THE ARUP JOURNAL

AUTUMN 1988

THE ARUP JOURNAL

Vol.23 No.3 Autumn 1988
Published by
Ove Arup Partnership
13 Fitzroy Street, London W1P 6BQ

Editor: David Brown
Art Editor: Desmond Wyeth FCSD

Contents

Front cover: Vaults at Tobacco Dock (Photo: Richard Matthews)
Back cover: The British Library under construction, August 1988 (Photo: Peter Mackinven)

Progress at the British Library

Architect:
Colin St. John Wilson & Partners

Peter Ryalls
Tony Stevens

Preamble

The last of three articles about the British Library was published in *The Arup Journal* nine years ago[1,2,3]. Readers who have been patiently awaiting further intelligence will be brought up-to-date by the following.

History

The British Library Act of 1972 established a national library for the United Kingdom which incorporated the library of the British Museum. Even before that date a new building had been planned for a location opposite the Museum, on the west side of Bloomsbury Square.

Early in 1975 that scheme was abandoned in favour of a site in Euston Road by St. Pancras Station. The architects, Colin St. John Wilson & Partners, prepared a feasibility study with contributions from a design team consisting of Steensen Varming Mulcahy & Partners, Davis Belfield & Everest (as they then were) and Arups. The report published in June 1975 was favourable and the Government authorized design development. Mr. Fred Mulley, then the Secretary of State for Education and Science, committed the Government to a start in 1979-80 'if economic conditions at that time permit'.

In the two years that followed, the architects in collaboration with Officers of the British Library, drew up a brief and developed their proposals. The final design report of November 1977 was the basis for detailed development of Phase 1A, part of the first and largest phase of construction.

In March 1978 the Secretary of State for Education and Science, by now Shirley Williams, repeated the Labour Government's intention to start building work on the Library in 1979-80, and instructions to proceed were given.

Tests to explore the feasibility of forming pile underreams in the Woolwich and Reading Beds were undertaken early in 1979[3]. But the preliminary contract for secant pile walls, piling and some excavation did not begin until April 1982. Substantive work on Phase 1AA began in July 1984.

Planning objectives

The departments of the British Muséum Library to be transferred to the British Library at Euston comprise:

The Department of Printed Books

The Department of Manuscripts

The Department of Oriental Manuscripts and Printed Books.

The Science Reference Library, currently located in Holborn, is also to be accommodated at Euston.

Accordingly, facilities are planned for:

Closed access Reading Rooms for Rare Books

Open access Reading Rooms with direct reference to the books and documents of the Science Reference Library

The book stores; and book retrieval and distribution systems

Accommodation for exhibitions, both temporary and permanent

Administrative offices

Catalogue and reference areas

Plantrooms and technical services.

To meet these requirements accommodation in Phase 1A is provided in four zones:

(1) The Rare Books Reading Rooms, located over the Exhibition Halls, are arranged to the west along Ossulston Street.

(2) The Open access reading rooms of the Science Reference Library and the Meeting and Lecture Halls lie along Midland Road.

(3) The Entrance Hall is located between the Rare Books Reading Rooms and the Science Reference Library, behind an extensive forecourt, the purpose of which is to preserve views of St. Pancras Station from Euston Road.

(4) Lastly, the basements accommodate the book stores and plantrooms.

The heights and forms of the roofscape of the Rare Books Reading Rooms were informed by light angles to Levita House, a block of council dwellings. The architects have planned the closed access Reading Rooms to be interconnected level by level and illuminated from above by clerestory and skylights.

The height and bulk of the buildings of the British Library, especially the Science Reference Library, are governed by planning conditions dictated in part by the presence of St. Pancras Station, a listed building. For this reason it was necessary to locate the book stores and plantrooms below ground.

The site and its environs

The sequence of soils over the site is:

(a) 2-3m fill from ground level, 20m OD

(b) London Clay down to −2m OD

(c) Woolwich and Reading Beds down to −20m OD

(d) Thanet Sands down to −25m OD

(e) Chalk.

The water table perched above the clay gives roughly half hydrostatic pressure that falls to

The original Phases:
Rare Books to the left, Science Reference Library (SRL) to the right

zero in the Thanet Sands. The water table in the chalk is at −50m OD, where the water regime has been determined largely by historic under-pumping, now proceeding at a decreasing rate.

Two pairs of Underground tunnels cross the site from east to west under Phase 1 — the Northern and Victoria Lines. The presence and level of the Victoria Line tunnels at the north end of Phase 1A limits the number of basements to two. The Metropolitan and Circle Line tunnels lie under Euston Road at the south end of the site.

Many buildings are close by. Levita House lies across Ossulston Street to the west. St. Pancras Station is immediately to the east of Midland Road. Several important buildings including St. Pancras Town Hall stand on the south side of the Euston Road.

The presence and proximity of buildings and tunnels has been an important factor in the design of foundations and substructure.

The building

Substructure

Basements for Phase 1A are of two types, each with an appropriate method of construction determined by its form.

It was recognized that the removal of clay soil to form the foundations and basements of the Library would induce movements in the ground that would affect both the London Underground tunnels and buildings close to the site. The method and sequence of construction was therefore designed to limit such movements to acceptable levels.

Deep basements, five levels below ground to the south of the site, have been built in top-down construction for reasons of economy and to control movements in the ground. Augered piles 1.8m in diameter, with enlarged bases, 4.4m diameter, are founded at −18m level in the clayey strata of the Woolwich and Reading Beds. Surrounding retaining walls are formed in secant piling.

The basement floors need to be sufficiently stiff to support the good operation of the mobile book-stacks and sufficiently strong to resist the thrust from retaining walls transferred north/south and east/west between opposing faces. Therefore the floors are reinforced concrete 400mm thick on a grid of columns 7.8m square with column heads 3.9m square, 800mm deep overall.

Grade 50 Universal Steel columns of section 356mm × 406mm, installed as part of the top-down sequence, are cased in concrete for fire-resistance and to increase their load-bearing capacity.

Basements in the central area at the north of Phase 1A are limited to two levels to clear the Victoria Line tunnels below. The foundations are necessarily reinforced concrete rafts (piles would foul the tunnels). Perimeter secant pile retaining walls were held up temporarily during construction by ground anchors until they could be propped in the permanent works by basement floor slabs.

The basements, 25m deep in the south area and totalling in volume about 300,000m^3 (the largest non-military in the UK), are important to the Library project, not only to accommodate the book stores and plant-rooms, but because of the potentially adverse effect of their construction on adjacent and existing buildings and structures.

Earlier reports[1] described the arrangement and construction method for the basements in principle but implementation lay ahead. Today the construction of the basement is behind us, as a consequence of gaining four important objectives:

Firstly, design intentions have been successfully developed, justified and embodied in construction drawings, specifications and contract documents.

Secondly, Arup predictions of behaviour, specifically movements, of the Library itself and of the surrounding ground and adjacent buildings and structures have been vindicated in performance as verified by systematic surveys and monitoring.

Thirdly, the basement works have been constructed to completion within time and budget and in accordance with contract and design intentions.

Fourthly, to date there has been no claim for damage or loss of operation in any building or structure potentially affected by the construction of the Library basements.

Phase 1A structure: SRL half completed

A view from Euston Road: as it will be

Superstructure

The form and geometry of the elements of the superstructure, required by planning, favoured the choice of reinforced concrete. But to limit the size of certain critical columns, Universal section Steel Columns are continued above ground level.

The floors of the Rare Books Reading Rooms and the offices of the Science Reference Library are supported by conventional reinforced concrete coffered slabs of overall thickness 400mm. Reinforced concrete walls of the stair and lift shafts stabilize the building, separated in phases of construction by expansion joints that exist only above ground floor.

More height is needed in the spaces for exhibitions under the Rare Books Reading Rooms to the west, where the 7.8m square grid is carried through.

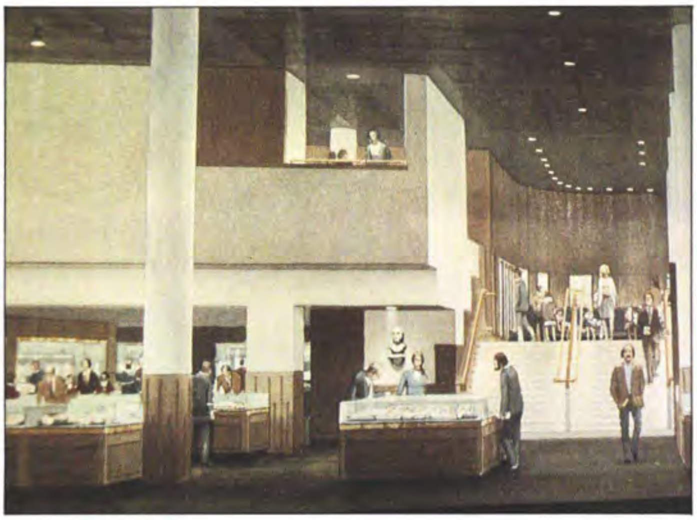
But in the Entrance Hall, architectural and planning requirements call for more generous volumes and for floor areas uninterrupted by columns. Asymmetric portals in lightweight reinforced concrete span 15.6m north to south at 7.8m centres to meet such requirements. Here and over Rare Books the framework carries precast concrete lightweight slabs, laid to falls to support a natural slate-covered roof.

Meeting and conference rooms are located at the south end of the Science Reference Library, the largest to seat 250 people. This latter is acoustically separated from the main building, to achieve the standards required. The inner chamber has a reinforced concrete stepped floor mounted on resilient bearings to eliminate perceptible structure-borne noise and vibration, the source of this being chiefly the Underground railway.

In general the structural frame is protected from corrosion by the building envelope. Both the brick cladding and the fenestration are designed for long life, the former being carried by precast concrete beams designed to isolate, so far as is possible, the brickwork from the movements of the structural frame. Very high quality concrete is employed in the cladding beams and, where exposed to the weather at the lintol that supports the brickwork, the reinforcement is stainless steel.

Left:
Entrance Hall,
Exhibition area,
and below:
as it will be

Left:
Entrance Hall,
looking south,
and below:
as it will be



The contracts and their performance

Contract work for the secant pile walls, large diameter augered piles and preliminary excavation, began in April 1982, over a year before the appointment of the construction manager, and completed November 1983.

Laing Management Contracting, appointed in mid-1983 to be construction managers, began at once to plan and organize Phase 1AA, comprising the substructure for all Phase 1A and the superstructure for the Rare Books Reading Rooms and the Entrance Hall. In July 1984 work began on Phase 1AA. The contract period was to be 78 months — determined, at least in part, by limitations to annual cash-flow.

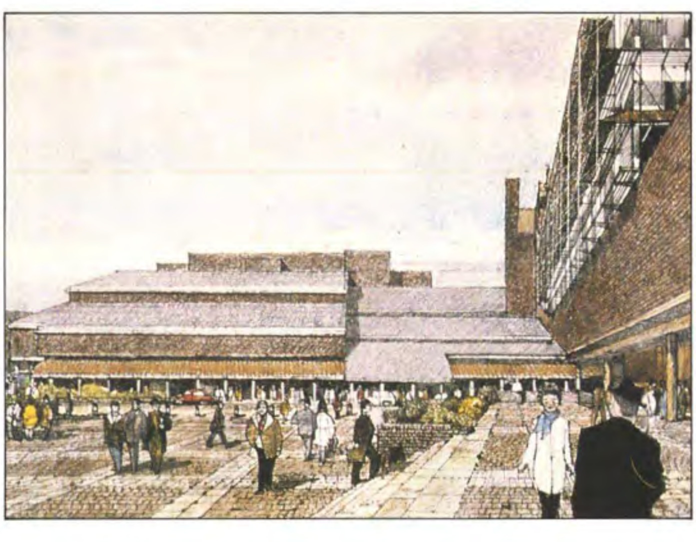
In all there were 12 Work Parcels for the structure of Phase 1A, 10 of them being in the substructure. The two most important below ground were for the deep and shallow basements respectively. Construction of the substructure in its entirety was accomplished in 37 months. Superstructure construction began nine months before the substructure for the deep basements was completed and some three months ahead of the construction programme.

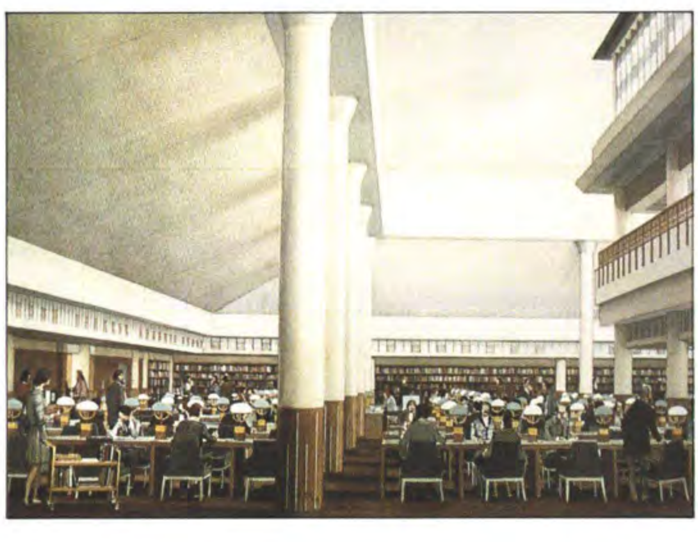
Work for the remainder of Phase 1A, designated Phase 1AB, was authorized in January 1987. This comprises the superstructure of the Science Reference Library, located along Midland Road.

All the superstructure within Phase 1A was built under two sub-contracts, Work Parcels 2105 and 2605. Parcel 2105, comprising the Rare Books Reading Rooms and the Entrance and Exhibition Halls, and of gross area about 14,250m^2 was completed at the beginning of October 1987, after 18 months' work. Parcel 2605, chiefly the Science Reference Library, but including the more com-

Left:
Looking towards
the entrance,
and below:
as it will be,
Rare Books to
the left, and SRL
to the right

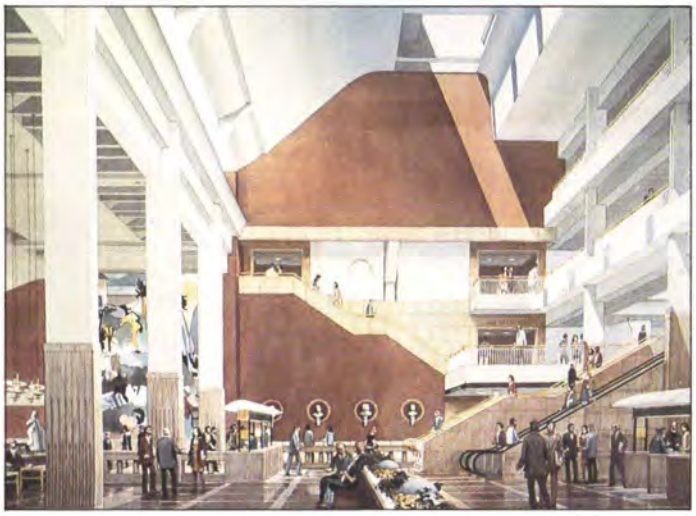
Left:
Rare Books
Reading Room
and below:
as it will be





Left:
Entrance Hall,
looking west,
and below:
as it will be

Left:
Entrance Hall,
looking north
in the background
communications
bridges and stairs,
below: as it will be



plicated Meeting Rooms, and of gross area about 25,000m², is due for completion at the end of January 1989, 18 months after the start, and is currently a little ahead of programme. With the completion of work on Parcel 2605 the structure of Phase 1A will have been completed to budget and to programme.

Coordination of the commissioning handover and fitting out of the re-combined Phases 1AA and 1AB has resulted in Phase 1A becoming due for completion in March 1993. Its final cost is predicted to be a total of £192M in 1993, with the structural works amounting to £44M of this.

The future

Studies completed in the mid-1970s pictured Phase 1 as sufficient to accommodate all in the British Library that it was planned would move to Euston, and to meet operating needs to the end of the century. Phases 1B and 1C, which with Phase 1A would comprise Phase 1, were expected to extend over a gross area of about 48,000m².

With the authorization, early in 1987, of the last section of Phase 1A, attention was turned to the requirements for Phases 1B and 1C. In December 1987, the Minister for the Arts authorized the second and final phase of Phase 1, this being a combined and reduced version of 1B and 1C. After a re-evaluation of needs and of funds, a new target was set. This 'Completion Phase', as it is now called, was to be planned to a net usable area of 25,000m² within a total construction budget given at today's prices.

The feasibility study commissioned from the design team in January 1988 reported favourably in July. The needs of the British Library can be met within space and financial targets. The Completion Phase can be designed and constructed for handover to the Library in mid-1996. As much as possible of the noisy and disruptive construction will be done before the Library move into Phase 1A in March 1993.

Although these dates lie well into the future they must be viewed against the history of the enterprise, since a new building was first considered in 1962, and since the Act of 1972 established the British Library Board.

It was always considered possible that further development of the site for the British Library might take place, to accommodate as-yet-unforeseen future needs. This was tentatively designated as Phases 2 and 3 beyond 1A, 1B and 1C. At present no work is planned beyond the Completion Phase, but it is still not impossible that it might be undertaken, though certainly not before the end of the century.

At present, however, with the structural works complete, the weather envelope well advanced and authority to proceed with Completion Phase 1, prospects are as bright as they have ever been. There is some evidence that critics of the scheme may relent.

Most important, renewed enthusiasm can be discerned in the corridors of British Library for their move to Euston and for the commissioning of their new HQ.

References

(1) CROFT, D. *and* RYALLS, P. The British Library. *The Arup Journal, 13* (4), pp. 2-6, December 1978.

(2) CROFT, D., *et al.* The British Library: a computer model for London clay. *The Arup Journal, 14* (1), pp. 26-31, April 1979.

(3) EVANS, P.B. *and* O'RIORDAN, N. British Library pile test. *The Arup Journal, 14* (3), pp. 26-31, September 1979.

Credits

Client:
The Department of the Environment
Extended client:
The Office of Arts and Libraries
User:
The British Library Board
Architect:
Colin St. John Wilson and Partners
Structural engineers:
Ove Arup & Partners
Services engineer:
Steensen Varming Mulcahy and Partners
Quantity surveyor:
Davis Langdon & Everest
Construction manager:
Laing Management Contracting Ltd.
Sub-contractors (basements):
Tarmac Construction Ltd., John Mowlem & Co. plc
Sub-contractors (superstructure):
Norwest Holst Construction Southern Ltd.

Photos: Ove Arup & Partners
Artist's impressions: Colin St. John Wilson and Partners

Right: SRL Reading Room as it will be

Tobacco Dock

Architect:
Terry Farrell Partnership Ltd.

Michael Courtney
Richard Matthews

Introduction

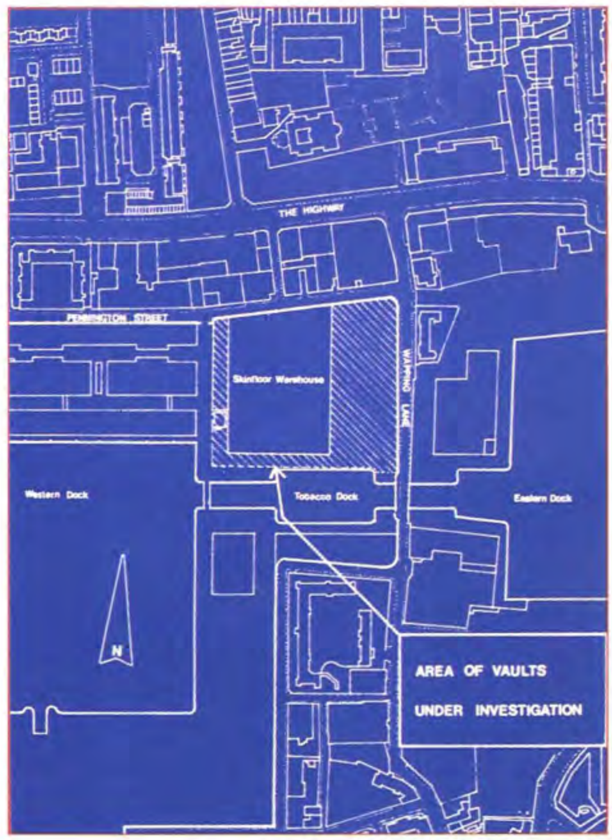
Between the Tower of London and Limehouse — on the marshy land between the Roman Highway and the broad sweep of the river around Wapping — lie the four major enclosed docks built close to the heart of the City of London at the beginning of the 19th century. The Docks were the result of an enormous increase in trade which could no longer be handled by the riverside wharves (Fig. 1).

Following the construction of St Katharine's, the massive London Dock was built and, to the east, the much smaller and related inlet that formed the Tobacco Dock (Fig. 2). As part of the change in the technique of handling goods, from that appropriate to small riverside wharves to what was suitable for the trade through the massive docks, surrounding sites were developed with vaults beneath the quays and new warehouse buildings above. Generally these buildings were multi-storey, with timber post and beam construction over brick basement vaults. An 18 ft. by 12 ft. module was adopted for the vaults to suit the limits of timber floor spans above.

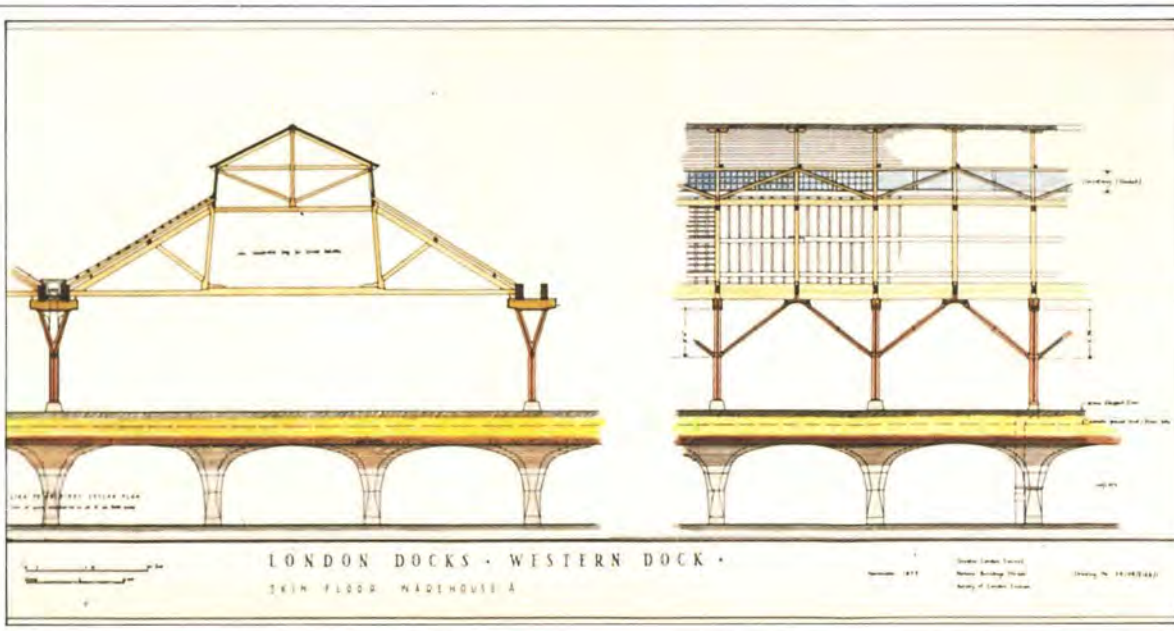
The warehouse at Tobacco Dock, known as the New Tobacco Warehouse, was designed specifically for the storage of tobacco and the collection of customs duty. There was a fear that keeping tobacco on upper floors would produce a loss of weight (and hence duty) by evaporation; so the new building was to be of single-storey construction, built over wine vaults, and surrounded by a massive enclosing wall with only one entrance to ensure additional security.

The New Tobacco Warehouse, designed by Daniel Alexander, Surveyor to the London Dock Company, originally extended over nearly five acres. It was constructed in 1813 as a series of large 54 ft. span queen-post roof trusses supported by unique bifurcated cast iron columns at 18 ft. centres. These columns are supported on the 18 ft. square groined vaulting beneath, the use of this more economic and convenient square module being possible due to the absence of the normal small timber spans above (Fig. 3).

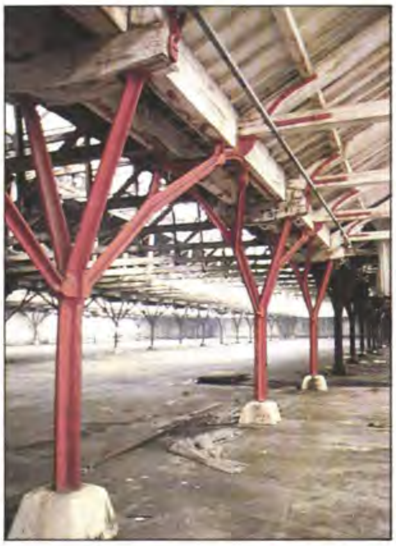
1. Map of the London Docks

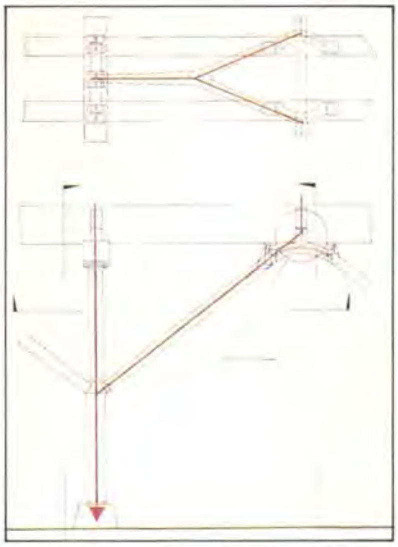


2. Map of site showing area of vaults



3. Sectional views of original warehouse structure (Original drawings by GLC Architects' Department)





The columns and their associated roof structures are the most significant elements of this important building. The large roof spans were unlikely to have been a specific requirement of the storage process, although there would doubtless have been practical advantages in having few components to assemble and few valley gutters to maintain. However, prestige and the dramatic exploitation of the superior compressive strength of cast iron were clearly also important elements in the development of this unique but transitional structural form.

The roof trusses — particularly elegant with their long lantern lights and inward canting of the queen-posts — are at 9 ft. centres; they occur alternately over the columns and midway between them. Pairs of timber gutter beams span between the columns; these are neither strong nor stiff enough to carry the roof trusses at mid-span, and are therefore supported by cast iron raking struts which spring from the columns at mid-height. In order to accommodate the wide valley gutters, the ends of the roof trusses are offset to each side of the column; both columns and struts therefore divide to provide a seating for each truss.

This superstructure sits on an imperforate area of brick groin vaults on granite columns.

The columns have a brick base, sustained by timber piles driven through the alluvial ground and just into the flood plain gravel overlying London Clay.

The original drawings of the building are still held by the Port of London Authority in their library.

The clarity of the structural engineering approach is seen in the carrying of the loads by axial force in members rather than in the weaker bending mode. This is particularly clearly expressed in the cast iron work (Figs. 4 & 5).

History

The New Tobacco Warehouse has been subjected to major changes in its 170-year history; two have affected its use, and three have affected its physical state.

Firstly, with the pressure for additional area of enclosed dock space, the Tobacco Dock itself was extended right through the warehouse — severing it into two separate buildings — to gain access to the new Eastern Dock beyond Wapping Lane.

Later, with the opening of the Royal group of Docks, the tobacco trade was transferred down river, and the Warehouse was used for the storage of furs and animal skins, to serve the rapidly expanding fur trade north of Queenhithe. The Warehouse became known locally as the Skin Floor Warehouse.

During the Second World War, extensive damage was caused to the building. This led to the dismantling of the Warehouse structure to the east of the central fire-resistant division wall, and the formation of an enclosed open yard over the vaults. The brick elevation to the Dock was demolished, two bays of the structure were removed to provide additional quayside space, and corrugated iron sheeting was fixed to the existing structure as the new southern enclosure.

The surviving building is about 250 ft. wide and 350 ft. long, uninterrupted by intermediate walls.

With the closure of the London Dock in 1968, the Tobacco Dock Skin Floor became vacant and deteriorated considerably, although it was listed Grade 1 in the mid-1970s (Fig. 6).

The development

In 1983 Tobacco Dock Developments Ltd. was formed with the aim of redeveloping the site whilst retaining most of the historic building. It was proposed to develop the site by refurbishing and renovating the Skin Floor Warehouse and the underlying vaults to form a massive area of leisure shopping.

The structures were surveyed to establish the extent of dilapidation requiring repair and to provide some basic understanding of the possibilities of alteration. A scheme was developed by the architects, Terry Farrell Partnership, to provide a high quality development of leisure shopping, i.e. shops, restaurants, bars, etc. (Figs. 7 & 8).

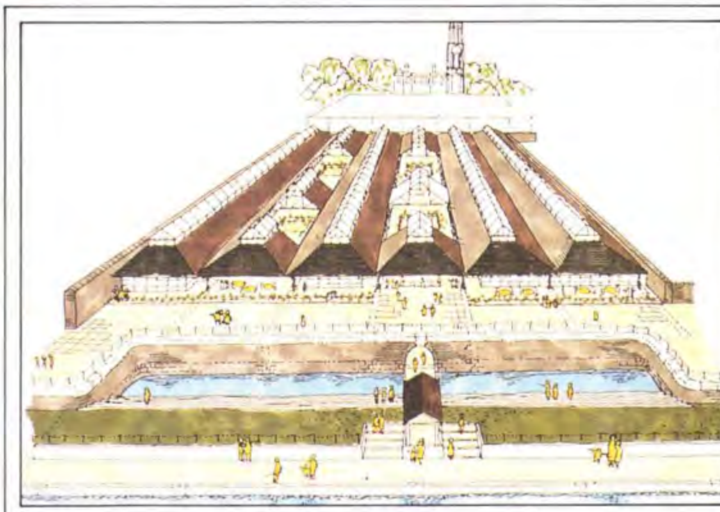
4. Cast iron columns (Photo: Richard Matthews)

5. Axial forces in iron members

6. Aerial view of Docks 1980

7. Plan of proposed development

(7. & 8: reproduced by courtesy of the architect)



8. Architect's impression of proposals

The essential elements of the scheme, which was the subject of a planning application by Tobacco Dock Developments Ltd. on 15 October 1984, are:

(a) The careful dismantling of the western bay of Skin Floor Warehouse, between grids 5 to 8, and its rebuilding on the vaults to the east, between grids 17 and 20.

(b) The construction of a new service yard and basement car park to the west, between the extended News International printing works and grid 8. These facilities are to be jointly used. The service yard will be shared during the daytime, and the 350 parking spaces will be used for the benefit of the Skin Floor development during the day and by News International during the night.

(c) The formation of arcades through the building which includes the creation of large openings in the roofs and brick vaults to take light and air down into the basement. These openings also provide escape paths for smoke in the event of a fire and provide space for stairs to link the different levels.

(d) The provision of access openings through the massive perimeter walls and the dock wall, with staircases linking the streets and the dock with the vault floor and the Skin Floor.

(e) The provision of services; light, power, drainage, ventilation, and sprinklers, necessary for the intended use.

Structural conservation, restoration and renovation

The major structural issues established during the feasibility study were:

(1) The replacement and repair of rotten timber in the roof members

(2) The prevention of progressive collapse of the superstructure in an accident

(3) The construction of the large penetrations of the brick vault floor

(4) The load capacity and durability of the timber piles. It was necessary to demonstrate these properties for the existing foundations to avoid the excessively large expense of replacing the original timber piles with new concrete pile foundations.

Timber trusses

The 19th century design had dealt with rainwater on the roof by providing lead-lined gutters on the lines of the columns Every sixth column was a hollow circular pipe which carried the rainwater down to drains beneath the vaults and thence away to the main sewers. Soon after the closure of the Dock in 1968, the lead lining had been stripped from the gutters and the timbers of the gutter beams and roof truss ends were exposed to the weather. Substantial rot had occurred. The gutter beams had to be replaced but it was better conservation to repair the rotten truss ends than to replace the trusses. After much investigation of steel plates and brackets a simple approach of scarf jointing in new timber was conceived as being in sympathy with the original timber work.

9. Truss repair
(Photo: Peter Mackinven)

The section sizes and qualities of the *Pinus sylvestris* (European Redwood) timber members of the original trusses are larger and better than currently available in Britain. Green Douglas Fir members able to provide the quality and size required are available in Canada, however, and were specially obtained from there.

In exploring designs for the repairs to the truss ties, concern was expressed regarding tolerances, lack of fit, etc., but the craftsmen carpenters were reassuring that what was required could be achieved. Their work on site has demonstrated that accurate, close fit, good craftsmanship still exists in the British building industry (Fig. 9).

The trusses may not have been 'engineered' as would now be understood, but they conform very closely to the design advice for timber work given in Tredgold's Tables, which were published at about the time of the construction of Tobacco Dock.

Analysis of the trusses demonstrated that the most critical situation for the strength of the major members was bending due to asymmetric loads. The quality of the timber was good, though not as good as might have been expected of timber from the early 19th century. It was therefore demonstrated by simple frame analysis that the trusses, the joints and the repairs could take the anticipated loads in accordance with current codes of practice.

Approval of the scheme under the London Building Acts defined the project as a building within the category of Section 20. The District Surveyor interpreted this very strictly, requiring the structural members of the roof to have a one-hour fire period in accordance with *BS476*. A fire engineering analysis of the trusses considering charring rates, loads and stresses in the residual members, showed that the maximum period of resistance which could be demonstrated by this means was just under 43 minutes. After consideration and investigation it was agreed that the additional 17 minutes could be achieved by an application of clear intumescent paint. A proprietary product was chosen on the basis of the manufacturer's information, advice and test results.

The application has not been a success. The paint has crystallized in places creating a white bloom effect. The reasons for this are not clear and intense discussion is taking place between the contractor and the approved applicator.

Fortunately the building control system has now changed and the District Surveyor acting for the local borough has agreed that the structural members of the roof do not require a fire resistance period.

Cast iron columns

The properties of cast iron can be very variable. Essentially it is brittle and potentially has very low tensile strength. Properties are very dependent on quality of casting.

While the truss and cast iron column structure is well capable of carrying the forces from symmetric loads, it is very close to being a mechanism, there being little or no redundancy. The collapse of a single truss would generate unbalanced forces, from the alternate truss load, through the branching strut which would cause a column to fail in bending, creating an imbalanced truss load on the adjacent column and so on. Any failure of a major roof member, in accident or fire, would therefore lead to progressive collapse.

To prevent this, the rotten gutter beams were replaced with steel beams, eventually timber-clad, which span 18 ft. between columns under dead and incident load. The only load in the raking struts from intermediate roof trusses is now due to imposed load, the asymmetric portion of which the columns can take. This is the one part of the new structure which does not respect the integrity of the original building (Fig. 10).

The cast iron columns were cleaned and visually inspected for signs of cracking; none were found. The quality of casting was clearly very good and no deterioration or propagation of crack defects has occurred.

Brick vaults

The brick groin vaults are one of the most difficult and one of the most interesting parts of the building for the structural engineer.

The brick arches are stable because the compression thrusts in the arch and groin lie within the thickness of the brickwork under both symmetric and asymmetric loads. The abutments at the perimeter of the structure must be capable of maintaining the line of thrust in the arch and the resultants at the columns within a safe zone.

If this geometric situation is not extant then the thrust line and, if necessary, the arch shape will change to generate different abutment thrusts and so remain stable, provided of course that the material forming the arch does not fail by excessive cracking or compressive crushing.

The major treatise on masonry arch structures is 'The Stone Skeleton' by J. Heyman. The principles of analysis and geometric safety defined therein were adopted for the analysis of the brick vaults.

The criteria for the analysis and subsequent design of the brick vaults are that the thrust line under uniform, asymmetric and point loads should lie within the middle half of the brick arches and the stone columns, and that the safe crushing strength of the brickwork should not be exceeded (Fig. 11).

The brick groin vaults of Tobacco Dock are more difficult to analyze than most of the structures to which Heyman's work is applied as they arch in two directions and are supported at points by columns (Fig. 12).

The essential structural forces are the abutment thrust, which is related to the shape of the arch, and the vertical dead and live loads.

The objectives of the analysis are to establish likely stresses in the brickwork, to prepare brick repair methods and to establish the upper and lower bound levels of the abutment thrusts as the input to the design of the large arcade openings.

Samples of bricks and mortar were taken to establish their properties.

A drawing in the Port of London Authority library indicated that the brick arches were built high on centering and allowed to flatten into a parabolic shape. The geometric shapes of a number of vault bays were surveyed and the results compared with the original drawings. The survey showed that the arch shape varied, but not significantly, and that the vaults had settled and flattened considerably after their construction. The brickwork of the vaults was clearly tolerant of quite large movements without cracking or distress.

The various cracks in the brickwork and stone, in the areas where the vaults had been abused by overloading, especially patch loading, were repaired by resin injections.

The PLA rating for the Skin Floor allowed a safe working load of 2 $cwt./ft.^2$. Very early in the work it was realised that this rating could not be justified as a safe working load. The design live load adopted was 5 kN/m^2, as appropriate for the use, with design dead load being the self-weight of the vault brickwork and overlying fill. Eventually this fill was carefully removed in small sections and replaced with a lighter fill, and a concrete plank void floor to give an area for services distribution.

Two different ways of analyzing the brick arches were considered; a flow net computer program based on finite elements and a progressive analysis based on Heyman's work, assuming that the orthogonal arches span to the groin arch which then spans to the column. An early comparison showed that the latter system gave answers within a few per cent of the former, more complex and rigorous analysis. The simpler consecutive arch analysis was adopted for ease of use and engineer control.

The analysis is iterative. An 'abutment thrust' is chosen for an orthogonal arch. The thrust line in this arch is drawn, combining the horizontal thrust with the vertical loads.

If this thrust line is within the central portion of the brick arch, the resultant end thrusts become the input to the diagonal groin arch; if not, the process is repeated with a different initial thrust. Once the arch loading, 'abutment thrust', onto the groin is established, the diagonal groin arches are similarly analyzed to establish a thrust line. If this is within the central portion, the analysis can proceed; if it is not it is back to the original thrust force choice. The effect of the diagonal thrusts from four vaults on a column is then checked to establish that the column force line lies within the central portion of the column (Figs. 13 & 14).

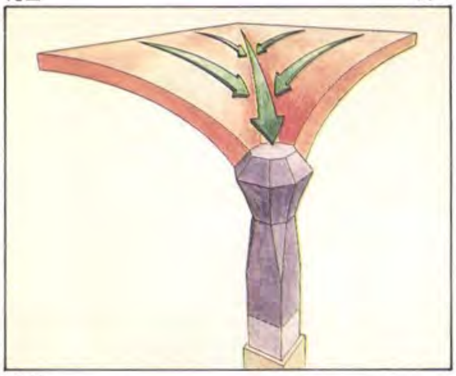
The thrust on the orthogonal arch is generated from the adjacent arch and the thrust on the columns comes from four arch systems. There is clearly an interaction. For symmetrical loads this is not of great consequence but asymmetric, patterned loads, both uniform and point, generate a very complex analytical situation.

The analysis process is clear, the work repetitive and time-consuming. Having established the analytical process and parameters, a program for the generation of thrust lines was written for the computer. The input was the geometry of the arch established from the survey, the vertical loads and a selected abutment thrust. The output was a graphical presentation of the resultant thrust line. The results were viewed at each stage of analysis and, if necessary, a new abutment thrust chosen by the engineer. It would have been possible to write a program which reiterated automatically but this would have required considerably more time to write than the program developed, and it could have taken considerable time to hunt for convergence to an acceptable solution.

An 'engineer interrupt' approach was chosen so that the engineer remained in full control and understood the assumed arch thrust profiles for each of the generated solutions. At an early stage it was accepted that the brickwork at the crown of the arch would transfer vertical shear when dealing with asymmetric and point loads. The completion

10△

11▽



10. New gutter beam (Photo: Richard Matthews)

11. Thrusts in arch forms

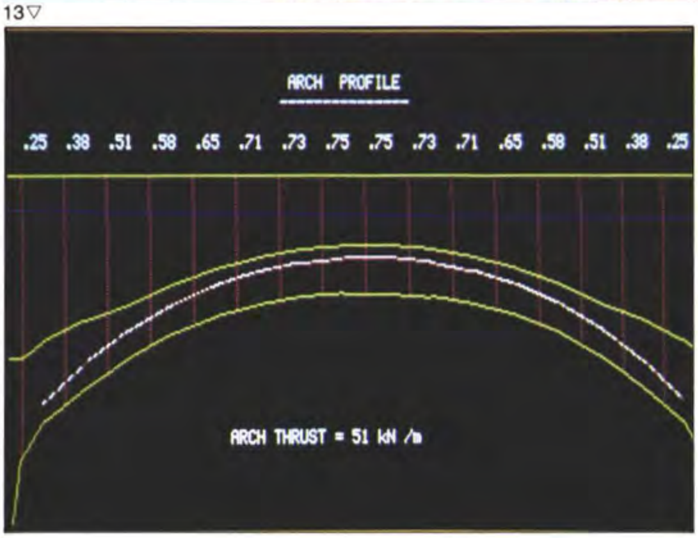
12. Arches (Photo: Noel Shirran)

13. Computer trace of thrust line in orthogonal arch

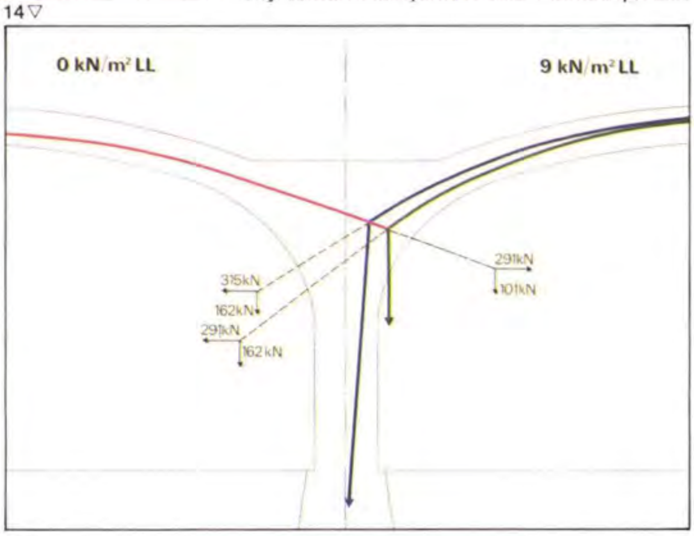
14. Thrust line in groin and columns

12▽

13▽



14▽



of the analytical work, including some sensitivity checking, leads to the establishment of a range of forces for the design of the structure of the arcade openings.

As an axiom for conceptual discipline it was stated that the cut edge of any opening should be at or near the crown of the arches so that the brickwork, and hence the thrust line, was sensibly horizontal. This discipline was not followed exactly in the development of the design but the analytical and design process was developed to deal with the variations finally adopted.

Feasibility studies for methods of support to the arches at the edge of the openings involving bending of members, new abutments and foundations all produced very visible, massive members and movements likely to alter significantly the arch shapes locally. These movements were unacceptable as they could lead to very different arch thrusts and possible collapse. The final concept chosen is a flat horizontal ring beam, on top of the brick arch with a corbel down into the brickwork. The width of the beam was made very large to keep bending deflection to a minimum (Fig. 15).

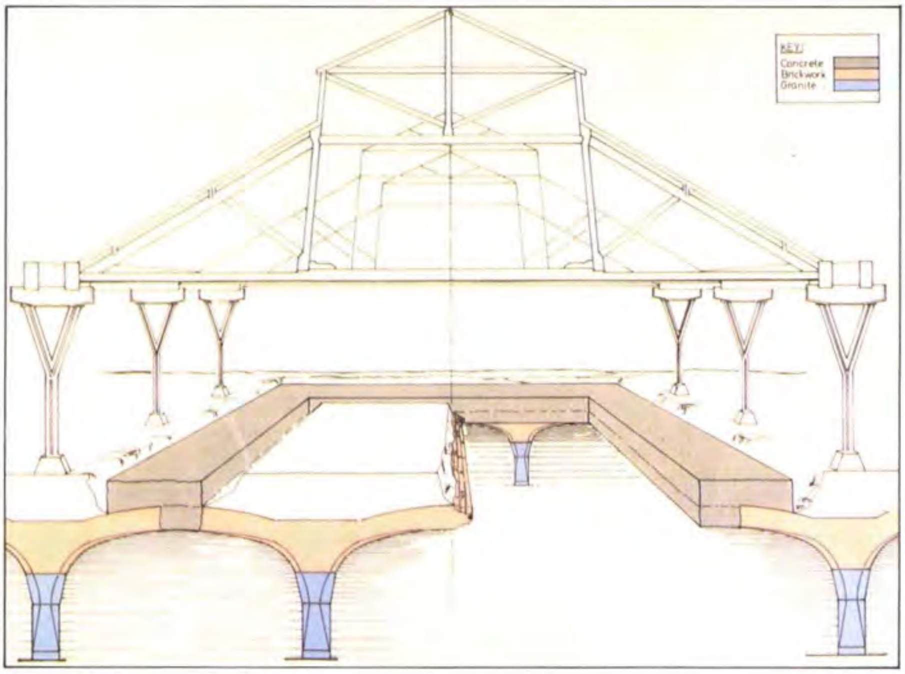
The corbels have been designed so they can be installed in short lengths thus maintaining the integrity of the brickwork during construction (Fig. 16).

As the primary action of this work remains axial the movements are small. The completed work is absorbed into the existing structural zones (Fig. 17).

Timber piles

The foundations of the Tobacco Dock Warehouse consist of timber piles, of which an average of eight support a timber platform under a brick base beneath each granite column.

The Building Byelaws prohibit the use of timber in foundations. The District Surveyor expressed his disapproval of timber piles and his view that on any renovation or repair work where his writ ran he would insist on new concrete foundations supporting all the existing brick vaults as well as the new work. The client was likewise worried about the reaction of possible funders and future tenants to a timber foundation to a long-term structure.



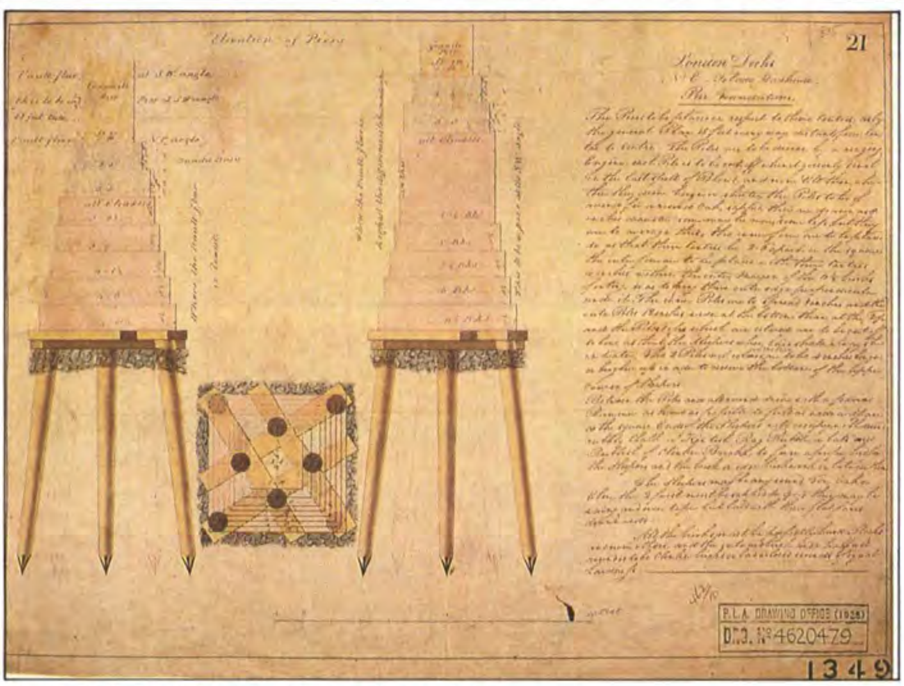
15. Typical ring beam round opening in brick vault

16△

17△

16. Installation of corbel in brickwork (Photo: Ove Arup & Partners)

17. Completed arcade opening in brick vault (Photo: Richard Matthews)



18. Original c.1810 drawing of timber pile foundation (Reproduced by courtesy of the Port of London Authority)

19. Extracted timber piles (Photo: Richard Matthews)

To underpin every existing column, while technically possible and in fact carried out in a small area of the warehouse, would have been a major, expensive and time-consuming exercise.

Timber piles have been used since Roman times. An intensive and extensive investigation and historical research demonstrated that timber is durable — provided it is submerged below the oxygen zone of the ground water. This work is being presented in a geotechnical paper at a conference in Athens.

The investigation of existing piles at Tobacco Dock, by way of trial pits, showed that they were ordinary pine, approximately 225mm square, driven through approximately 4m fill and alluvium just into flood plain gravel (Fig. 18).

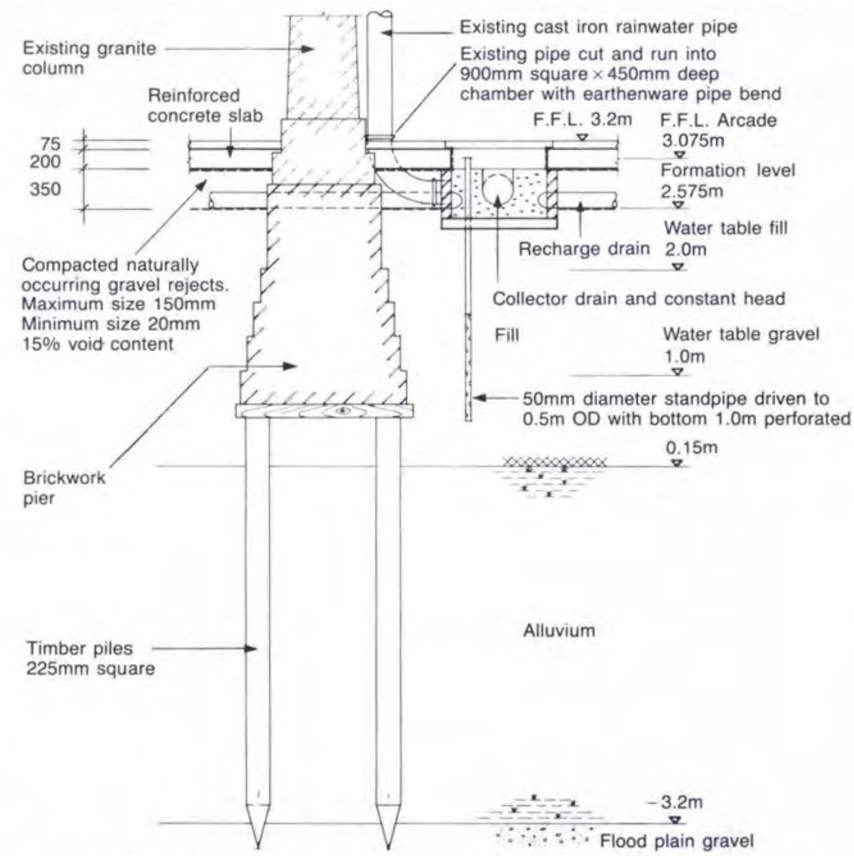
Load tests were carried out on three piles, which were then extracted from the ground for inspection and tests. The piles were capable of safely carrying the anticipated load from the self-weight of the structure and the live load. The load deflection graphs are very interesting because they show the result of the original driving method as well as the load capacity. Normal criteria for selecting safe loads on piles were not applicable (Fig. 19).

The timber of the extracted piles was inspected and tested. The saturated timber was in very good condition, as were other piles throughout the site when inspected by trial pits.

There are two ground water regimes on the site: the natural water table in the gravel and a perched water table in the fill over the alluvium. It is the latter which preserves the timber of the piles.

Records of water levels in the area over many years show a static situation. As a safety precaution, however, a recharge system was devised to maintain the water table. The system ensures that all rainwater falling on the site is channelled into the alluvium, with only overflow going to the sewers, and has facilities to enable the level to be monitored and to be artificially recharged if necessary (Fig. 20).

The client, the funds, tenants and the District Surveyor have all been reassured and the existing timber piled foundations have been maintained and re-used.



20. Ground water recharge system

Conclusion

Many other items required an engineering input, working closely with the architect to provide a finished development in character with the original industrial warehouse and vaults, but the four items described provide the major interest, excitement and satisfaction in conservation, restoration and renovation (Fig. 21).

Restoration and renovation of structures which have performed satisfactorily for a long time starts from an understanding that if the common analytical models and material properties in current practice lead to the conclusion that the old structure is and was unsafe, it is the modern approach, not the structure, that is wrong. This indicates a need to develop an understanding for, and grasp of, the real qualities of the structure, its material and form.

Credits

Client:
Tobacco Dock Development Ltd.

Project manager:
Kingsley Woodville Associates

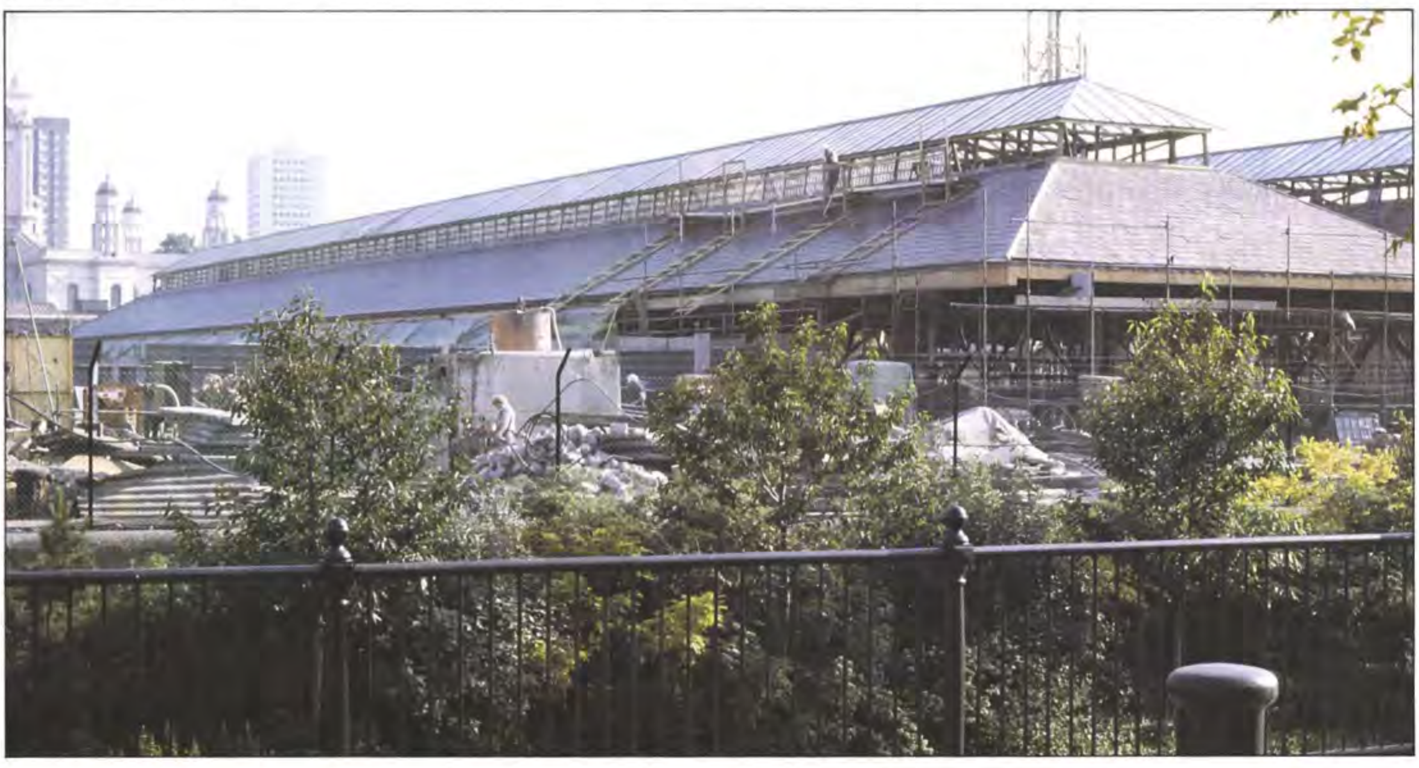
Architect:
Terry Farrell Partnership Ltd.

Structural engineer:
Ove Arup and Partners

Services engineer:
H.L. Dawson and Partners

Contractor:
Harry Neal Ltd.

21. Below: Development nearing completion (Photo: Richard Matthews)



Flue gas desulphurization study

Malcolm Noyce
Paul Johnson
Charles Milloy

Introduction

The combustion of fossil fuels, such as coal and oil, releases substantial quantities of sulphur dioxide and nitrogen oxides into the atmosphere. Power stations are the major source of these emissions, which are widely believed to be key factors in the production of 'acid rain'. Throughout northern Europe, acid rain is blamed for the severe effects on forests and lakes, particularly in the Federal Republic of West Germany and in Sweden. In addition acid rain accelerates the weathering of some stone-faced buildings. In common with other European nations, the United Kingdom, through the CEGB, has embarked on a significant emission control programme to meet some of the international concerns, viz. by the year 2000, a 30% reduction in the 2.5M tonnes of SO_2 released annually.

In the United Kingdom the Central Electricity Generating Board (CEGB) has made a commitment to the installation and use of Flue Gas Desulphurization (FGD) equipment at all new coal-fired power stations. This equipment will remove about 90% of the sulphur dioxide from the flue gas emissions.

As part of this programme, FGD equipment will be retrofitted to two existing coal-fired power stations and will be incorporated in the three new ones which the CEGB intends to build at West Burton, Nottinghamshire; Fawley, Hampshire; and Kingsnorth, Kent.

In its preparation for the installation of FGD technology, the CEGB undertook numerous generic studies to aid its understanding of the implications. In February 1987 the CEGB appointed Ove Arup and Partners to advise on the types and properties of solid by-products that would be generated from different FGD processes which potentially could be used in the UK. Two processes have been identified: limestone/gypsum and regenerative. Each process generates different solid by-products. The Ove Arup and Partners' study had to define the physical and chemical properties of the by-products and then to determine generic disposal options for each product. Advice was given on the possible types of disposal operation, the principles of that operation, the necessary management criteria, environmental impact and long-term monitoring. On completion of this work, assistance was given in support of the consent applications for the proposed new power stations and the development of assessment procedures for solid by-product disposal sites.

Before discussing the disposal of solid wastes produced by the FGD processes, it is worth understanding the background and the processes themselves.

Background to FGD in the electricity generating industries

The United Kingdom led the way in FGD technology with the installation of plants at Bankside and Battersea in London in the 1930s. However, given the success of the policy of dispersing emissions from tall stacks and the consequent reduction in ground level sulphur dioxide concentrations, no FGD plants were subsequently built.

The early British work on FGD was extended in the USA, Japan and West Germany, where large amounts of generating capacity have been fitted with FGD plants of various types in recent years.

Flue gas desulphurization takes place when the sulphur dioxide gas combines with wet or dry materials (reagents) introduced into the flue gases within an absorber. Products of commercial purity can be made, provided the process is designed to separate the impurities contained in the coal and the reagent.

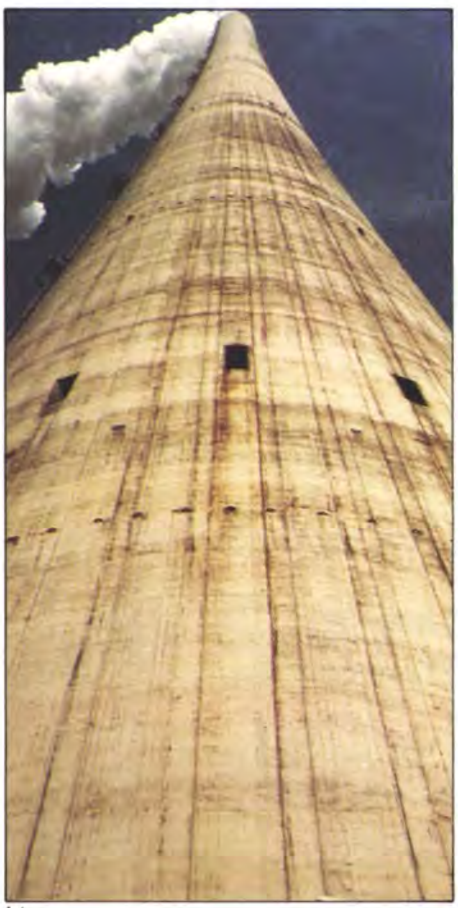
When pulverized coal is burnt, the fine ash produced is removed from the flue gas by electrostatic precipitators or other methods.

This pulverized fuel ash (pfa) is at present the principal by-product at coal-fired power stations and is either sold for the manufacture of building materials or disposed of to reclamation projects wherever possible.

FGD processes

The limestone/gypsum process requires the importation of large quantities of lime or limestone which reacts with the flue gases to produce calcium sulphite. This is oxidized to calcium sulphate dihydrate (gypsum). To differentiate this gypsum from naturally occurring rock gypsum or other chemically processed gypsum, it is referred to as FGD gypsum or desulphurized gypsum. The process can be operated to produce gypsum of commercial quality for use in the plasterboard industry. In addition, a sludge is produced from the process wastewater treatment which also has to be disposed of.

Regenerative processes utilize an absorbent which is subsequently chemically or thermally regenerated for re-use and also produce a commercially valuable product. The Wellman-Lord system is one example of such a process. In this system sodium sulphite is introduced as the reagent and within the process absorber vessel it reacts with sulphur dioxide to produce sodium bisulphite which is then removed and heated to revert to sulphur dioxide and sodium sulphite. The latter is re-used and the pure sulphur dioxide gas can then be used or converted to either



1△

1. Tall stack emission (Photo: Paul Johnson)

2. Voerde Power Station, West Germany, showing limestone gypsum FGD installation in foreground (Photo: Malcolm Noyce)

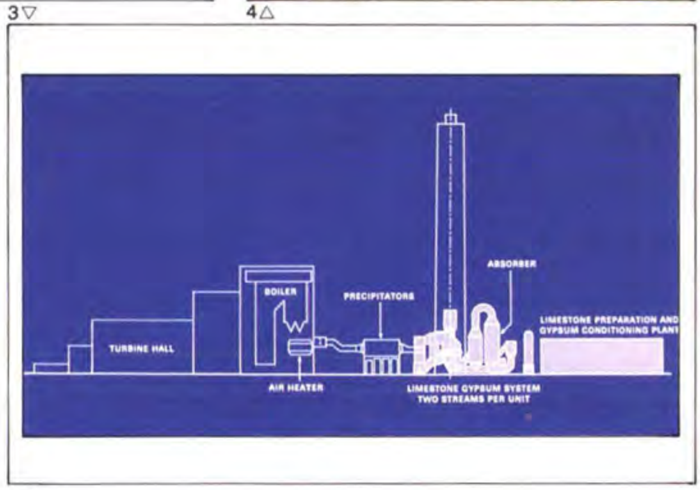
3. Typical installation of limestone gypsum system for a 500/660 MW unit station (Reproduced by courtesy of the CEGB)

4. Buschhaus Power Station, West Germany, showing Wellman-Lord FGD installation (Photo: Paul Johnson)

4△

2▽

3▽



sulphuric acid or elemental sulphur. These products can form raw materials for the chemical and manufacturing industries. A sludge is also produced from the wastewater treatment plant.

Although the FGD plants in Europe are now coming on stream and disposal experience is being gained, this knowledge cannot readily be applied in the UK where coals can contain significantly higher concentrations of sulphur and chlorides. It is for this reason that the CEGB is undertaking additional research covering many aspects of FGD.

Disposal options for gypsum and sludge

FGD gypsum, in its output form, contains a minimum of 95% calcium sulphate (when expressed on a dry weight basis) with a free moisture content of 8-10% by weight. In this form, gypsum would be of commercial quality and could be used in the plasterboard industry. However, if gypsum had to be disposed of, it would be capable of being transported in bulk and could be placed and compacted by civil engineering equipment, although the moisture content needs to be controlled. Gypsum could therefore be tipped, in bulk as a landfill material for the restoration of worked out voids, or for the reclamation of derelict land.

Lining and capping layers might be required, depending on the characteristics of the disposal site. Its final surface could be covered in pulverized fuel ash and topsoil and be landscaped to blend in with and enhance the local environment.

The sludge from the wastewater treatment plant is non-hazardous but would contain impurities from the coal and limestone as well as some fugitive ash. There are several options for disposal of the sludge; these include intermixing with gypsum and pulverized fuel ash using a cellular construction form for the disposal operation. In this state it would allow constant monitoring of the material, and possible treatment of any leachate.

In addition to the identification of the materials and their potential for disposal, a list of criteria was developed on the selection of suitable disposal sites. These criteria addressed the technical, environmental, planning and legislative issues which would govern a disposal site and scheme.

Disposal options for sulphur or sulphuric acid

The sulphur dioxide gas which is produced from the regenerative process can be converted to either elemental sulphur or sulphuric acid. Because of the quantities that would be produced and because of the high value of these products, it is not expected that they would be disposed of as waste materials. Indeed the choice to install this type of equipment would probably only be made if there was a guaranteed market for the product.

On this basis, advice has been given on the methods of handling, storage and transport of these materials prior to commercial use.

Support for consent applications

Ove Arup and Partners have supported the CEGB in its consent applications for the retrofit of a limestone/gypsum process to Drax Power Station in North Yorkshire, which is the largest coal-fired power station in Europe. Similarly we have supported consent applications for new power stations at Fawley and Kingsnorth.

For each of these stations we have identified potential disposal sites in the region technically capable of receiving solid FGD wastes and pulverized fuel ash. We have applied our criteria developed in the generic study to recommend a short list of sites to the CEGB.

Additionally we have provided chapters on solid waste disposal to the Environmental Statements which the CEGB has submitted in support of the formal consent applications.

Assessment procedures

The final area of work on this project has involved contributions to the development of the CEGB's own assessment procedure which is used internally to determine the optimum route for waste disposal. This procedure identifies various forms of disposal schemes in different locations and requires a team approach to a structured decision analysis technique. It examines technical, environmental and economic issues and costs and determines in abstract terms the preferred disposal route.

Summary

In order to undertake and advise on a technology which is to be adapted for use in the UK, a multi-disciplinary team was formed comprising geotechnicians, a chemist, an environmental scientist, process and water engineers, with general support from civil engineers. These were brought together from various parts of the firm including Arup Research & Development, Arup Geotechnics, Industrial Engineering and Civil Engineering. This team was able to come to grips with a range of complex industrial processes, the properties of waste materials, and the development of concepts to handle and dispose of these wastes. The generic design solutions were then refined and management criteria detailed. This will ensure that those solid wastes which have to be disposed of are deposited in a safe and environmentally acceptable manner.

Nevertheless, it is interesting to reflect that as a means of meeting the concerns on acid rain, the technology which achieves those aims itself produces waste products which have to be disposed of. In turn this creates other environmental concerns. It is important therefore that the total environmental impact is reduced. We hope this rewarding project will play a part in achieving that global goal.

Credit

Client:

Central Electricity Generating Board

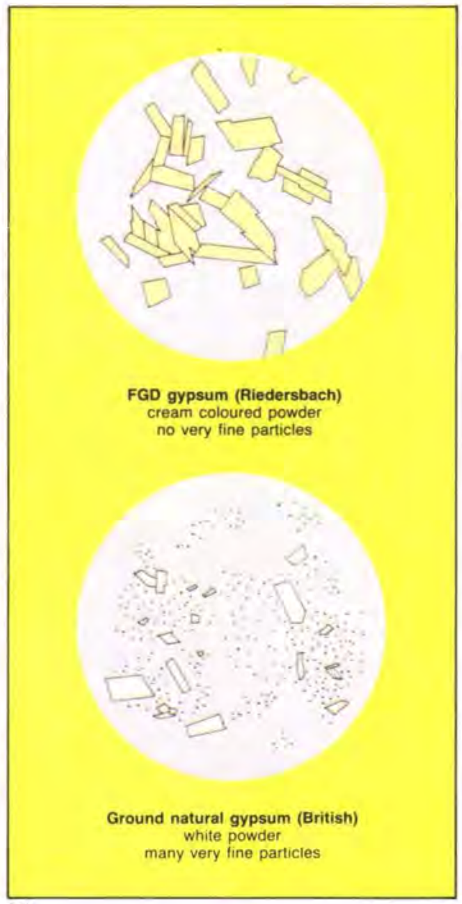
5△

5. Gypsum emerging from FGD plant on vacuum filter belt (Photo: Malcolm Noyce)

6. Typical installation of Wellman-Lord and NO_X plant for a 500/660 MW unit station (Reproduced by courtesy of the CEGB)

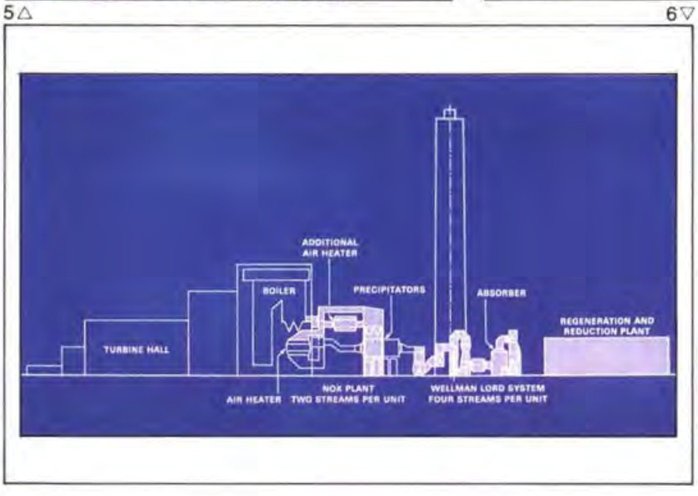
7. Practical test of gypsum handlability (Photo: Ken Cole)

8. FGD and natural gypsum magnified for comparison



8△

6▽



7▽

Glasgow Garden Festival: Maritime Area and Pavilions

Architects:
The Parr Partnership
Jack Fulton Associates
Bruce Patiences & Wernham
ASSIST Architects

Alistair Smith

This summer Glasgow displayed its Garden Festival to the world, the third to be held in the UK. The site is in derelict dockland on the River Clyde, right opposite the new Scottish Exhibition and Conference Centre, and within a stone's throw of the centre of Glasgow itself. The site, which extends over 40ha, includes the old Princes Dock, itself 7ha in area. On completion of the Festival, two thirds of the total is due to be redeveloped for housing; the remainder will become an industrial park, with a yacht marina in the Dock. The Edinburgh, Glasgow and Dundee offices were involved in the various projects described here.

Maritime area

The Dock being such a large portion of the site, it was naturally decided to include it as part of the Festival and initial ideas were to have features on the water to which the public would have access. Our first brief therefore was to design a 'kit of parts' of floating units which could be strung together in different ways to form floating features. For our first contract we produced a scheme based on two types of floating units, both on a module of 12m by 5m. One type was designed for public access with an allowable live load of 3.5kN/m^2. The other unit had an allowable applied load of 1.5kN/m^2 and was intended to have no public access. Only static objects would be placed on it, such as exhibition features, or gardens, etc.

2△

3▽

4△

1. Multi-jet fountain on River Clyde

5 ◁

6 ▷

Also included in the tender package were access ramps 25m long with an allowable live loading of 5kN/m^2. This is considerably longer than one would find in similar situations such as yacht marinas, but the possible tidal variations at this part of the River Clyde are excessive. Normally one expects Highest Astronomic and Lowest Astronomic Tides to be the limit of tidal fluctuations, but once or twice a year it is possible to have tides 1m to 1.5m above or below even these levels. The maximum tidal difference can therefore be of the order of 8.5m, which even with a 25m long access bridge, makes for quite a steep slope.

The final form of the contract was to have two river landing stages in the Clyde itself, each using a 25m bridge and a 12m × 5m float to land on, and in the Dock itself, one 25m bridge with five of the public access floats.

The river landings would permit ferries to drop visitors to the Festival, the Dock landing would provide trips 'around the bay'.

In evolving the scheme for the Dock it was eventually decided to have a yacht marina for the display of yachts to the public. However, in order to try and save on costs it was decided to use 'off the shelf' products. We therefore prepared a performance specification for a marina for 44 yachts but with an allowable live loading of 2.5kN/m^2. Although this was less than the original scheme loading of 3.5kN/m^2, it was still considerably in excess of normal marina loadings of 0.75 to 1.25kN/m^2. Nevertheless, the authorities decreed that in permitting even this reduction, strict control of the numbers of people on the marina would have to be maintained at all times.

William Reid (Forres) were the successful tenderers, using variations on their standard marina units to cope with the additional live loading. The scheme consists of a 25m access bridge onto a central finger walkway with mooring fingers for a variety of sized yachts from 6m up to 10m each side.

Out in the river itself, Water Sculptures were commissioned to design and construct a multi-jet fountain. The jets are controlled so that they go through a continuous cycle of varying patterns. Our brief was to provide the floats and the moorings.

In the early days of the Festival planning, the company had acquired from the Army 10 LFB bridging pontoons, of which we decided to adapt four to make a float for the fountain. The pontoons are made of aluminium and come with plenty of lugs to link them together, so it was not too difficult to devise a structural frame to link them into a cruciform shape.

2. Official logo for the Festival

3. View looking towards the marina

4. to 6. Floating units: types of landing stages and access ramps

One of the parameters we had to bear in mind for all schemes was that the Clyde Port Authority required the Dock to be virtually cleared, apart from a small area at the landward end, at two hours' notice. Large vessels coming this far upstream are unable to turn around as the river is too narrow at this point. In order to achieve this, vessels carry out a three-point turn by reversing from the Clyde into the dock and then proceeding from there downstreams.

As far as the Festival was concerned, therefore, all systems floating in the Dock had to be capable of being unmoored from their restraints and towed into a designated area at the far end of the Dock.

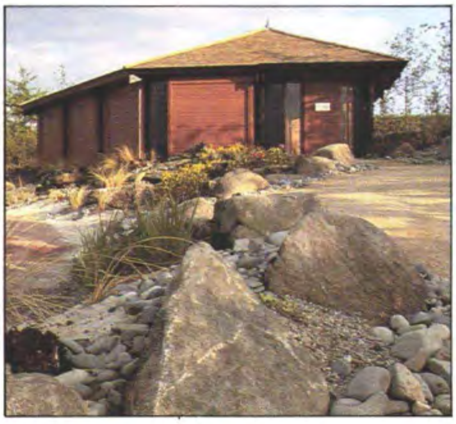
The overall final effect of the Maritime Area on the Festival is to create a colourful air of bustle on the water, which is wholly appropriate to the setting by the river.

The Crystal Pavilion

The initial concept for the Pavilion was devised by Dr Graham Durant, curator of Glasgow University's Hunter Museum and architect Ian Bruce of Bruce Patience & Wernham. Dr Durant's concept was for a building to house man-made crystals and for that building to reflect the shape of such crystals.

The Pavilion is a building in the shape of a hexagonal quartz crystal and is clad in 13.5 tonnes of blue-tinted glass. The supporting structure, which is completely demountable, is hexagonal in plan formed by three steel portal frames each spanning 15.0m. The columns and rafters are dumb-bell shaped as are the eaves and intermediate beams.

The basis of the glazing system is structurally bonding the glass facade of the building to a support frame using structural silicone sealants to achieve the aesthetic effect. The Pavilion is a fantasy structure for the science and technology theme, housing hi-tech exhibitions from holograms to laser shows. The main aim of the exhibits is to educate through entertainment. The Pavilion proved to be very popular, with approximately three million people visiting the Crystal during the Festival.



Pavilion for GAFLAC

This pavilion for the General Accident Fire and Life Assurance Co., is shaped like an elongated hexagon 17.5m × 8.5m on plan with a pitched roof having 'lipped' ends, each of which return round. The architects were The Parr Partnership.

The superstructure is of laminated timber columns and twin rafters, the upper ends of which terminate at ridge level where they are supported by a laminated timber ridge beam. This beam in turn spans some 9m between laminated timber columns each comprising two members spaced apart by timber blocks, those at the top providing a physical seat for the ridge beam.

The rafter and ridge beam assemblies are in the form of 'railway trusses' with the lower tensile members being 25mm diameter mild steel bars.

Lateral stability is given at column footing level where fixity is provided by the columns being located in steel sockets formed from hollow sections. These were in turn cast into the in situ ground slab. The ground slab had a 600mm step in level roughly along its mid-line and was designed as a raft, the sub-base being of unconsolidated, good quality fill.

With the exception of the ground slab the entire structure was prefabricated and is demountable. It is to be dismantled and re-assembled at Ardnamurchan following the closure of the Festival. We will have to carry out a careful re-assessment of the wind stability when this happens.

The Environment Show 1988

This exhibition was promoted by the RTPI, RIAS, and Landscape Institute (Scotland) to promote public awareness of architecture. Within a simple portal-frame pavilion designed by ASSIST Architects, a free-standing wall system developed by Jack Fulton Associates carried a 'high-tech' display; we were involved in the design of both pavilion and wall, the latter being irregular in plan, and standing 3.5m high.

The system had to be demountable at the end of the exhibition, of dry construction, fast to erect given the tight programme, and capable of withstanding crowd loading.

The solution was a plasterboard-surfaced wall with lightweight steel stud framing. To accommodate video displays and storage, the wall was 800mm thick in some places, which made room for a heavy base of dry concrete blocks to act as a counterbalance for the stud framing, cross-braced between the studs, which cantilevers to the head wall.

This structure is invisible and, ironically, the public bypassed what could have been an interesting display in its own right.

Glasgow Garden Festival

Client:
Scottish Development Agency

Main contractor:
Bovis Construction Ltd.

Structural engineers:
Ove Arup & Partners Scotland

Architects:
The Parr Partnership
Jack Fulton Associates
Bruce Patience & Wernham
ASSIST Architects

Fountain:
Water Sculptures

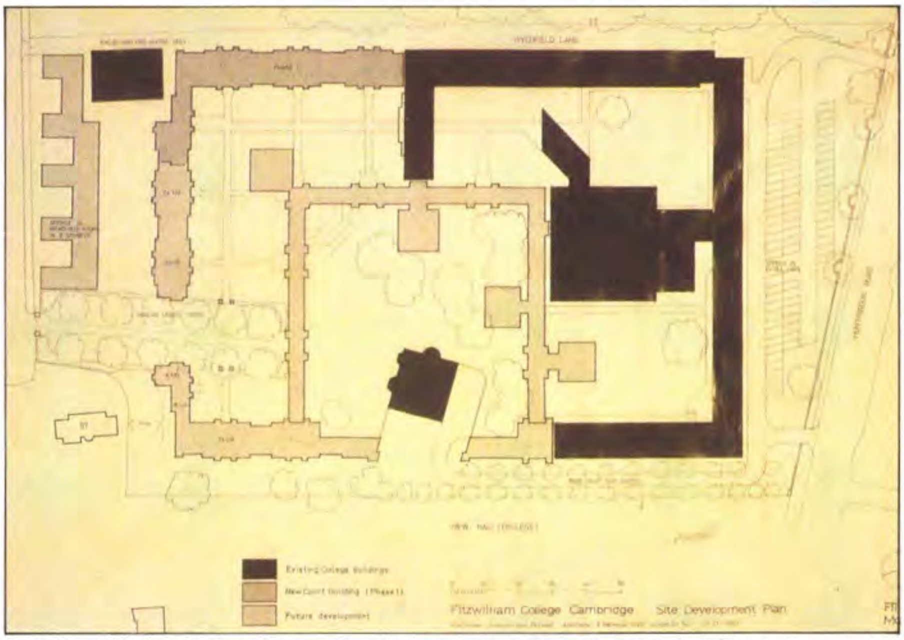
Sub-contractors:
William Reid (Forres) Ltd.
William de Venny, W.B.S. Keillor
R.J. McLeod, Neslow Interiors
Frank Duncan Engineering Ltd.
Capital Aluminium Systems

Photos:
Alistair Smith, Peter Mackinven

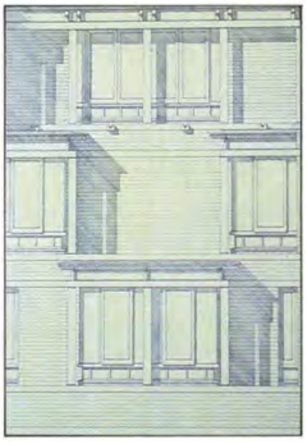
Fitzwilliam College, Cambridge

Architect: MacCormac Jamieson Prichard & Wright

Robert Pugh



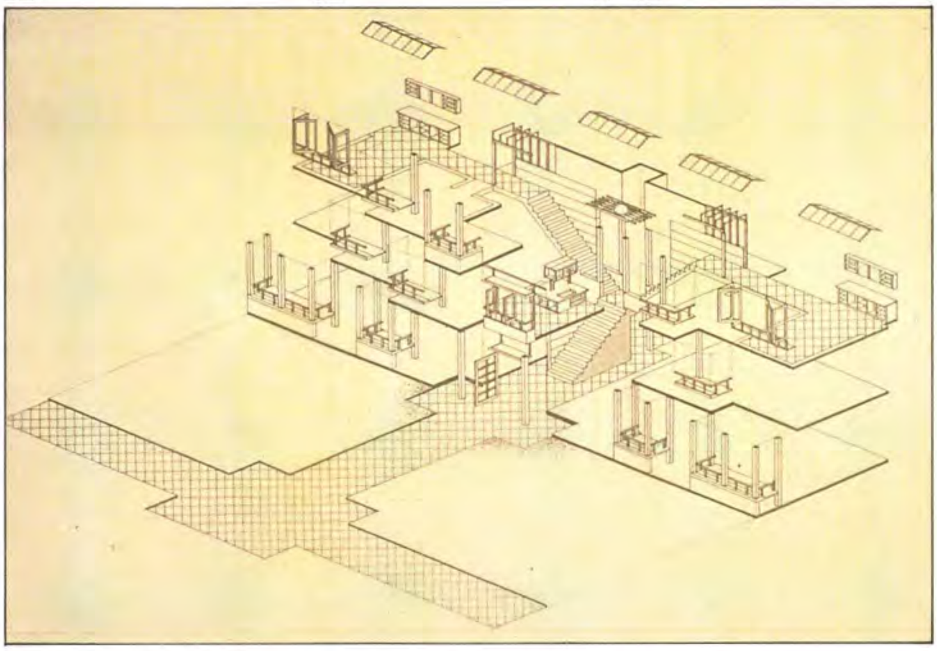
1. Architect's master plan showing development proposals and existing buildings



2△

3△

4▽ 5△



2. Architect's detail elevation

3. Elevation of Sir John Soane's Museum

4. Architect's isometric of main staircase

5. Interior of Sir John Soane's Museum

Introduction

Many people may consider that the centre of our architectural heritage lies within the distinguished buildings in the university towns of Oxford and Cambridge. Thus it is always a great pleasure to be involved in new college buildings that form part of this great tradition. A recent example is the hall of residence at Fitzwilliam College, Cambridge, which was completed nearly two years ago. This article outlines the concepts behind the form of the completed building.

Architectural concepts

It is of interest first to consider the background to the architectural concepts, both from the point of view of the college tradition and of the theories applied by Richard MacCormac. These theories of course set out the tactics of design which, if we as engineers understand them, should enable us to contribute more fully to the total design.

Due to an increasing intake of students causing them to out-grow their existing 1960s Sir Denys Lasdun-designed campus, Fitzwilliam College appointed MacCormac Jamieson Prichard & Wright in early 1984 to provide a master plan for the expansion. The subsequent proposals (Fig. 1) returned from the contemporary open spiral of the Lasdun plan to the more traditional Oxbridge courtyard, the geometrical planning pattern naturally suited to the courtyard being a development from MacCormac's previous housing and college schemes. The project considered here is the first phase of this development, providing accommodation for 89 students and resident fellows.

The treatment of the elevation (Fig. 2) followed from various influences as well as aspirations. Using history as a reference rather than a crib, the formal classical facade was strongly influenced by Sir John Soane's Museum at Lincoln's Inn Fields (Fig. 3), and the horizontal bands reflect the layering of the existing Lasdun buildings. The stepped planes of the facade aspire to create a separate external social identity for the various student rooms, entrances, and shared kitchens, as well as to provide the occupants with both oblique and direct vistas.

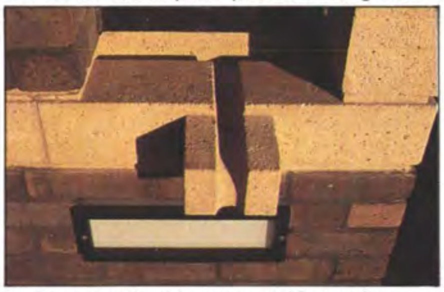
Inside the building the rooms are arranged on each floor in groups of eight with shared bathroom and communal kitchen facilities. The principal influence on the organization of the internal space is the main staircase (Fig. 4). Rather than the conventional dog-leg, a branching staircase is provided. This gives a different layout and appearance on each floor and therefore a sense of identity and destination, as well as adding interest through the resulting variety of room shapes. The rooms themselves also demonstrate a Soanian influence (Fig. 5) in the use of daylight brought in at high level through the stepped bay windows.

Structural concepts

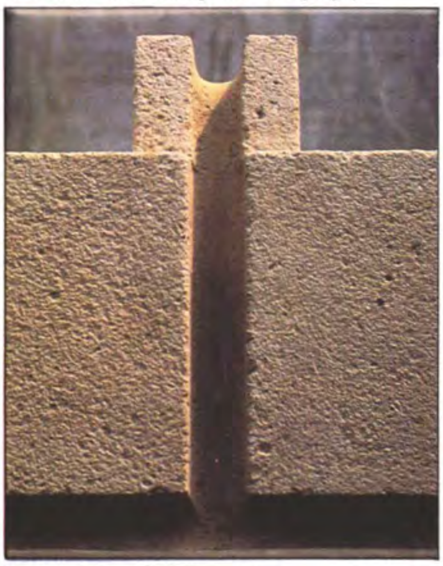
The general construction of the building obviously follows the traditional domestic-sized approach of reinforced concrete slabs on loadbearing masonry walls with a timber-framed pitched roof. However there is an important theme of 'the look of having been built', although this is not necessarily an 'expression of how'. This is reflected in the resolution of some of the details, particularly evident in the extensive use of precast concrete units architecturally expressed in the facade and structurally used at slab levels to support the panels of facing brickwork.

As described in the preceding section the plan arrangement of internal walls varies from floor to floor and the facade walls are stepped in different planes. Thus a solid in situ reinforced concrete slab was used at the upper floors to act as a transfer plate, with stiffening upstands where necessary, to deal with misalignment of loadbearing walls.

6. Precast unit in place prior to casting slab



7. Precast unit with gutter and gargoyle



8. Gargoyle detail close up

10△

11△

12▽ 13△

14▽

9▽

9. General view

10. Stepped elevation view

11. Stepped elevation detail

12. Typical 'house' elevation

13. Detail elevation

14. Stepped elevation detail

15. Main staircase at ground floor

16. Main staircase first landing/luminaire

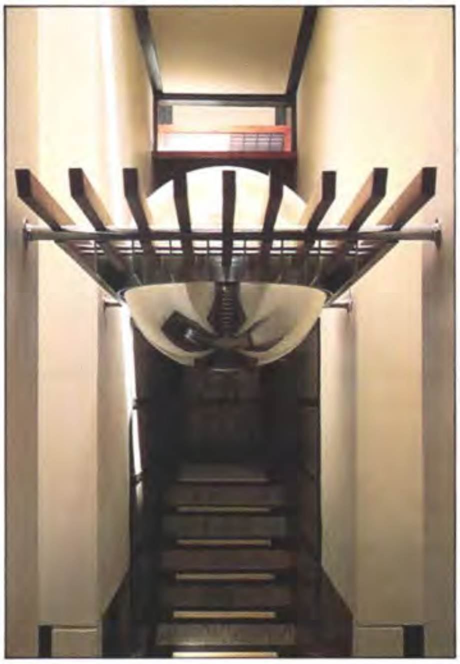
17. Main staircase first to second floor

18. Main staircase second floor

19. Typical student bedroom

20. Typical student bedroom (second floor with exposed timber roof frame)

15



16

17

18

To alleviate differential movement effects, the stepped panels of facing brickwork were supported at each floor level. This support was provided by connecting the 'lintol' level precast units to the slab. The units were formed with an insulated backing to alleviate cold-bridging, and the connection was made by projecting nibs cast in with the slab (Fig. 6). High quality concrete with stainless steel reinforcement was used for durability and the light colour achieved by using white cement. The final finish was gained by a light sand blast treatment. Additionally the sill level units were formed with an inward draining ledge and open channel leading to a gargoyle (Figs. 7-8). This was an effort to reduce rainwater washing from the windows over the sills and causing staining. The generation of drawings to cover the variety of conditions for the range of elements, and to ensure practicality of construction within the small scale and tight tolerance, required very fine attention to detail.

Services concepts

A starting point in the design of building services is to establish major horizontal and vertical distribution routes. These would normally follow the people circulation routes, staircases and corridors. In this case the services distribution was not obvious. The complexity of the staircase had generated the variety and disposition of room shapes described earlier. The success of the services design relied on the ability to establish simple horizontal and vertical routes. A decision was taken to centralize heating and hot water plant to free local space planning. This was then horizontally distributed to each 'house' in the roof space to serve vertical risers in the bathrooms. Although the plan arrangement of the bathroom varied from floor to floor the riser was kept in a common position, but had to be carefully co-ordinated due to the tight space limitations.

A one-pipe radiator heating circuit, with pipes buried in the screed, simplified terminal installation. The radiators themselves were detailed into the bay window seats. The return pipe was looped through the shower rooms to provide warmth under foot and evaporate water, and under the baths to make the bath act as a radiator. The result is that no part of the system is visible. The simplicity of this system offered a very economic solution.

No lighting to the student rooms was provided in the base design, instead a 5 amp circuit at dado rail level was featured into which Anglepoise lamps could be plugged at a variety of locations.

The completed building

The building was completed after a 16-month contract in July 1986 and fitted out for occupation by the end of September 1986. The contract sum was a little over £1.5M for the 2700m^2 gross area.

External views of the completed building are shown in Figs. 9-14, together with internal views of the main staircase and a typical student bedroom (Figs. 15-20).

It is evident that a building following such strong architectural ideals necessarily becomes complex, but aims for high quality. To realise this quality through workmanship to the finished product was demanding on the contractors. Full credit is given to Sindall Construction as main contractor, precast concrete sub-contractor, and joinery subcontractor; also to Sotham Engineering, part of the Sindall group, as mechanical and electrical sub-contractor.

Credits

Client:
Fitzwilliam College, Cambridge

Architect:
MacCormac Jamieson Prichard & Wright

Structural and services engineers:
Ove Arup & Partners

Quantity surveyor:
Dearle & Henderson

Main contractor:
Sindall Construction

Photos:
6: Robert Pugh; 7, 9, 11, 14: Harry Sowden; 8, 10, 12, 15 to 20: Martin Charles

19

20

Printed in England by Reedprint Limited, Windsor, Berkshire