarity of the main roof suspension systems. They would not accept longitudinal members connecting to the bipod masts; at least not above the services plant where they could be seen. We did not want to introduce restraint at low level to the bipod masts since this would introduce bending stresses and compromise their behaviour as simple axial struts.

10. Silhouette of masts (Photo: Otto Baitz)

An apparently unrelated design decision solved our dilemma. The architects decided to light naturally the central spine with a skylight and to do this the roof-mounted services were raised clear of the roof onto services platforms, continuous along the length of the building. It was obvious that these platforms should be suspended from the bipod masts since they further justified the need for the masts. This was done using hangers from the mastheads. Cross-bracing the services platforms down to the main roof level would prevent them from displacing longitudinally, and we realized that they could thus be used to stabilize indirectly the masts.

If the platform support hangers were in the same vertical plane as the bipod mast a stable equilibrium system resulted (Fig. 9a). As the mast rotated under the influence of out of plane loading a restoring force was mobilized by the change in geometry of the system. Although the system had no initial stiffness, the rate of gain of lateral stiffness was rapid. We decided to anticipate this gain and by presetting the platform support hangers at relatively slender angles to the bipod mast, obtained the final mast geometry (Figs. 9b and 10).

Interestingly, therefore, whilst the services platforms are held in place by the bipod masts, it is these same platforms which prevent the masts from toppling over. Without the building services plant there would be no requirement for the platforms and hence no mast stability system. Thus the building services help to justify the structure and vice versa. Also at no point do the horizontal platforms connect directly to the bipod members. This is emphasized in the completed building by the different colour paint finishes, to maintain the visual clarity of the simple bipod masts transmitting the building's weight down towards the ground.

Construction details

The bulk of the steel weight is in standard rolled I-sections, with only some special visible external elements being designed in non-conventional rods and pin-ended columns. However, the rods, hollow section columns and even the clevises and turnbuckles were selected from the American Institute of Steel Construction standard products. This was important in the environment of the American construction industry which penalizes non-conventional construction heavily.

The only elements uniquely made for the project are the annular node plates. These were chosen to avoid complex castings and to enable the standard clevises to be used at the ends of all tension rods. During the scheme design, we proposed that joint instability at the mast heads should be overcome by the use of twin bolts for the bipod connections (Fig. 11). However, this detail was later improved by using one large bolt which can be seen and one small bolt which cannot (Fig. 12). Tension rods were selected in preference to cables because of their higher modulus of elasticity and because they were easier to paint.

A lightweight metal decking roof is supported by secondary beams at 4.5m centres, which span between the main roof beams.

These main beams are below the roof and are continuous over their 24m length. Profiled lug plates welded to the top of the main beams project through the roof deck to connect to the external suspension system (Fig. 11). The overall weight of structural steelwork equates to about 45kg/m^2.

The building floor is a simple power-floated ground slab, with a local perimeter thickening and other internal longitudinal thickenings to accommodate underfloor piped services channels. In certain areas a flush floor trunking is set into the floor on a regular grid. Pad foundations bearing on undisturbed natural sands are used for the main structure.

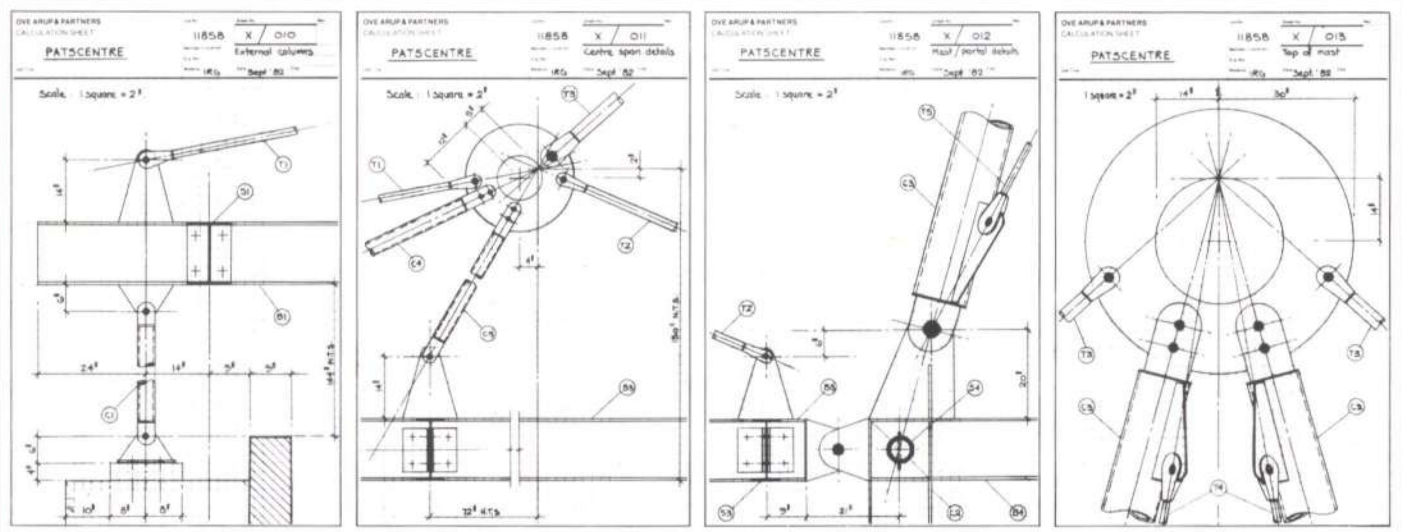
Cladding

New buildings are required to have cladding envelopes which satisfy criteria relating to energy efficiency, as defined by the American ASHRAE 90/75 code. These relate to thermal transmission, light transmission and solar gains; with certain trade-offs permitted between roof and walls depending on their particular characteristics.

The architects were keen for the perimeter wall cladding to contain as much glazing as possible, and we undertook energy and daylight studies to identify the scope for realistic trade-offs. For various walling systems, with different combinations of glazed area and insulation performance, the studies identified the required performance of the roof insulation.

We were also concerned that large glazing areas would constitute a glare source with unacceptable contrast levels between perimeter and interior zones of the research enclosures. Overhang shading studies were therefore undertaken (Fig. 13).

A successful compromise was reached by the use of a Kalwall translucent cladding system. This proprietary system comprises a sandwich panel formed by bonding two specially formulated, light transmitting, fibreglass sheets to either side of an interlocked aluminium grid frame. For maximum light transmission the gap between the sheets is left empty. To increase the thermal insulation the gap is filled with special inserts of translucent fibreglass. These inserts are fitted within the aluminium grid frame and their density is selected to achieve the required insulation and light transmission. The overall panel thickness is



11. Early concept sketches for structural connections

12. Centreline view of mast structure (Photo: Otto Baitz)

70mm. Panels arrived on site set into 1.5m wide modular frames of full storey height.

Whilst the introduction of the central spine skylight helped the structural design it further complicated the building envelope analysis. Studies were done to assess the shading provided by the external ducts to establish a preferred arrangement for ducts and skylight, and the energy trade-offs between walls and roof were reassessed. The Kalwall specification was set accordingly; providing 20% clear glazing area with the remaining area having a 17% light transmission and a 1.3W/m^2°C U-value. From inside the building the overall effect is somewhat akin to that of the Japanese paper screen (Figs. 14 and 15).

Services

Patscenter is a highly serviced building of approximately 4000m^2 floor area. The occupied space is entirely on the one ground floor level. At scheme stage we were asked to allow for a comprehensive range of services to be incorporated (Table 1). The main task, therefore, was to establish the method of horizontal services distribution.

Table 1

The following services are provided:

Air-conditioning
Ventilation
Fume hood exhaust
Industrial hood exhaust
Compressed air
Towns gas
Hot water
Cold water
Heating
Electrical power busbar and trunking
Communication trunking
Foul drainage
Surface water drainage
Laboratory waste drainage
Heat detectors
Fire alarms
Sprinklers
Lighting
External lighting
Emergency lighting
Lightning protection

The planning concept of the central spine provides an ideal route for primary services distribution and enables major plant to be located centrally without impeding the use of the building. Mechanical and electrical plant are located at ground floor level adjacent to the spine. Air handling and condenser plant are located on the platforms above the spine. The two research enclosures are equally sized and on either side of the spine, so both plant and primary distribution are effectively placed at the centre of services load and can take full benefit from any load diversities. The bulky primary air ductwork is external to the building envelope whilst the primary electrical and piped services are at high level within the spine (Fig. 16). The absence of specialist research activities within the spine ensures primary services are readily accessible for maintenance.

Lateral feeders running internally at high level provide the secondary distribution into the research enclosures. In these areas an integrated zoning strategy has been evolved for the services and building (Fig. 17). Such a strategy determines a fixed zone or route for each service or band of services, with none being allowed into another's zone. It ensures that all services will in fact fit into the building, standardizes installation details, and greatly assists maintenance.

The very rigid discipline which this zoning strategy imposes might be thought to inhibit adaptability. However, the reverse is true. By applying the same zoning strategy throughout the building a space is allocated for every service in each planning module. This is the case whether or not all of the services are initially installed in every module. Therefore, if the usage of an area is changed and in consequence requires a previously omitted service to be installed, then this is always possible because a distribution philosophy and route already exists for the service.

One further advantage of the zoning strategy is that the rigid discipline makes it possible for the services to be expressed. It was known from the start that the engineering services were to contribute to the architectural image of the building, both inside and out. Without precise control over the locations of all services it was unlikely that they would be visually acceptable.

HVAC

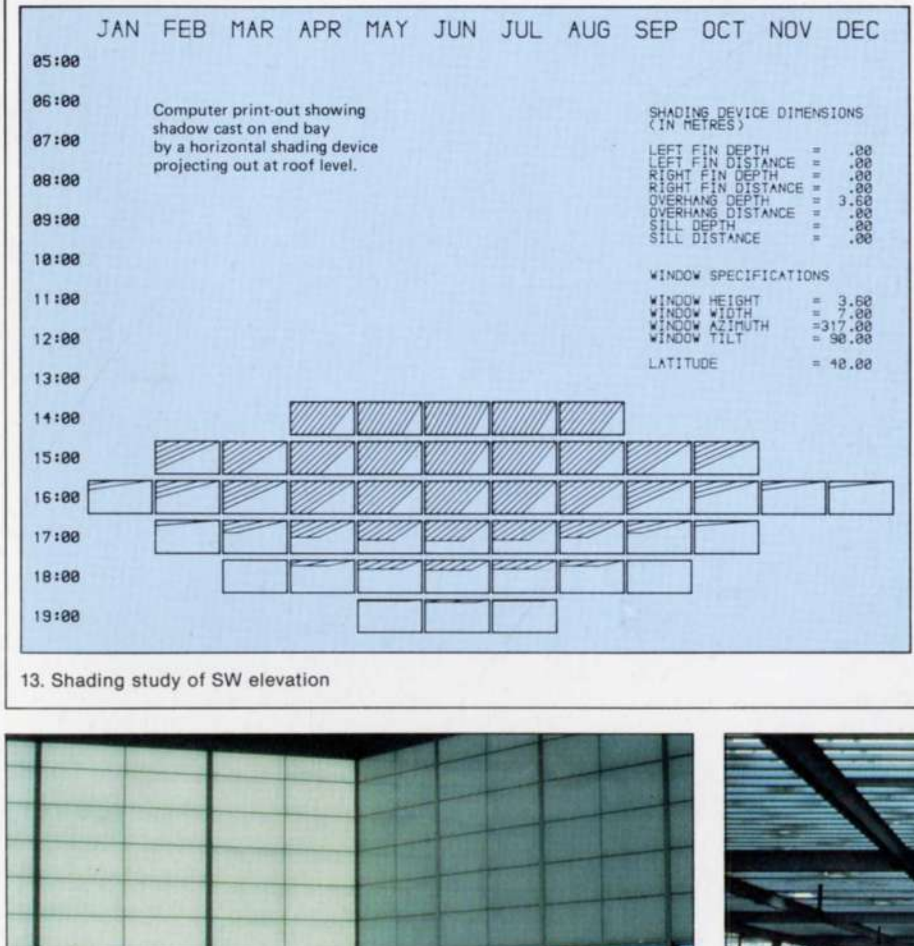
The building is air-conditioned by a variable volume system using fan-assisted terminal units. Generally one fan terminal unit is provided to serve two 9.0m × 4.5m planning modules in the internal areas, and one terminal per module in the spine and perimeter areas. Two central packaged air-handling units incorporating acoustic treatment, fans, humidification, filtration, direct expansion cooling and direct gas-fired heating are located above the spine. The two air-handling units connect to common circular supply and extract ducts suspended below the air-handling plant platforms. Connections are taken off the primary distribution ducts into the building (Figs. 18 and 19).

Ventilation is provided to toilets by separate roof-mounted fan units, and similarly, industrial exhaust hoods when required are connected to individual extract fans on the roof interlinked with the VAV terminals.

Supplementary heating is provided by perimeter baseboard and skylight finned tube elements, with fan heaters in the loading bay. Heated water is distributed from a central gas-fired boiler plant.

Piped services

With the exception of the drainage systems, the piped services are distributed at high level with lateral feeders from the primary spine distribution. Cold water is distributed at mains pressure and hot water from a central storage cylinder located in the ground floor plant room.



Computer print-out showing shadow cast on end bay by a horizontal shading device projecting out at roof level.

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SHADING DEVICE DIMENSIONS
(IN METRES)

LEFT FIN DEPTH          =   .00
LEFT FIN DISTANCE       =   .00
RIGHT FIN DEPTH         =   .00
RIGHT FIN DISTANCE      =   .00
OVERHANG DEPTH          =  3.60
OVERHANG DISTANCE       =   .00
SILL DEPTH              =   .00
SILL DISTANCE           =   .00

WINDOW SPECIFICATIONS

WINDOW HEIGHT           =  3.60
WINDOW WIDTH            =  7.00
WINDOW AZIMUTH          =317.00
WINDOW TILT             = 90.00

LATITUDE                = 40.00
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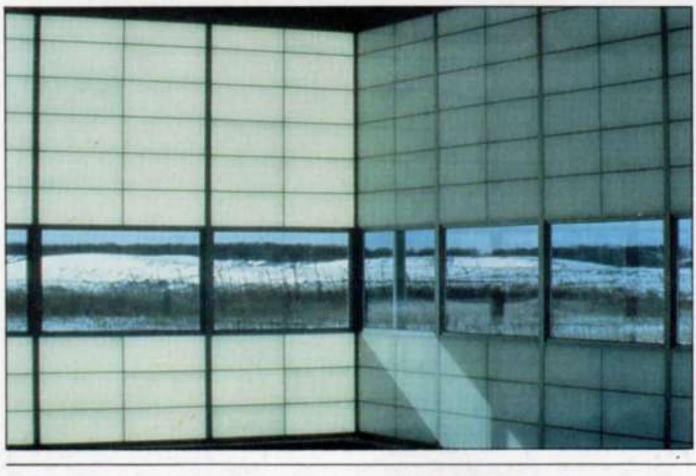
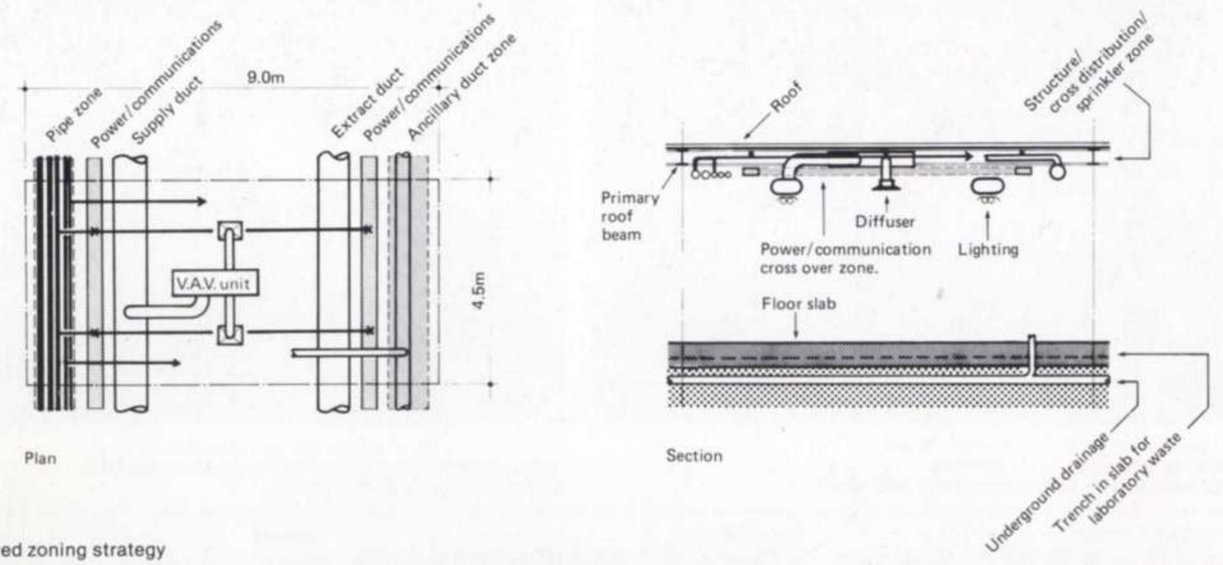
13. Shading study of SW elevation



14. Left: Interior view of *Kalwall* cladding during construction

15. Above: General interior view of research enclosure, prior to casting ground slab or installation of services, showing column-free interior and translucence of *Kalwall* cladding. (Photos: Ram Ahronov)

16. View of high level primary services in spine on either side of the central skylight (Photo: Otto Baitz)



17. Integrated zoning strategy

18. Air handling plant on yellow support platforms with primary ducts below (Photo: Otto Baitz)

19. Primary ducts above spine skylight with connections to lateral feeders in research enclosures (Photo: Otto Baitz)

Industrial quality compressed air is distributed to laboratory areas from a central compressor/receiver set. Where pressure reduction or additional filtration or drying are required this is carried out locally. Towns gas is also distributed to the laboratories and the boiler and air-handling plant from a metering point in the main plant room.

The building is provided with full sprinkler protection using an offsite storage tank and pumping and valving equipment at ground floor level in the main plantroom.

Separate drainage systems are provided for foul, surface water and laboratory waste. Whereas the surface and foul drainage run in underground systems, the laboratory waste is provided for by preformed trenches cast into the ground floor slab with continuous access covers.

Electrical installations

The HV switchgear and substation for the incoming electrical supply are in an enclosure remote from the building, with underground cables laid into the LV switchroom located in the plantroom; the need to keep the transformer away from the building arising because of the sensitivity of the optics laboratories to electrical fields. From the LV switchroom cables rise to high level and run on a cable ladder to the spine.

The primary distribution for lighting and power for the laboratories and offices is at high level on either side of the spine. Frequent tap-off points, at 600mm centres, allow connections for laboratory and lighting supplies to be made. Distribution panels are provided in the spine for lighting and general purpose power, whilst the research laboratories are each provided with a free-standing three-phase distribution board.

Sub-circuit wiring will be taken to high level and distributed on cable ladders in the laboratory areas with vertical drops installed to suit bench and equipment layouts. In the office areas the flush floor trunking system is used.

Lighting to open plan areas without false ceilings is generally by continuous troughs with fluorescent tubes. The troughs contain the control gear trays, reflectors, louvres and cable tray, the louvres being continuous throughout the length of the trough. In the central spine the lighting is a mixture of continuous fluorescent tube-track and tungsten feature lighting.

For telephone and data wiring a three-compartment metal trunking is provided down each side of the spine. This also provides wireways for the fire alarm and emergency lighting installations.

20. Annular node plate of suspension system, looped tapes for continuity of lightning protection can just be seen (Photo: Barry Dunnage)

21. External view of corner during construction, again showing looped tapes for continuity of lightning protection (Photo: Ram Ahronov)

Lightning protection

Good use is made of the structural steel frame for the lightning protection of the building. Each masthead has a lightning air terminal projecting above it and the steelwork provides the continuous path to ground. At the structural joints, looped tapes ensure conductor continuity. These tapes are neatly screwed to the inside of the clevises and to the outer edge of the node plates (Figs. 20 and 21).

Conclusions

Completed in October 1984, Patscenter on the whole successfully realizes the objectives which were set for the project. Both structure and services designs make unusual use of standard components commonly available in the American construction industry and the building is certainly distinctive. It cannot be missed with its red structure, yellow services supports, grey air-handling plant and white walls, all set amidst open parkland (Fig. 22). There is already talk of extending the building so it will not be too long before the bay-by-bay extensibility is tested. The client has got the building he wanted at an acceptable cost, and last year the entire coversheet of the worldwide PA organization's annual review was devoted to a photograph of the completed building; linking it with the organization's commitment to innovation.

Credits

Client:
PA Technology
Architect:
Richard Rogers & Partners
in association with Kelbaugh & Lee
Project architect:
Ram Ahronov
Structural engineer:
Ove Arup & Partners/Robert Silman Associates
Services engineer:
Ove Arup & Partners/Syska & Hennessy
Cost consultant:
Hanscomb Associates

22. General view from landscaped parkland shortly after completion (Photo: Otto Baitz)

Experimental concrete housing

Architects:
Peter Ledward and Clarence McDonald

Roger Hyde

INTRODUCTION

This project provided an unusual and satisfying involvement in the details of basic building materials and traditional building design and construction.

Experimental housing may not sound technically demanding but nevertheless required a wide range of skills and expertise, and needed an approach to the design and the resolution of often unquantifiable and incompatible concepts that is characteristic of more visibly complex projects.

The design of, and materials for, housing whether experimental or not, must satisfy statutory and financial institutions who approve or fund construction. These houses were also built to be sold and lived in, so experiment and creativity had to satisfy some hard taskmasters.

In housing, structure has a small part in the total concept and the proportion of non-numeric problems is high. We are thus forced in this type of project to think more and more widely, and calculate less, which is an admirable lesson.

THE PROJECT

Blue Circle Industries were concerned with the image concrete had in housing and wanted to improve it, and they approached architects Peter Ledward and Clarence McDonald.

Jeffrey Tonkin from Blue Circle, who became our effective client, is an economist by training and professed little knowledge of the building industry or why concrete wasn't popular in housing; he had a disturbing habit of asking simple but unanswerable questions and was a refreshing, stimulating client. He wanted to build concrete houses. He cited what was being done elsewhere in Europe and felt that we ought to be able to learn from past experience.

The architect's initial response to 'concrete houses' was 'yes' to the houses and 'why' to the concrete, and to advise against it. He was persuaded to pursue the possibilities of concrete, on condition that:

(1) Houses should be real houses for real people – not experiments. This committed the designers to reality – this was not to be a play project.

(2) Blue Circle would have to become house builders with the responsibility that implied. It was important that they too had a visible commitment and recognized the risks.

Blue Circle had some land at Halling in Kent and planning permission was obtained for the development of an estate of 16 houses.

Appointing the engineer

It was clearly time for some engineering advice. They came to Arups and Turlogh O'Brien told them the reasons for not using concrete in domestic buildings; but they were not dissuaded and Turlogh asked me to talk to them. Their ideas sounded slightly mad, but interesting, so I agreed.

I was well-briefed and primed for the occasion and I told them all the reasons why concrete was the wrong material. It was too strong, too hard, too brittle, too noisy, too impermeable to water and water vapour, too permeable to heat, it cracks, suffers from carbonation, the reinforcement rusts, it has a bad image, bad past form, control of quality is a major problem, and so on. They listened patiently, then asked: 'Why, if you know all the things, that are wrong with concrete, can't you help find the right solution?' It wasn't a fair question, but it was a fair challenge.

My conditions for the contest were:

(1) It would need a lot of my time.

(2) We would need to do a lot of tests. Some on a large scale.

(3) It might all come to nothing.

(4) The houses might be built and then have to be knocked down.

The architect's objectives

The architect's objectives were simple. The development should make the best use of the site, the houses should be sensible, normal-looking speculative houses. They should not look like everybody's idea of a concrete house.

The engineer's objective

This was simple also and was to minimize our involvement – no giant steps forward for mankind and technology. Housing is about building not engineering. We should limit the areas of experiment so that the effect could be judged.

Most successful domestic building has been technically traditional and these houses should be as traditional as possible. We should design a house for Kent and not for all areas of the UK. We should design specific houses and not a system.

We would try to go back to basics, would review where concrete had been used in housing to see the primary sources of concern or areas of success.

REVIEW OF INFORMATION

The scheme, when we joined the team, was to construct all external house walls as a shell of dense, in situ reinforced concrete using a formwork system to cast two walls 100mm thick separated by 50mm of insulation; to all intents an insulated cavity wall. The formwork was cast aluminium, rigid, light, made in the USA and expensive.

It sounded difficult. There was not enough space in 100mm of wall for reinforcement and cover; it would be difficult to keep the insulation in place; 100mm was too thin to place and compact concrete properly.

On the other hand, the cavity wall construction was very traditional. The Americans had no difficulty holding the insulation foam in place (they said). We could use superplasticizers to improve workability and overcome difficulties of the 100mm thickness. But what about reinforcing and also quality control?

There were too many possibilities, too many questions, too many apparently better alternatives, and no basis for comparison. We stopped to look at what had been done in the past. It wasn't a total review but it led us to some very general assessments:

(1) There had been some successes in concrete houses. Typically these were early brick rubble concrete, no-fines concretes, fly ash concretes, some lightweight concretes – all essentially unreinforced, low strength, simple technology.

(2) The majority of structural problems revolved around corrosion of reinforcement. Most arguments about carbonation of concrete, thickness of cover, accuracy, water penetration, etc., were in the end about durability of reinforcing or embedded steel.

(3) In situ systems were generally better than precast.

(4) The successful use of concrete was not well publicized whereas stories of failures were.

(5) Although concrete is and has been used very widely within Europe in housing, many of the problems that have been found in the UK have occurred, elsewhere, particularly with system-built flats. So we are not unique.

(6) It was going to be difficult to be economically competitive with more traditional methods.

A general conclusion was that high strength structural concretes were inappropriate to housing and that concretes which were low strength, low technology materials were preferable. The more we looked at why this was, the clearer it became. Our concrete should have properties as similar as possible to bricks or masonry used successfully in housing.

We had to get away from structural concrete which meant high cement content for strength, durability and the protection of reinforcing. High cement content necessitates high water content and the overall result is high strength, high shrinkage, low permeability, and high modulus of elasticity. None of these characteristics are needed in houses.

The current worries about durability of concrete are related to reinforcing corrosion and structural viability. Low stressed plain concrete does not need to satisfy the same durability criteria as structural concrete. If an area of concrete deteriorates then it can be cut out and replaced, in the same way as masonry is maintained.

What should the properties of this low technology concrete be? And why might its use reduce the previous problems found with concrete?

1. A view of the estate

ENVIRONMENTAL PERFORMANCE

Condensation

An enduring criticism of concrete housing has been the tendency to excessive condensation. Although it is dependent on the life style of the occupants as well as the simple thermal properties of building fabric, the degree of apparent condensation also depends upon the permeability of the surfaces on which it appears.

Accurately finished structural concrete, with minimal finishes is impermeable to moisture and any condensation occurring stays on the surface. Houses, built less accurately in bricks and using thick plaster to line up the walls, contain materials able to balance out changes in the temperature/humidity regime and reduce the visible occurrence of condensation. Many older houses, although badly insulated, were also inadvertently draughty or had chimneys which ensured a higher level of ventilation than is current in newer construction.

All these factors affect the way the building behaves. We had to decide what thicknesses of finishes, levels of permeability, ventilation and insulation would maintain the sort of environment people expect in their homes.

The high mass, high insulation nature of the design obviously suggested the use of passive energy conservation techniques. These were considered but although not developed, the energy usage of the houses is very low.

Noise and feel

Traditional construction has an acoustic softness resulting from the use of timber floors, thick plaster on walls, and timber stud partitioning, which all contribute to the feel or resonance of a space. The mechanical hardness of concrete and its accurate surfaces will create a hard, bright and noisy environment which is not what most people want in their homes. The connection or similarity between noise and condensation is clear, and any decision affected both. Apart from the approach to the concrete itself, it was decided to batten and timber the ground floor, use timber rather than concrete for the first floor and construct all internal partitions in timber studwork.

Weathertightness

Much concrete housing has flat roofs and plain walls. Rain falling on the walls ran down the surface, over the windows and finally into the building through a joint, crack or weathering detail.

Structural concrete absorbs virtually no water, so the weathering details around doors and windows in concrete walls have to cope with more free water than traditional construction assumes, and any water which does get past the point of exclusion runs on into the building as it will not be absorbed by the brick or masonry inside.

Overhanging roofs, of course, keep a lot of water off the wall surface in the first place – which seems sensible, and in Kent, weatherboarding or tiles have traditionally been used as well. Both were adopted. But if we used traditional weathering details, would they be satisfactory and if not what should we be doing? A great deal of effort and trials went into the detailing for weathertightness.

As far as possible the general house details were traditional. Damp proof courses were incorporated in the walls, a cavity tray detail was developed for all windows and doors, which was fixed after concreting.

The external wall was constructed in forms held together with removable ties at about 600mm centres vertically and horizontally which left a slot 3mm wide × 30mm high right through the wall.

We felt that these slots had positive advantages and although they would be sealed by finishes except where they occurred behind weatherboarding they should not be sealed with the intent to make them water or vapour tight. We saw them rather like perpends between bricks which are seldom full of mortar and must therefore allow the wall to breathe.

Water vapour movements

We carried out an analysis of temperature and water vapour in the wall under various static conditions of external and internal temperature and humidity. The results showed very little likelihood of condensation either in the cavity or on the wall surface.

We looked at the thermal bridging effect of the GRP spacers and of concrete intruding between joints in the insulation and connecting the inner and outer leaves, and at the behaviour of a fully filled cavity. We checked that neither the insulation nor the external rendering was vapour proof. We decided that the high risk areas of kitchens and bathrooms were best alleviated by providing an extractor fan.

All our work in this area led us to believe that the houses would perform satisfactorily.

Formal basis of structural design

The design of the concrete walls had to satisfy Building Regulations and we based the structural calculations for the walls on *CP111: 1972* Load-bearing walls, which was an Approved Document. The remainder of the structural design was conventional using deemed-to-satisfy rules wherever possible.

General system

The party walls between houses were 300mm solid; the external walls were a sandwich of 100mm concrete, 50mm foam insulation and 100mm concrete. A movement joint was created between all houses. The insulation was a rigid closed cell polystyrene held in place with GRP rods incorporating dome spring fit washers. The rods were deformed at each end to bond mechanically into the concrete, and would obviously tie the two concrete leaves together but they were not British Standard cavity ties, nor was the long-term performance of GRP in concrete certain. The action of the GRP ties was unclear. We were not sure whether we wanted the two leaves of the wall to act in unison or independently. We pondered what a cavity tie does – what loads it is expected to resist, what strains it should accommodate and these are matters the Building Research Establishment is currently investigating. But they had no answer for this project.

Our investigations into the walls convinced us that there is very little understanding of the behaviour of cavity walls under varying temperature and other conditions and we had to reach our own conclusions.

The strength of concrete was utilized and we designed the walls without formal ties except at floor levels and roof levels, where standard double triangle 6mm ties joined the leaves.

Reinforcement in walls

We decided that reinforcing was philosophically incompatible with the concept of concrete we were developing. It took longer to convince ourselves that we could do without it.

For general stability purposes, both during construction and in the long term, we wanted a continuous tie at floor and roof levels and this is provided by one bar in each leaf.

A single reinforcing bar was provided above all windows and doors, balanced by a bar below all openings for crack control. With so little reinforcing, we felt less worried about corrosion, but as an added safeguard all steel was hot-dip galvanized. All bars had a cover of about 40mm which is satisfactory.

Concrete mixes, shrinkage and cracking

The simple theory of low technology concrete is that a coarse concrete with low cement content, low fines content and low water content is basically pieces of stone in contact with each other bound together with a cement matrix. There is virtually no shrinkage or shrinkage cracking. Such concrete must have a higher voids ratio than more homogeneously graded materials – which is also what we wanted, rather like the rougher variety of dense concrete blocks.

So how to create this new wonder material (but I thought I said no great leaps forward for mankind). The specification of what we wanted was:

Cement: ordinary Portland cement

Aggregates: dense

High workability:
slump greater than 150mm

Low bleed

12-hour strength greater than 1 N/mm^2

Low water/cement less than 0.6

Cement content less than 200 kg/m^3

Coarse aggregate preferably 20mm size

Pumpable.

We did some trial mixes and these were used for the trial walls.

Subsequently, Pioneer Concrete, who supplied concrete for the houses, developed the final mix design at their Essex Laboratory. It was coarse, workable and pumpable; it used an air entraining and water-reducing admixture and 220kg of ordinary Portland cement/m^3, and had a slump of 100–150mm.

Foundations and thermal effects

Ground movements and thermal effects often result in distortion and possibly cracking in buildings. It is not generally economic to design small buildings to avoid all movements and part of the art of building is in the organization of detail and mass to minimize the effect of these essentially secondary strains. Masonry has the advantage of many joints, and small movements tend to be well-distributed and not initially visible. We were concerned that the greater homogeneity and brittleness of concrete would lead to fewer and larger cracks. The arrangement of the floor level reinforcing was considered to help reduce this likelihood, and the crack-inducing propensities of the form ties were also seen as a means of increasing the frequency and hence decreasing the size of any cracks which might occur.

We concluded that the houses could be constructed using conventional foundations, in this instance, trench fill strip footings, and noted that the extremes of thermal movements were reduced by the use of external cladding.

Test walls

Part of developing a buildable design was a series of full-scale tests. We designed a storey height test wall 5.5m long which incorporated the most awkward construction features of corners, large windows and difficult returns. We constructed a total of three such walls at the Cement and Concrete Association, Wexham Springs. The objective of the tests was to try out concrete mixes, test the foam locating devices, check the ease of erecting and stripping formwork, and whether forms could be stripped 12 hours after placing concrete.

Clarence McDonald and I felt the first test should incorporate the designers and accordingly we set up the formwork, placed insulation, reinforcing and concrete in front of an uninvited but substantial audience. We participated in a less physically onerous role in the subsequent two tests, but the experience was invaluable when the job got on-to site.

2. Concrete placing

3. A finished shell

4. Fitting out

5. Finished houses

A great deal was learnt from this first test. The insulation floated – we thought that would happen – but not that the forms would float as well. The American insulation locating devices were not foolproof. The concrete did go under the windows and did not crack. We could strip the forms after 12 hours without difficulty. Quality control by the ready mix concrete supplier was not impressive, difficulties were very apparent and the need for simple in situ tests was never more clear than when trying to experiment with mix designs and admixtures. It was all a rather painful experience and not reassuring.

In subsequent tests we improved the method for locating the insulation and the forms. We changed the mix design but, with disappointment, dropped superplasticizers because it was clear that their use was not efficiently controllable. Design slumps were limited to those which could be checked with a slump cone. Blended cements were tried but found to give inadequate early strength.

APPROVALS PROCEDURE

Building Regulations

When we had a clear view of what we intended to do, but early in the development of our ideas, we met at Rochester with the Building Control Officer on Medway City Council. He was not enthusiastic about the idea of concrete housing. The Council had problems with their own stock of 50s concrete flats.

We did not disguise either our enthusiasm or misgivings and this led both to useful discussions, and an honest relationship. The submission for Building Regulations approval was a substantial document dealing with each clause in considerable detail and in due time the approval was received.

NHBC, Agrément, Building Societies and external reviews

All, or virtually all, new housing is sold with a National House-Building Council 10-year insurance against structural defects and it was necessary to either obtain NHBC approval or to organize equivalent private insurance, so that potential purchasers could obtain mortgages and not be open to unusual financial risk.

As a further independent check or review, we felt it desirable that the basis and detail of the design as submitted for Building Regulations approval should (i) be used for a review by the Agrément Board as a preliminary phase to granting an Agrément Certificate and (ii) be subject to an independent appraisal by the Building Research Establishment covering sound insulation, foundations, thermal performance, fire, moisture and structure. Comments received as a result of these reviews were incorporated into the design.

The same Building Regulations document also formed the basis of a submission to the NHBC, on which they agreed to insure the houses.

Construction

Several builders were interviewed and the housing development selectively tendered with the concrete walls to be constructed effectively on a cost plus basis and the remainder of the work competitively priced.

During construction, the American formwork suppliers provided supervisors to help develop expertise in using their system. This help was invaluable, but real improvement in production was not achieved until a formwork and concreting gang was formed who were paid a significant bonus for production achievements.

The process of construction was to do the foundations and drainage and ground-floor and then complete the concrete walls up to roof level. A house shell was then available to be fitted with roof, floors, windows, cladding and internal fittings. The target programme was six days for the construction of the concrete shell for a pair of semi-detached houses. The best achievement was seven days for the shell complete.

During construction of the shells, a number of improvements were made, particularly in relation to concrete placing, and after an initially slow start the rate of progress improved dramatically.

Richard Matthews was our resident engineer on site during the concrete work and his presence was important to demonstrate our commitment, particularly to the Building Control Officer and the contractor, as well as technically vital both for quality control and in learning from and improving the methods and techniques.

While on site Richard developed a device to check the position of the insulation after concreting which used the slots left by the form ties. This ability to check the finished wall led to a better attitude towards concrete placing by the formwork and concrete crew who quickly learnt the advantage of checking their own work. It gave everybody a great deal more confidence. It also led to an area of incorrectly positioned insulation being successfully removed by cutting out the affected area of wall and reconcreting, which demonstrated the advantage of minimal reinforcement and relatively low concrete strengths.

FINALE

The development of the system, the tests, approvals and getting a builder onto site took some 11 months and construction a further 10 months.

The houses were finished about 12 months ago. They are all sold and the final inspection has been completed. Fuel bills for some of the houses are being monitored. Thus far the experiment has been successful.

The houses constructed at Halling were not competitive with current conventional methods. The system was too demanding of control and supervision to be suitable for general application.

Blue Circle are looking for further sites for another stage in the experiment where we hope to continue with low technology concrete, but perhaps using lightweight aggregates, solid walls with external insulation, and even perhaps superplasticizers.

Credits

Client:
Blue Circle Developments Ltd.
Architects:
Ledward and McDonald
Quantity surveyor:
Edmund Shipway & Partners
Builder:
T. Headley Ltd.
Photos:
1 by the client, 2 to 5 by the architects

Swakeleys House Hillingdon

David Brunt

Architects: Kirby Adair Newson

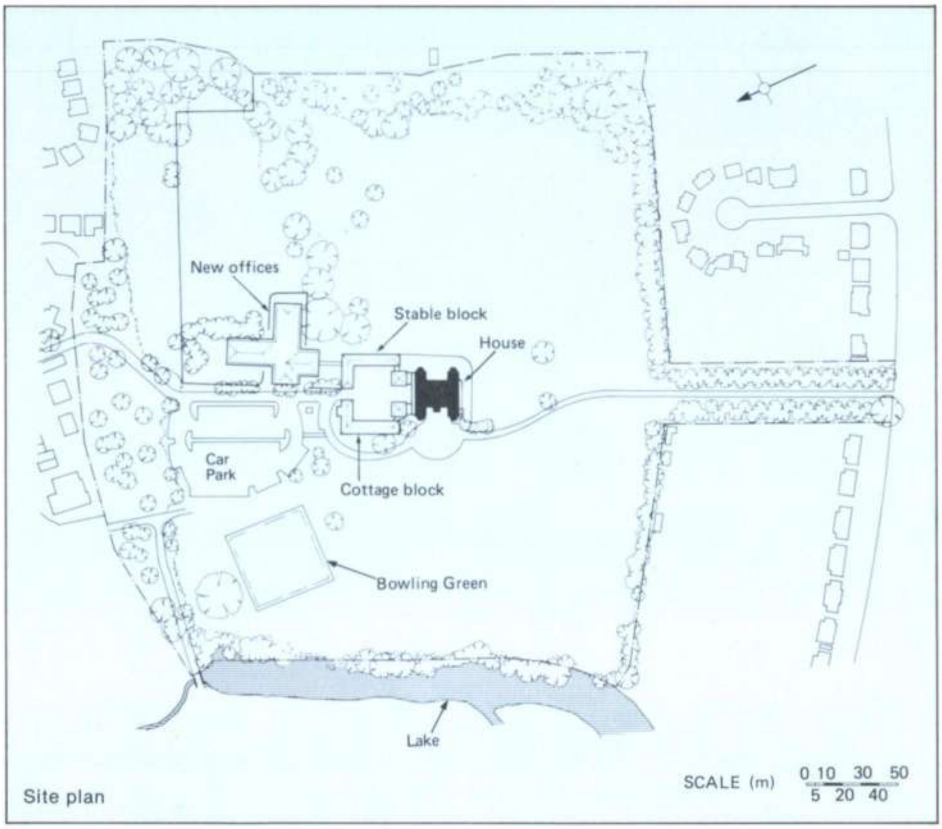
Introduction

In 1955 the London Postal Region Sports Club boasted of its recently acquired facility comprising two football pitches, one cricket pitch, four tennis courts, a bowling green and a 200 years old croquet lawn all set in 27 acres of heavily wooded surrounds which included a fishable lake.

However, during the following years of their occupancy, less pride was afforded to the obvious centre piece which they described in their inaugural brochure as 'a clubhouse of 20 rooms with ballroom and bar'.

The clubhouse was in fact a Grade I listed three storey Jacobean Mansion completed in 1638 for Sir Edmond Wright, a London merchant, later to become a Lord Mayor of London. Although little-known as a place of historic interest, it nevertheless contained many fine examples of period design and craftsmanship.

During its earlier years Swakeleys attracted the interest of many notable people including Charles II and Samuel Pepys. It was fitting therefore that some 350 years later HRH the Duke of Edinburgh should show a personal interest in the realization of a viable scheme for the restoration and re-use of Swakeleys House, to the extent of his making several visits, the last being in May 1985 on completion of construction work.



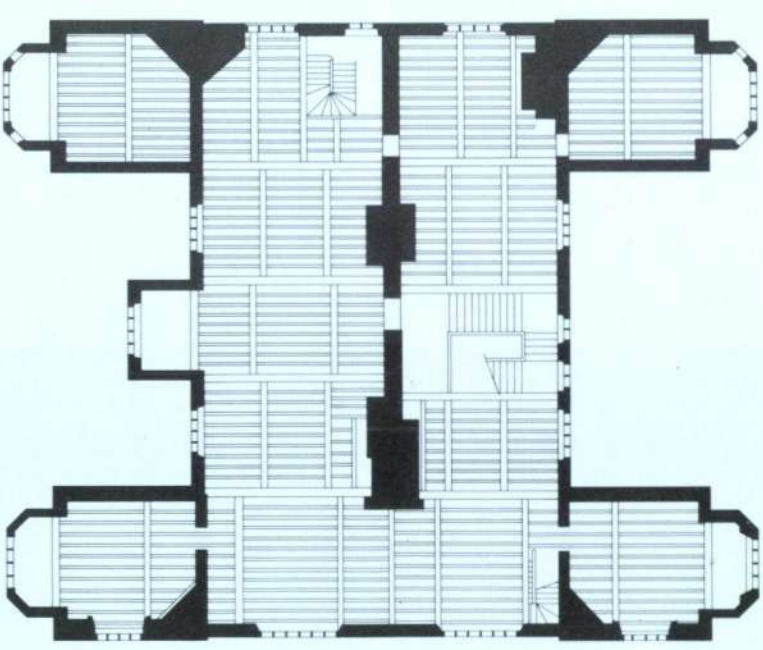
Site plan

The story behind this restoration and improvement carried out in the early 1980s is one that future historians and researchers studying the building's past are likely to quickly focus on as being not only interesting but particularly critical to the continued life of the house.

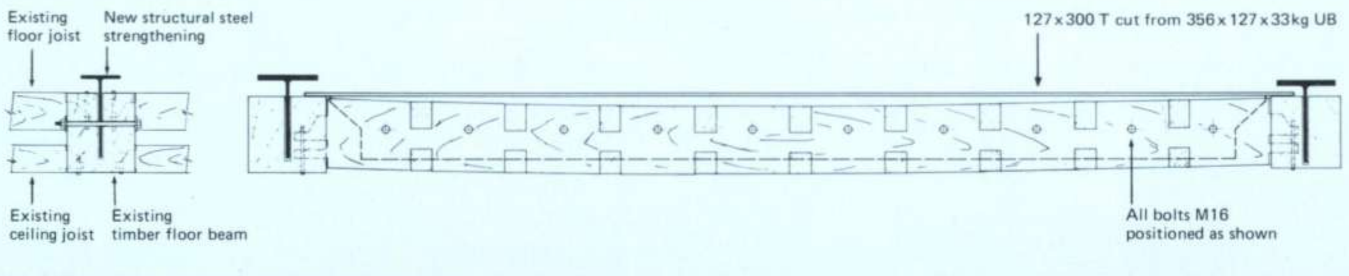
A number of formal planning applications to realize the commercial potential of the house and its grounds, (one of which was by a large international company who proposed to convert the house to offices and add over 20,000m^2 of new office building) met with so much local dismay that a local protest group was formed. Following successful objections to such schemes, three of the protestors: a solicitor, an engineer and a marketing manager being near neighbours of Swakeleys House, concluded that the most effective means of ensuring that any development be appropriate and sensitive to its environment was to be in control of it! Thus Swakeleys House Ltd, a private company, was formed with this one enterprise in mind.

The House

At the time of the establishment of Swakeleys House Ltd, deterioration of the house and its outbuildings had reached an advanced stage. Habitable occupation ceased during the 1930s when members of the Gilbey family (of Gin renown) moved out and held a sale of many of the house contents. None of the subsequent occupants which included the Army during World War II, and the Foreign Office afterwards, lavished the care and affection towards the building which it called for and by the early 1980s it was of shabby and dismal appearance both externally and internally. Initial examination confirmed the presence of leaking roofs, dry rot, wet rot, warped panelling, death watch beetle, mould growth, cracked brickwork and window frames.



First floor showing layout of beams



Typical floor beam showing strengthening measures

1. Courtyard elevation before commencement of works

2. Courtyard elevation after refurbishment

3. West elevation after refurbishment

Photos in this article:
1-7, 9-17: Harry Sowden
8: Ernie Hills

4 to 6. The original building fabric at second floor level

Considerable imagination was needed to foresee how the house and its outbuildings could be transformed for future use without detriment to the character of the place.

The architects appointed by Swakeleys House Ltd to design the new outbuildings and the modification and repair of the house worked patiently to meet the exacting requirements of their client, as well as the Historic Buildings Division of the GLC, the Hillingdon Borough Planners, and those members of the local community who had already voiced their opinion concerning earlier planning applications!

A geotechnical site investigation indicated that the 17th century builders had founded the main walls at a depth of 1.5m below ground level, thus conforming to current Local Authority bye-laws introduced after the 1976 drought that brought havoc with shallow foundations in the local clay elsewhere in the Borough.

The main walls of the house are solid bonded brickwork of substantial thickness varying from over 600mm thickness at ground level to 220m thickness at the second floor gables.

It was calculated that provision for future superimposed floor loadings of 5 N/m^2 would increase foundation bearing pressures by generally less than 10% and that such an increase was acceptable. Crushing tests on bricks taken from the original structure gave an average crushing strength of just under 15.0 N/mm^2 and a range from 10.0 N/mm^2 to 24.0 N/mm^2.

Floor timbers presented more of a problem partly on account of some rotting at end bearings in the brickwork, and partly because of very irregular cross sections which for a number of the main beams meant strengthening to meet the new superimposed floor loadings. The strengthening was provided by inserting the web of a mild steel 'T' section into a vertical saw cut down the centre of the main beam which was then drilling horizontally for bolting timber and steel together. This method was adopted after consideration had been given to alternatives that included resin bonding, and it had the advantage of leaving intact the tenon and dowel connections between secondary and primary beam which tie the whole beam grid together and make it impossible to extract an internal beam without substantial saw cutting. In addition the flanges of the 'Ts' provide support for a level floor in place of the previous irregular slopes caused by long-term sagging of the main beams. The heavy section timber in contact with the 'Ts' provides good fire protection and although intumescent paint was considered for protection of the flanges, this was not an actual requirement of the Fire Authority.

The other main reconstruction work carried out in the house and the adjoining cottages and stables consisted of:

Treatment of all timbers
Rebuilding of chimney stacks
Retiling of roofs and minor repairs to roof timbers
Replacement of lead work to gables, guttering and parapets
Repairs to and some rebuilding of roof gables
Localized repair of brickwork
Some rebuilding of window structures and frames
Wall panelling removed, treated and re-erected
Some internal stud walls removed; others stripped down and repaired
Secondary staircases rebuilt
Small basement floor area lowered to give increased headroom for a boiler plant room.

In addition a hydraulic passenger lift has been installed together with new heating, electrical and plumbing systems, and new outbuildings constructed within the courtyard and adjacent to the house to provide two conference rooms and a reception area.

A decision was taken early on in the design process not to air-condition the house because of its location in the midst of a large open tranquil environment, the house having high ceilings and sufficient opening windows to cope with most extremes of an English summer. Space provision has been made within the enabling building to allow for the addition of air-conditioning plant should this be required in the future.

The main work of art, a wall and ceiling mural to the grand stair painted by Streeter, was restored, which involved physically isolating the main staircase area for a major part of the 15 month main reconstruction contract.

7. Ceiling to first floor reception room before and 8. after refurbishment

9. Ground floor reception room showing the ornamental screen with bust of Charles I and *amorini* holding heraldic *cartouches* over side arches

10. 'New meets old': the new reception area against the north facade of the original house

11. Second floor level

12. The offices in use

13. Roof details to front elevation

14. New plantroom in the basement

15. Refurbished stalls in stables

16. New office development adjacent to the house

17. The main staircase with mural by Robert Streeter (1624-1680)

The new office building

The most controversial element of a combined historic restoration and new build is invariably the latter, as it has to blend in with the existing and also provide the commercial soundness of the overall project, thus enabling it to be realized.

In this case just over 2,000m^2 of new office accommodation has been created in a two storey, barn-like building which on plan is a non-symmetrical cruciform shape.

The accommodation is located close to the main courtyard and has an external plantroom which is housed in a single-storey building based in shape and size on the original brick dovecot/icehouse, which was demolished in the 1950s, and was some 80m away from the main buildings.

A new access road and landscaped car park with provision for over 80 cars has been provided to the north of the courtyard.

14

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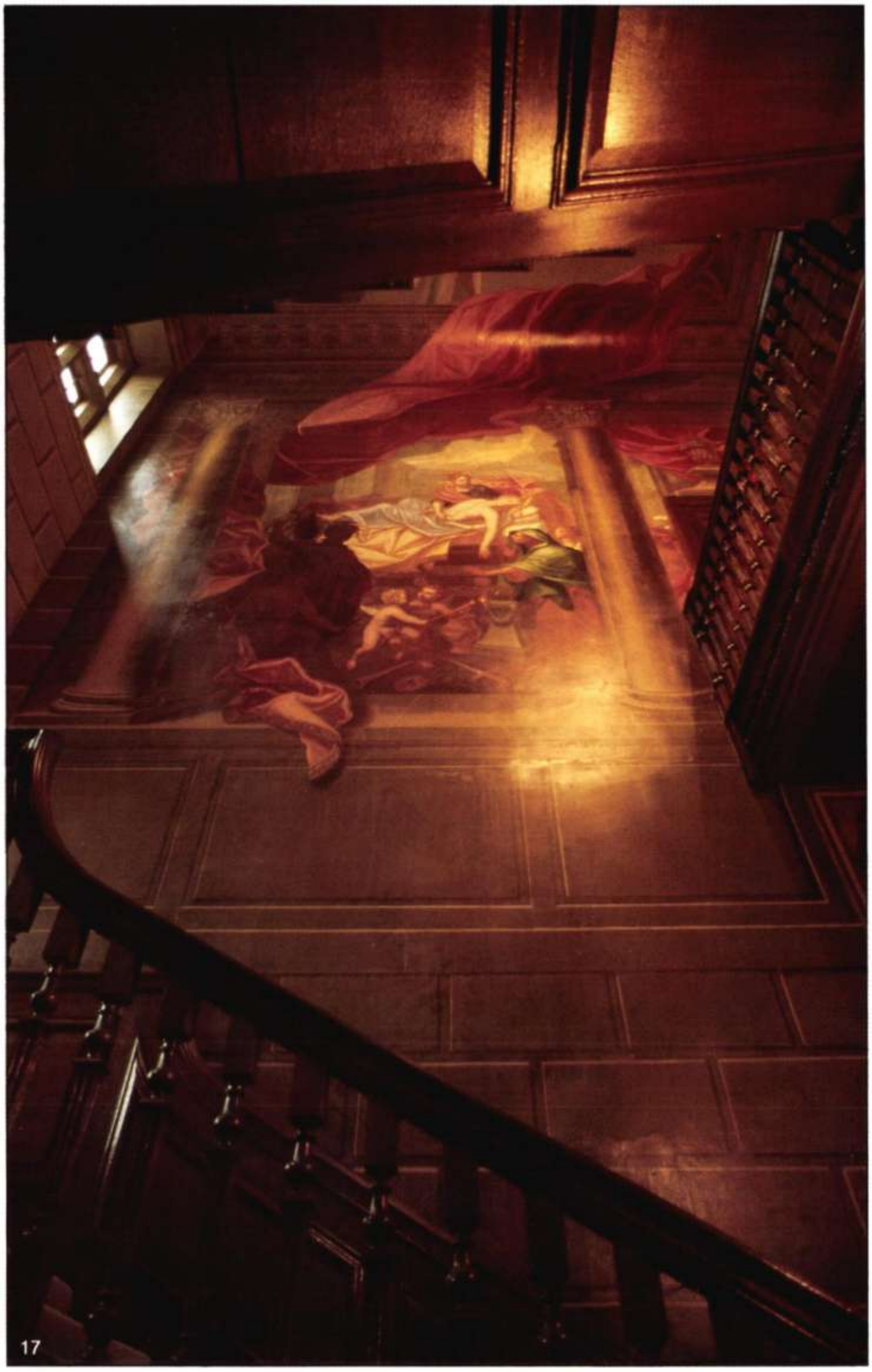

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Postscript

Soon after contract completion, the complex was let on a full repairing lease to Bristol-Myers Company Ltd., who are now in occupation.

The terms of the lease lay down that the house will be open to the public on three days each year, and although the tenant has private use of most of the grounds a public walk by the lakeside will continue to provide impressive views of the house across the extensive lawns. Certain traditions, such as the annual summer fete in the grounds of the house will continue.

Credits

Architect:
Kirby Adair Newson
Project manager:
Richard Ellis
Quantity surveyors:
BDB Surveying Services
Consulting engineers, structure and services:
Ove Arup & Partners
Contractor:
W. S. Try Ltd.

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