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Front cover: Sussex Grandstand, Goodwood (Photo: Peter Cook)

Back cover: Loadbearing steel lift tower in Bracken House atrium (Photo: Martin Charles)

Bracken House
John Thornton, John Berry

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Ove Arup & Partners were the engineers for the refurbishment, as offices for Industrial Bank of Japan, of the former *Financial Times* building in the City of London. A new central block, in quadrants around an atrium, was built between the preserved wings of the 1959 building.

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20 self-catering homes were built for individuals with physical disabilities and other special requirements on a tightly-enclosed site near London's Victoria Station. Structural engineering for the project was by Ove Arup & Partners.

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Ove Arup & Partners Hong Kong advised on the stability against Hong Kong's high winds, of a work by the French artist César, a 6.4 tonne bronze statue, erected on a plinth outside the Hong Kong Cultural Centre.

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The demolition of the Victorian Holborn Viaduct required the realignment of four railway tracks along a new tunnel, viaduct, and bridge complex. Ove Arup & Partners designed the major civil engineering works, as well as the structural, services, communications, and fire engineering of the new City Thameslink station.

Sussex Grandstand Goodwood Racecourse
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Arup Associates prepared the masterplan for the development of Goodwood Racecourse. The Sussex Grandstand comprises its second phase, completed in time for 'Glorious Goodwood' in 1990.

Bracken House

Architect:
Michael Hopkins and Partners

John Thornton
John Berry

Introduction

Bracken House, which is on Cannon Street close to St. Paul's Cathedral, was completed in 1959 as the printing works and offices for *The Financial Times*. In 1986 an architectural competition was held for the redevelopment of the site after the *FT* moved to other premises. During the competition the site was bought by the developer Obayashi; shortly after this the building was listed. Obayashi nevertheless decided to continue with Michael Hopkins, the architect who had won the competition, although his scheme was based on replacing the existing building. Ove Arup & Partners were appointed in November 1987 as structural and services engineers; hitherto the firm's involvement had been as services consultants only.

The existing building, designed by Sir Albert Richardson, was based on the 17th century Palazzo Carignano in Turin which consists of two wings enclosing an elliptical central block. It was recognized that the architectural merit of Richardson's building lay mainly in the end wings, the centre being compromised by its use as a printing works. The new scheme went back to the Carignano Palace as a source of inspiration and replaced the centre with a new block whose symmetrical curved form followed more closely the original model.

The new centre block is in the form of four rectangular segments around an atrium. The corners are closed by the four quadrants of a circle and it is in these that the junctions with the end wings occur. This disguises the fact that the wings are neither on the same axis nor quite parallel. The floors in the two wings are at different levels and more closely spaced than those of the new centre block; cores containing service risers, stairs, lifts and toilets separate the wings from the centre block and act as a buffer zone to absorb these differences in level. Within the atrium are two steel towers each containing a pair of glass-sided wall-climber lifts. The access bridges to the lifts are glass block slabs on steel frames and the atrium roof follows the same principle. By this means the maximum amount of light is brought down into the atrium.

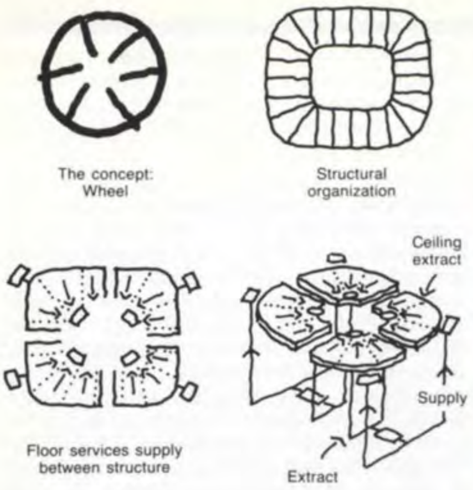
Apart from the plan of the site and the retention of the wings, the most important factor governing the design was the St. Paul's height rule which restricted the height of the building to that of the wings to avoid obstructing the view of the Cathedral.

In order to fit six floors within the superstructure height available, while maintaining the clear heights and raised floor depths required of a modern City office, the depth of the floor zone had to be as small as possible. Similarly, to achieve within the three basements the necessary space for accommodation, plantrooms and parking, the depth lost to structure below ground had to be minimized.

Top left 1. Astrological clock over original main entrance on Cannon Street.

Left 2. New centre block between retained side blocks, viewed from Friday Street.

Below 3. New main entrance.


The concept: Wheel

Structural organization

Floor services supply between structure

4. Structure/services concept.

Integrated floor system

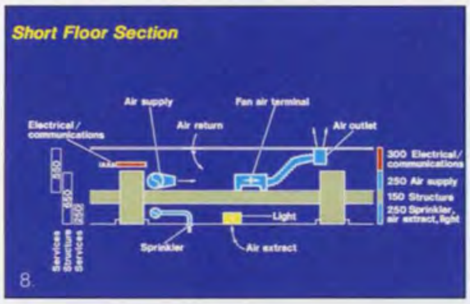
From the engineering point of view, one of the main features of the design is the integration of the structure and services in the centre block and the way this is linked to the construction of the façade.

The design of the centre block is based on the principle of a wheel in which circumferential primary services routes around the outside of the building and inside the atrium connect to radial secondary routes running between radial beams. The outer circumferential route is supplied from risers located in the cores between the wings and the centre block. The inner circumferential ring connects to air exhaust risers contained within quadrant shaped columns (Fig. 5) in the corners of the atrium.

7. Reduced depth beam/column connection showing stepped beam on left, and steel angle floor supports in foreground.

5. Radial beams and quadrant-shaped column at atrium corner, March 1990.

6. Construction at July 1990, showing atrium on right.



8.

The radial beams, which are 605mm deep and at 3.6m centres, span 12m from a column at the atrium to a column which is set back 4.2m from the façade, and then continue on to the façade where they are supported again. In each of the quadrant corners, eight radial beams are supported on a continuous corbel which springs from the quadrant column. There are no circumferential beams.

The soffit of the slab is above the soffit of the beam and this zone is used for the false ceiling, sprinklers, lighting, and the extract air plenum.

9. Quadrant showing circumferential route before laying of services.

10. Services placed in circumferential route prior to floor laying.

The zone above the 150mm slab is used for the floor-based air supply, electrical power, and communications. The raised floor is 300mm above the beams.

The false ceiling fits between the beams, the soffits of which are exposed. In the zone between the façade and the first column, the beam is of reduced depth (Fig. 7) and does not project above the slab; this creates the space needed for the circumferential services route.

By reversing the beam at basement and roof, a flat surface is provided for car parking and roof finish, with a service zone for high level distribution and the ceiling-based kitchen and dining room ventilation.

By placing the slab towards the middle of the beams the benefit of T-beam action is lost, but the usable height gained by this strategy far outweighs the reduction in structural efficiency.

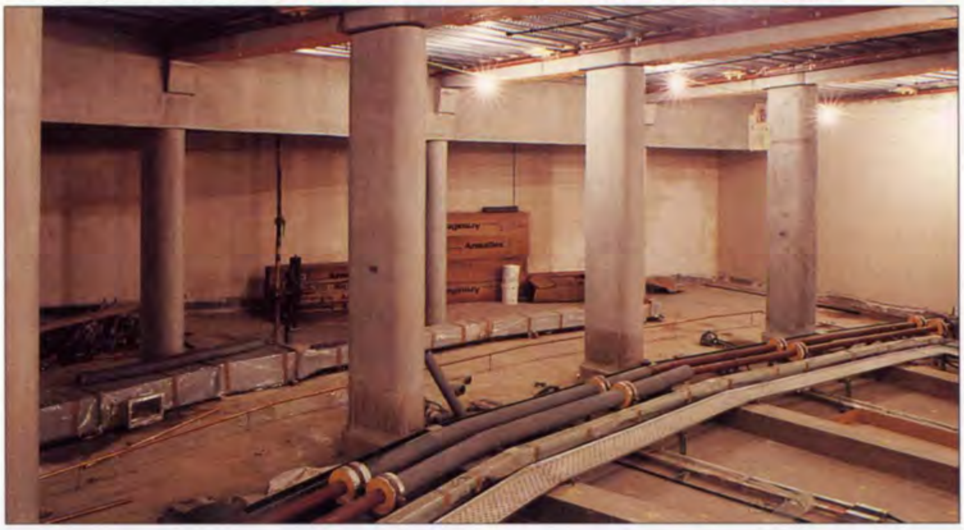
The overall floor system is extremely space-efficient. Neither the slab nor the services zones above the below could be any shallower, while crossovers are eliminated by locating primary services routes outside the main span. The result is a 12m clear span, with a 950mm overall floor which provides a clear zone of 300mm for telecommunications and small power.

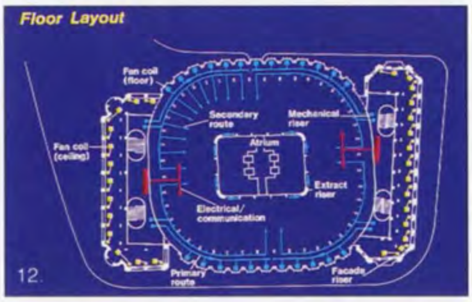
Services

The engineering services reflect the sophistication of a modern banking and dealing facility. Industrial Bank of Japan, who occupy Bracken House as their European headquarters, depend heavily upon them. Design was undertaken in two stages. Initially the base building, devoid of tenant requirements but anticipating future tenant needs, was designed and tendered. Later, when the Industrial Bank of Japan's specific requirements were known, they were incorporated into the original base design and grafted onto the building contract for continuity. In essence the two designs become one and through Obayashi the Arup team strove to satisfy IBJ's particular needs.

Attention to the initial planning process proved a key factor in the successful integration of the tenant needs into the overall building design. It is difficult to second guess what services provision an unknown incoming tenant may require, particularly for additional plant space, risers, cooling, data, and telecommunications.

11. Dealing floor, lower ground level, with electrical cabling and supplementary cooling pipes.





12.

In anticipating the need, and planning accordingly for 500 dealers in any location, dining rooms and kitchens for staff and entertaining, central computer rooms, and an executive suite, the way was paved for seamless integration.

Base building systems were enhanced to meet the later brief, particularly for standby electrical generation (6MVA), clean and uninterrupted electrical power (2MVA), cooling (3.5MW), ventilation, security, data, and telecommunications.

The design addresses the important issues of energy conservation and a healthy working environment. Computerized lighting and plant control, automatic solar blinds, and heat recovery minimize energy use while the floor-based ventilation, coupled to a thermal wheel, ensures that adequate fresh air is delivered to the workplace with the minimum pollution and energy penalty.

Foundations

Although the new centre block is lighter than before, the arrangement of columns is very different. The original intention for foundations was to retain the existing raft and to cast on top a new raft. However, this would have absorbed too much height and so the raft was replaced by cutting it out in a series of 6m wide strips, and recast using screwed reinforcement couplers to provide continuity. This work started at

13. Completed dealing room with supplementary coolers at rear, fronting every other column.

the same time as the demolition above because the existing floors, designed for the loads of a printing works, were strong enough to provide protection to workers below and the floor height was sufficient to allow access for machines.

Frame

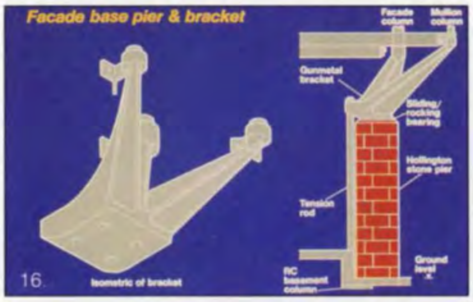
The beams are of reinforced concrete for fire resistance. Fire-protected steel was unsuitable because the bottom of the beam is exposed to view in the false ceiling while the top is vulnerable to damage during the installation of services. For speed of construction the beams were precast, whereas the columns were cast in situ because this had no time penalty. Alternating in situ and precast permitted a very simple connection detail: the beam swelled out at the column position and a pocket was left out at this point: the column reinforcement passed through the pocket, which was concreted up before casting the next lift of column. Except for the projecting bays, which were precast, the slabs were cast in situ on profiled steel metal deck supported on steel angles bolted to the sides of the beams.

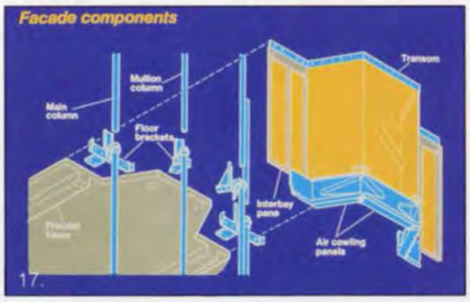
Façade

The structure of the façade is of cast gunmetal. Brackets are bolted to the ends of the beams and bay slabs; these brackets are then propped by a series of posts down to a base-bracket. The base-bracket has three arms which cantilever out to pick up the posts. The bracket itself sits on a bearing on top of a solid stone pier and is stabilized by two stainless steel tie-downs. Hollington stone, a sandstone, was the same as that used in the retained wings. Gunmetal (which is a type of bronze) and bronze were used for the structure and other parts of the façade because they provided visual continuity with the bronze used in the end wings. They also do not require maintenance as would steel.

The loss in strength of the façade structure in a fire is overcome by the design of the floor. The reduced depth beams in the perimeter zone do not have sufficient strength or stiffness to cantilever under normal working loads and require the façade to prop them; but they are adequate in the event of a fire when reduced live loads and load factors are permitted.

Left 14. Façade support bracket, with stainless steel tension rod on left. and below 15. Gunmetal support bracket.





18. Top level of façade. Right 19. Main column on façade with smoke extract door behind.

Conclusion

The three key stages in construction were celebrated by ceremonies attended by the Lord Mayors of London holding office at the time; this attested to the importance to the City of its links with Japan.

Demolition started in May 1989. Topping out, when a cask of sake was opened in the traditional way, was in November 1990, and the building was completed in November 1991.

20. The completed atrium.

Credits

Client:
Obayashi Europe BV
Architect:
Michael Hopkins and Partners
Structural and services engineers:
Ove Arup & Partners:
Structural: John Thornton, Rob Kinch, Tony Clowes (RE)
Services: John Berry, Geoff Higgens, Michael Edwards, Alan Todd, Tony Minchington
Geoff Thomas (RE)
Peter Doorey (RE)
Quantity surveyors:
Northcroft Neighbour and Nicholson
Construction consultants:
Schal International
Main contractor:
Trollope and Colls
Structural engineer for competition-winning entry:
Whitby & Bird
Photos:
1-3, 5-7, 9-11, 18-19: Peter Mackinven
14-15: Rob Kinch
20: Martin Charles

Castle Lane

Architect: CGHP Architects

David Kaye

Just a few minutes walk from London's Victoria Station is Castle Lane, and tucked away between Victorian tenement buildings is the Castle Lane project. It was formally opened in February 1992, some two years after commencement of the design.

The building is in complete contrast to the immediate surroundings and provides a sense of fun and colour in an otherwise dreary environment. The scheme, designed for the Look Ahead Housing Association, comprises 20 self-catering homes for individuals with physical disabilities and other special requirements. The units vary slightly in arrangement in that some share bathroom facilities and kitchens whilst others are completely self-contained. This enables residents to live independently but also provide assistance to each other if they wish.

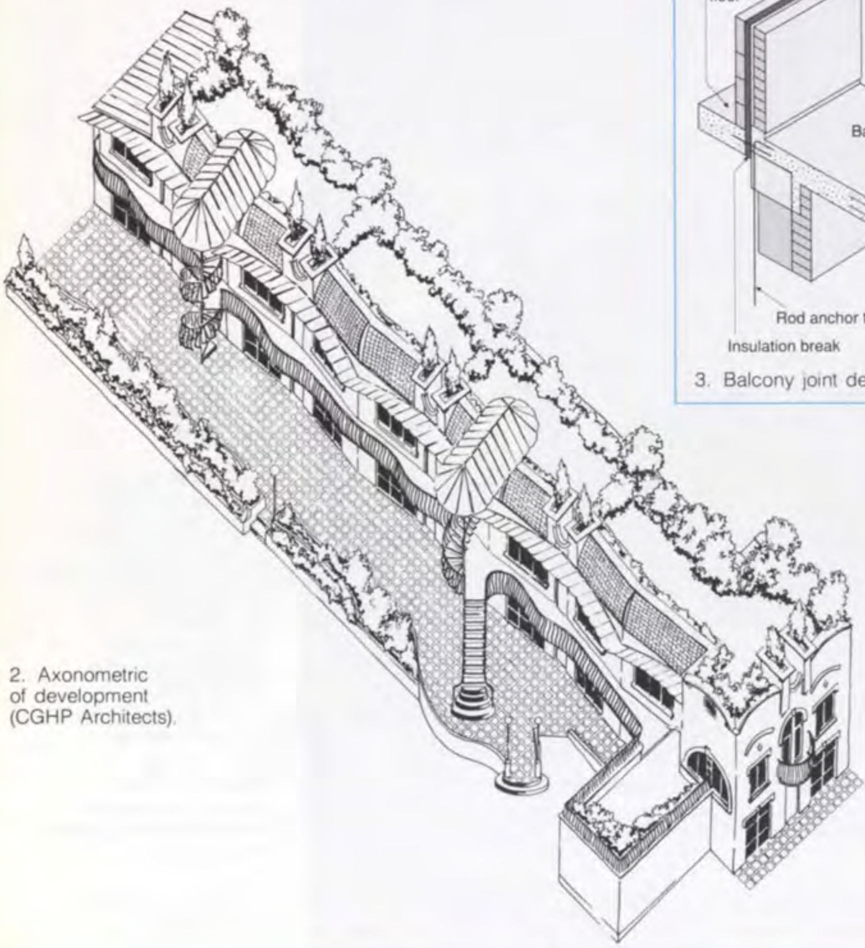
In spite of the impression given perhaps by the unusual geometry of the façade, the structure of the building is simple. Its two storeys are supported by masonry crosswalls founded on mass concrete footings. Floors and roof are in situ reinforced concrete and the ground slab is ground-bearing with the façade walls supported by ground beams. The design has some particularly interesting features; for example the roof garden, which includes lawns, plants and shrubs and an irrigation system, all on a special membrane for green roofs.

4. Canopies.

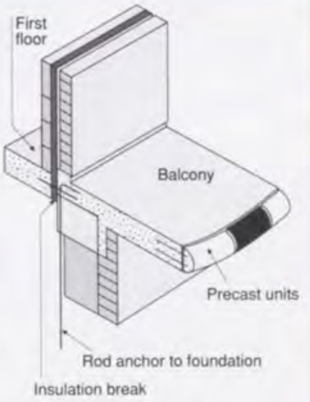
5-6: First floor balcony: the black-and-white detailing is for the benefit of the partially-sighted.

7. Canopy detail from roof garden.

1. East end: roof profile altered to accommodate light to adjacent properties.



2. Axonometric of development (CGHP Architects).



3. Balcony joint detail.

There are also gardens at ground level with tactile paving to help partially-sighted residents. While simple in concept, the design called for a number of innovative details to assist the building's thermal efficiency. A good example is the first floor balcony, which posed an interesting structural problem. Whilst it was seen as a simple cantilevered extension of the first floor, the architect required an insulated break between the two to avoid a cold bridge. This required us to devise the simple engineering solution shown on Fig. 3. The curved edge to the balcony was achieved by the use of 150mm long precast units forming permanent shuttering. The curved windows were formed using precast concrete semi-circular lintels complete with keystones.

There is a sophisticated alarm system within the building which alerts occupants to fire and smoke, and provides the facility of direct communication with the warden. The design of the building, with its curves, turrets, curiously shaped spiral stairs and balconies, has been described as slightly eccentric. Certainly an aim was to avoid an institutional atmosphere and bring a sense of movement and colour which could be enjoyed by both residents and neighbours. The designers responded enthusiastically to the spirit of that challenge and the result bears testimony to their achievement.

Credits

Client:
Look Ahead Housing Association
Architect:
CGHP Architects
Structural engineer:
Ove Arup & Partners
Quantity surveyors:
Boydens
Contractor:
J.J. McGinley Ltd.
Photos:
© Sue Beck


4△


5△


6△


7△

'The Flying Frenchman'

David Vesey

The Cartier Foundation is an organization sponsored by the fashion house Cartier International for the promotion of modern art, normally but not invariably by French artists. In 1989 the Foundation commissioned a monumental bronze from the well-known French sculptor César as a gift to the people of Hong Kong. Entitled 'The Flying Frenchman', it was duly completed, and being 8.4m long, 4.8m high, weighing 6.4 tonnes, and intended for an open air site outside the Hong Kong Cultural Centre, some attention had to be given to its structural stability.

The Hong Kong Urban Services Department asked Cartier of Hong Kong to provide certain technical data, such as overturning forces for the design of the plinth and reassurance that the piece would safely resist Hong Kong's winds; Cartier in turn commissioned Ove Arup & Partners Hong Kong to undertake a structural audit of the piece, as well as provide advice regarding its installation.

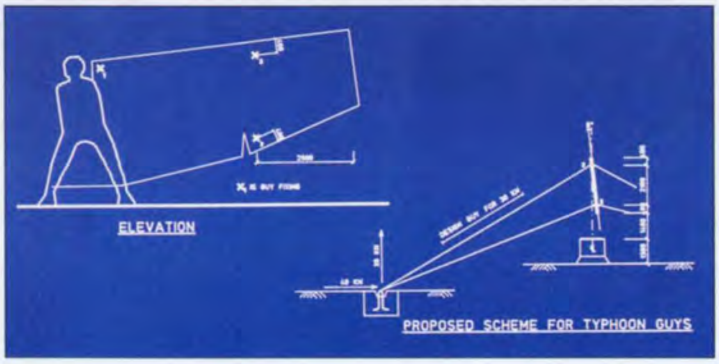
In structural terms the body of the sculpture can be considered as an A-frame supported by the feet, with a long wing plate cantilevered from the body. Thus the action of wind on the sail-like wing could cause large twisting and overturning on the legs. The sculpture was nearing completion at the foundry near Fécamp in Normandy when Arups became involved, firstly with a structural inspection to check dimensions and thicknesses, and estimate stiffness by attaching a spring balance to the wingtip, pulling it with a fork lift truck, and measuring the deflection.

It was also possible to measure the fundamental modes of vibration by exciting the wing, and comparing these with calculated values to confirm assumptions about the underlying structural system.

The sculpture is formed from cast bronze plates and components, bronze butt-welded together with MIG equipment. The essence of César's work of this type is that shapes are formed from assemblies of industrial scrap like bolts, old ships' propellors, valves, etc. In his earlier works components such as steel gear wheels would be used; latterly the effect is obtained by casting bronze copies. Thus it was possible for bronze replicas of T12 reinforcing bars to be taken back and tested at the University of Hong Kong to provide some confirmation of the strength and modulus of the bronze. Calculations based on reasonable assumptions indicated that the sculpture would be able to resist static equivalent wind loads, but there was some concern because of the possible variability of material strengths, and difficulty of testing the bronze welds of, in structural terms, a most unusual and organic creation.

Without full-scale wind tunnel tests it was not possible to be sure about possible wind-induced dynamic effects. Whenever typhoons or strong winds are likely to occur in Hong Kong, signals graded in severity are hoisted at HMS Tamar, the British Naval base on Hong Kong Island, and Arups advised that temporary guy cables be installed when the first (No. 3) warning signal was raised. At these times it is normal for shutters to be closed across windows, so the temporary guy wire system was felt to be acceptable by the sculptor and other parties.

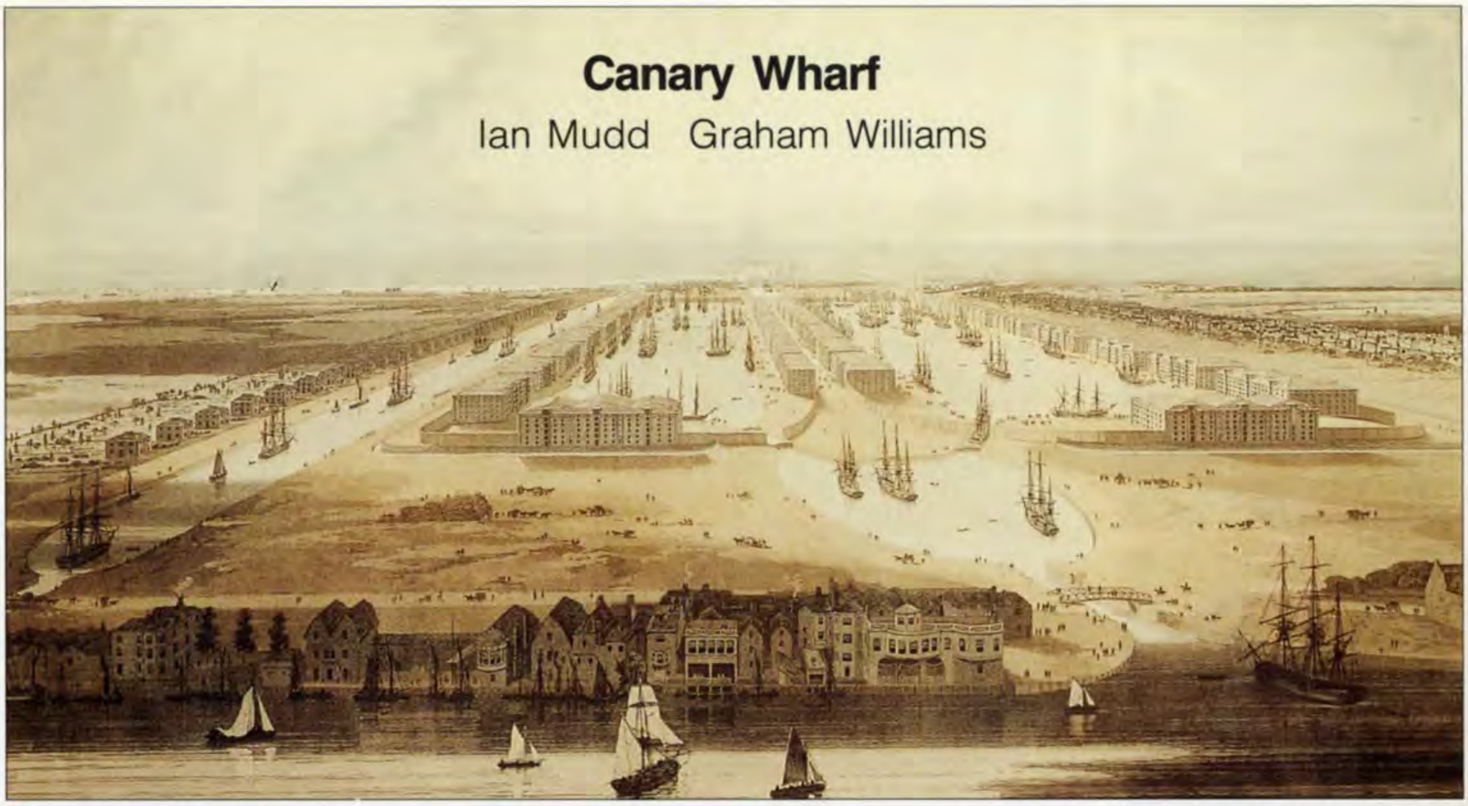
With the audit completed to the client's satisfaction, the completed sculpture was shipped out from France to Hong Kong. In April 1992 'The Flying Frenchman' was successfully installed on its plinth with the aid of a 50 tonne crane, in an eight-hour operation starting at midnight. Arups provided advice on the finish for the plinth and during the installation.



Credits
Donor:
Cartier Foundation
Client:
Cartier International (Far East) Ltd.
Technical consultant:
Ove Arup & Partners Hong Kong
Installation:
Urban Services Department Hong Kong
Photo:
Colin Wade

Canary Wharf

Ian Mudd   Graham Williams



1. Daniell's aquatint of 1802, looking west from Blackwell to Limehouse: left to right, City Canal, Export Dock, Canary Wharf, Import Dock. (courtesy: National Maritime Museum, Greenwich)

Introduction

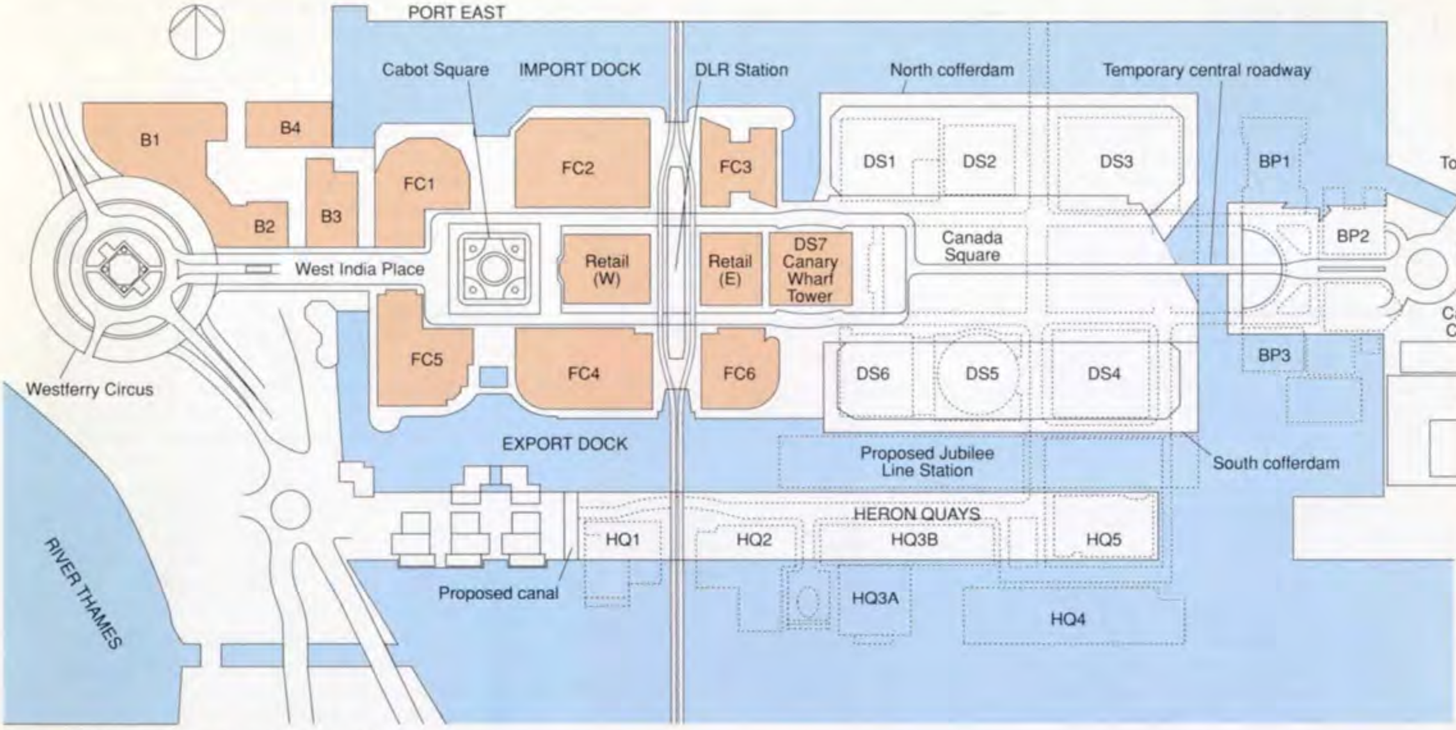
Canary Wharf in London's Isle of Dogs Enterprise Zone has never been far from the news since 1985, when the American developer G. Ware Travelstead decided that London had a shortage of high quality office space and that Docklands was the only place with enough room to allow a development without constraint. At that time, Canary Wharf was an empty spit of land, 90m wide by about 650m long, occupied only by a television studio in a converted banana warehouse. The dominant feature of the landscape was the slender viaduct of the Docklands Light Railway, which crossed the dock from quay to quay, carrying its trains some 9m above the water. Travelstead's masterplan, designed by Skidmore Owings & Merrill (SOM), was on a scale which dwarfed all previous Docklands schemes. Due to Arups' wide experience in Docklands work, the firm was engaged as the London-based consultants. The Canary Wharf development then comprised three high-rise towers and a range of smaller buildings to give a total some of 1Mm^2. After two years of negotiations, a master building agreement with the London Docklands Development Corporation (LDDC) was ready to be signed, but the developer was unable to secure enough financial backing and the project was taken over by Olympia & York (O&Y). In just six months, they had signed the master building agreement, modified and expanded the masterplan to suit their own requirements, appointed a pantheon of designers, and commenced construction.

There followed a 39-month roller-coaster of the most intense construction activity, during which the landscape was transformed and about 500 000m^2 of building created. In September 1991, the first tenants were able to move into the central tower. At 250m, this stainless steel-clad structure is the tallest building in Britain, visible for up to 20 miles, and providing the project and Docklands as a whole with an instantly recognizable focus. The first phase represents just over one third of the total O&Y scheme. When the remaining sites to east and west are completed — together with the adjoining ones on Heron Quays which O&Y subsequently secured and integrated into their masterplan — about 1.5Mm^2 will have been created. Taking other developments in the Docklands Enterprise Zone into account, the total floorspace will approach the 2.5Mm^2 of La Défense, the 'new' commercial district of Paris. It is interesting to reflect that this too had an uncertain start but now, some 25 years after its inception, it is thriving and fully accepted as part of the city.

The masterplan

Under O&Y's masterplan, the Wharf is now divided into four groups of buildings each surrounding a public space. The majority of the present buildings are grouped around Cabot Square with its central fountain. Immediately to the east of the Square is the retail building which has a concert hall above its western half. In the centre is the DLR station concourse with escalators up to platform level, and to the east a further retail area leads directly to the lobby of the central tower. A one-way road, generally raised one level above the original quay, loops around Cabot Square. 'Watercourts' between

2. Canary Wharf location plan.



3. Canary Wharf development masterplan.

the buildings terrace down to the waterside and pedestrian promenades then run round the perimeter of the project at a level about 2m above the water.

To the west of Cabot Square is West India Place linking to Westferry Circus. The latter is the second major public space and, as its name implies, is circular in form. The symbolic entrance to the development for those arriving by river, it is actually a two-level roundabout with an immaculately landscaped garden in the centre and a car park below.

The upper level roundabout gives access to the elevated roadway and the public areas of Canary Wharf, whilst the lower level takes through traffic and gives access to the service areas — including an underground roadway to the central tower. The first stage of building around the northwest quadrant of the circle is nearing completion, with Texaco due to occupy the first building this summer.

To the east of the main tower is Canada Square, where eventually six more buildings, including two further high-rise towers, are planned to frame a central park. At present, the land has been reclaimed by constructing two cofferdams. A temporary road runs eastwards connecting Canary Wharf to the new Docklands road network and thence up to the A13 and the Blackwall Tunnel.

The last of the four areas is known as Cartier Circle and is separated from the rest of the development by a boat passage which was cut across the original Wharf in 1925. Just as at Westferry Circus, the central structure has been completed and incorporates a car park under the roadways. Four further building parcels surround this area.

The well-publicised shortfall in public transport capacity prompted O&Y to press for the development of the Jubilee Line extension. At the time of writing, its fate depends on the ability of the developer to sign a commitment to provide a contribution towards funding of the line. If this obstacle can be overcome, work will start almost immediately on a deep cut-and-cover station which will effectively form a land bridge between Canary Wharf and Heron Quays to the south. This has required substantial further revisions to the masterplan, undertaken by Koetter Kim & Associates with engineering advice from Ove Arup & Partners. The area above the station is to be landscaped into a park providing a further public space. A shallow passage or canal will be cut across Heron Quays and will maintain boat access to the Export Dock which would otherwise be cut off. Heron Quays provides five final parcels which complete the development.

4. Aerial photograph c.1985 before development. White outline indicates area of Canary Wharf scheme.

5. Grade deck piling for building FC4, August 1988.

The grade decks

John Brazier

These structures provide support for the six mid-rise buildings surrounding Cabot Square. They consist of a reinforced concrete grillage supported on tubular steel piles with the areas between the beam typically infilled with pre-stressed, precast concrete inverted T-beams with an in situ topping. The largest is some 70m × 100m in plan and maximum column loads of 32MN were supported.

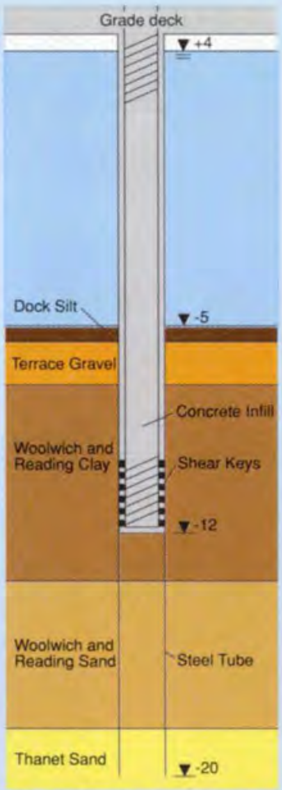
Ground conditions

The dock is impounded at a fairly constant level to give about 9m of water. A layer of silt had built up over the years, but below this was a thin layer of terrace gravel, followed by Woolwich and Reading Clays and Sands and then Thanet Sands. These were found to be a consistent dense green sand and all high capacity foundations were founded in this stratum.

Piles

The use of steel piles to support an office development is believed to be unique in England. It was accepted that high corrosion rates might be encountered in the dock water and the dock silt areas so the upper sections of the pile casings were regarded as sacrificial. The top of the Woolwich and Reading Clays was taken as the threshold below which the ground could be regarded as 'natural', where corrosion would not exceed 0.01mm per year. The piles were subsequently excavated to some 3m below this level (Fig. B). They were then filled with reinforced concrete which was designed to carry the loads to the transfer zone and thence into the steel. Transfer to the steel was effected by 25mm square bars welded to the inside of the casing prior to driving.

A design life of 125 years was agreed but the approving authorities insisted that a factor of safety of 3 should be applied to the most conservative rate of corrosion and that residual stresses at the end of the design life should not exceed 0.3 × yield. This resulted in wall thicknesses of up to 22mm being required. The piles were assembled out of 12m lengths or 'cans', welded together circumferentially; since the steel represented a large proportion of the cost, the upper sections were reduced in thickness to the minimum required to resist driving stresses.



A. (above): Details of tubular steel piles.

B. (below): Specially-developed hydraulic auger.

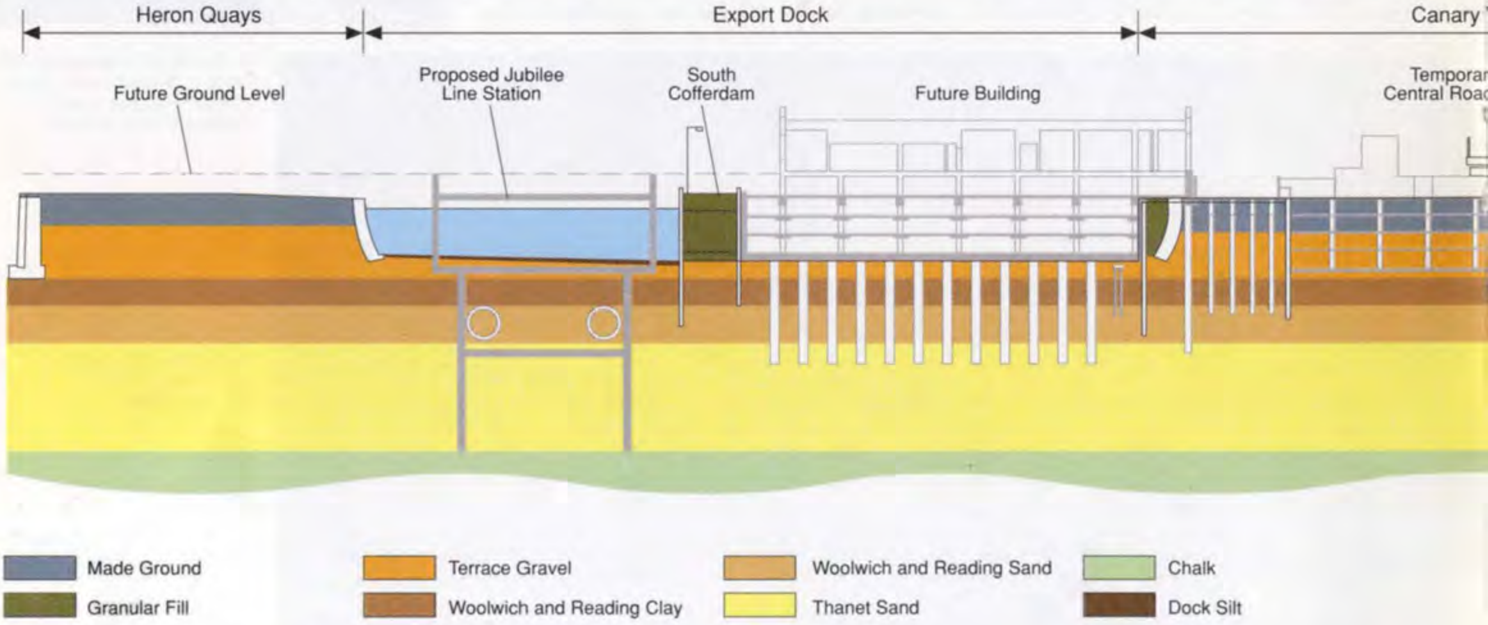
In a truly European operation, the pile cans were fabricated in Germany, welded together in Holland, delivered to site and prepared by Edinburgh-based Murray International and driven by the Danish Christiani & Nielsen! The pile driving was carried out using an IHC *S90* hammer, then the most powerful readily available, and the rigs were fitted with specially designed acoustic shields to minimize noise. Performance was monitored using a pile driving analyzer and, in all, over 1200 piles of 1022, 1254 and 1524mm diameter were installed.

The decks

The grade decks were required to provide both a basement floor and also to function as pile caps to distribute column loads between two-pile and four-pile groups. They also had to act as unbraced frames in conjunction with the piles to carry horizontal loads from the buildings above through 9m of water into the underlying strata. This was a particularly onerous demand as the owner was not predisposed to very large expansion joints, and it was agreed that lateral movements would be limited to approximately 25mm.

The depth available for these structures was extremely limited, mostly by a desire to keep the promenades and their associated retail spaces as close to the dock level as possible.

The structure was conceived as a series of wide beams to be cast in two stages, the first stage providing bearings for precast inverted T-beams (actually SBB bridge beams supplied by Costain Dowmac) with a structural topping over the full plan area. It was originally anticipated that the main beams would require their own precast concrete permanent formwork supported on temporary attachments welded to the piles. However, Christiani & Nielsen elected to use a hinged steel formwork system provided by the American Efco company. This proved to be very successful but it was found essential to agree to the construction sequence before reinforcement detailing could be undertaken. The steel shutters were very intolerant of holes for starter bars, so substantial use was made of couplers. As far as possible, cages were standardized and, in keeping with the logistical requirements, they were prefabricated and delivered to site by barge. All concrete was placed by pump and in deference to the long design life a minimum cement of 400 kg/m^3 was adopted with a minimum cover of 50mm.



6. Phase 2 cross-section showing existing construction and future substructures.

Phase 1

To those used to programmes in Hong Kong and North America, the construction of Canary Wharf may not appear dramatically fast. However, this would be to ignore two features which made it a particularly unusual site and an all-the-more impressive piece of construction. Firstly, the only building which is sited on land is the central tower; the remaining six around Cabot Square are all supported on reinforced concrete platforms known as 'grade decks' built over water, and designed by Ove Arup & Partners. Until these were complete no progress could be made on building superstructure. The process of piling and concreting, which was almost entirely a marine operation, occupied the first 12 months or so of the construction programme.


7. FC3 building.

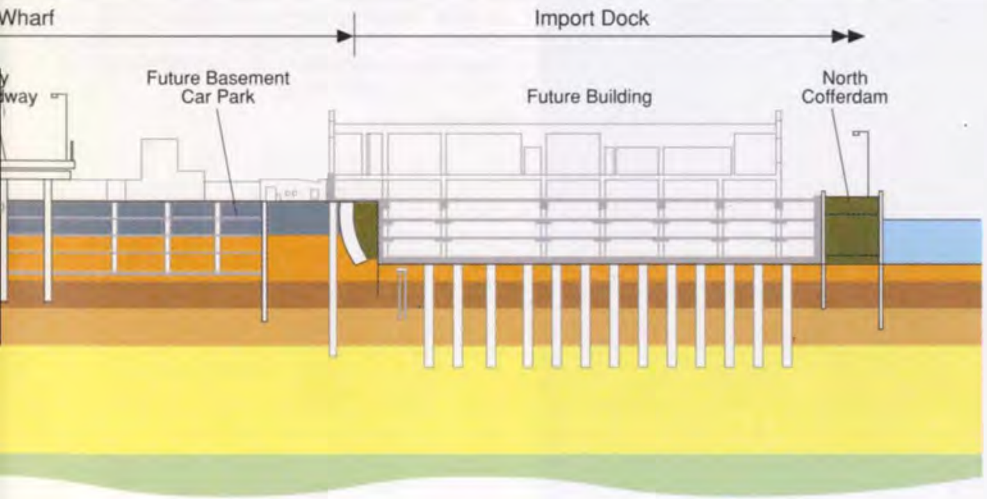
The second limitation was the logistics of bringing together enough men and materials onto a site which had access to land via only a single gate at the west and a temporary bridge at the east. Moreover, there was no space for storage on the site — in addition to the central tower and the six buildings over water, a three-storey deep basement car park was to be constructed over most of the quay area, and the remaining strips to north and south were to be occupied by the main roadways with the service infrastructure underneath. And the programme required that all these areas would be worked on simultaneously! The solutions adopted by O&Y and Lehrer McGovern International, their construction managers, were typically bold.

As far as possible, materials were supplied by barge, either directly from fabrication yards or via a holding trans-shipment area which was established at Tilbury Docks. A perimeter roadway known as the 'water road' was constructed using modified Bailey bridging to run outside the grade decks and provide a facility for vehicles to move around the site. In total, this covered an area of 10 000m^2, the equivalent of a mile of two-lane road. Concrete was batched on site using a floating plant imported from Norway and construction workers and managers became used to a gentle rocking sensation as their site huts were stacked on pontoons tethered alongside the various work sites. A rigorous system controlling all traffic movements — both land and marine — was imposed and controlled directly by the developers' own logistics group. In this way, the site was able to function and traffic on the overloaded local road network was kept to a minimum. Ove Arup & Partners were responsible for the water roads and the moving bridges which connected the construction area to land, all of which were designed in conjunction with Thomas Storey.

Of the Phase 1 buildings, only one has been designed by a UK practice — Troughton McAslan (Fig. 7) — and for this Arups were appointed structural engineers. In construction it is similar to the other Phase 1 waterside buildings, a composite steel/lightweight concrete frame on a 9m × 9m grid. It was the last of the waterside buildings to be commenced and featured a slipformed concrete core which could be started before the grade deck was complete, thus enabling the overall time for completion of the frame to be reduced. Further Arup commissions have included geotechnical advice for most of the remaining buildings and structures, and advice on methane hazards for the buildings over water.

Phase 2

Even whilst activity on the first phase was at its highest, the developers were planning for the future development east of the tower. Once again, buildings would be grouped, around the the central Canada Square. However, two of the designated parcels would be occupied by towers which at about 200m would be much taller than the grade deck buildings of Phase 1. These were already stretching the capacity of the driven pile/grade deck technique so it was necessary to devise an alternative construction method which would permit installation of base-grouted bored piles. These offer a capacity of up to 16.5MN for a 1.5m diameter shaft but, because of the water pressures in Woolwich and Reading and Thanet Sands, they have to be installed under bentonite and it is extremely difficult to avoid spillage of the slurry if this is attempted over water. The chosen solution was to surround the sites to north and south of the quay with cofferdams. These measure 250m × 60m in plan, are 9m in width, and retain 9.2m of water with the dock at its normal impounded level. They enabled the dock to be dewatered and building piles to be installed from the dock bottom. Construction will then be able to proceed in a conventional bottom-up



sequence with up to four storeys of basement car parking accommodated in the dewatered space without the usual expense of excavation.

The principal advantages of this system are as follows:

(1) The most noisy activity, pile driving, was completed before any tenants were in occupation in Phase 1.

(2) An immediate start can be made on further construction without any additional temporary works.

(3) The cofferdams provide construction access and routes for the temporary services which are needed during construction.

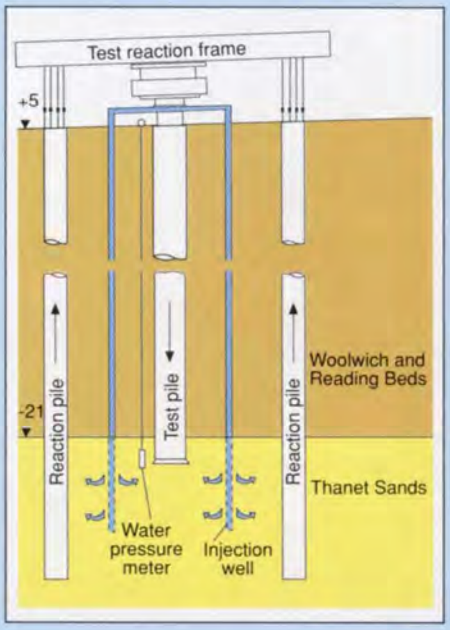
Various different types of cofferdam were investigated but the most economical form was found to be two lines of sheet piles tied together and filled with marine-dredged sand. The contract was let as a design/construct package and won by Costain/Mott MacDonald who were the only bidder to offer two levels of ties. The lower level required installation by divers, but allowed substantial savings in sheet pile sections. The inner walls are typically *Larssen 25W* sections and the longer outer wall *Larssen 20W*. Dewatering was successfully completed in the period November 1990 – January 1991. Since the stability of the structure depends on the shear resistance of the fill, it is particularly important that the water level is maintained as low as possible between the sheet piles. This is monitored regularly via a network of standpipes, and the cofferdams are also monitored for movements. Average lateral movements are about 250mm and they stabilized over a period of six months.

On the land area, a further basement car park was proposed. The design of this was coordinated with the cofferdams in that the perimeter diaphragm wall was installed as part of the cofferdam contract and is used as an anchor for the cofferdam with ties passing over the existing dock 'banana' wall which is Grade I listed. In turn, when the car park is excavated, the cofferdam wall will act as an anchor to the diaphragm wall, and the car park, which extends 10.5m below existing quay level, can be constructed without any further propping.

Pile testing

Viv Troughton

Large diameter bored piles with grouted bases (Fig. B) were adopted for the foundations of buildings sited on the original wharf, comprising the retail buildings, basement car parks, and the central tower. These piles are founded in the Thanet Sand, which forms part of London's aquifer where water levels are reported to be slowly rising. For these structures this rising water table presented a potential long-term risk of a reduction in pile capacity and increase in settlement. In order to quantify this risk, a special pile test was carried out where water was injected around the pile toe to simulate the combined effects of basement excavation and a rise in the water table (Fig. A).



The water pressures in the Thanet Sand around the pile toe were increased by up to 175kN/m^2 or 17.5m head during the test and the 1.2m diameter pile was loaded initially to its service load of 1000 tonnes and finally to a maximum of 2100 tonnes. At each loading step the load was initially applied without any water injection and the pile settlement recorded. The water pressure was then increased and the additional pile settlement noted before proceeding to the next loading stage.

The results of this test showed that at service load there was a negligible increase in settlement. The effects on ultimate capacity were equally surprising. Conventional pile design based on vertical effective stress would predict a 50% reduction in ultimate capacity for the 17.5m increase in water head achieved in this test. In fact the actual reduction in ultimate capacity was only 20%, the pile capacity being found to be proportional to the mean stress around the pile toe rather than the vertical stress.

Based on these test results it was possible to demonstrate that no additional pile length was needed on this site to accommodate a potential rise in the water table. This represented a substantial saving when considering that about 1000 bored piles of this type were installed for Phase 1.

A. (left): Aquifer pile testing assembly.

B. (below): Pile cage, showing tubes for pressure-grouting base.

8. Canary Wharf from the east, with cofferdams in foreground.

Finally, it was necessary to establish road access to the east. Building either of the permanent roadways would have hindered construction access to the future buildings, so a 'temporary' roadway has been built along the centre of the quay. This is supported on bored piles which were extended upwards to form columns and is designed so that the car park can be excavated around it. In this way, site traffic and public traffic are kept separate, there is a clear logistical plan for efficient future construction, and the developer is in a position to respond to any upturn in future demand in the shortest possible time.

Credits

Client:
Olympia & York Canary Wharf Ltd.
Construction manager:
Lehrer McGovern International
Phase 1 contractors:
Canary Wharf Contractors, Bovis, Mowlem, Ellis Don McAlpine, Trafalgar House Construction Management, Wimpey Tishman
Structural and civil engineers:
Ove Arup & Partners
Ian Mudd, John Brazier, Graham Williams, James Bown (structural),
Viv Troughton (geotechnical)
John Flaherty, John O'Mahoney, Ulrick Burke
Bill Horn (grade decks)
Gary James, Elliot Wishlade, Chris McCormack (FC3 building)
Allen Paul, Rex Humphreys, Andy Armstrong (water roads and bridges)
Paul Lacey, Charles Staunton (river wall)
Adam Chodorowski, Rob Robson (geotechnics)
Lorna Walker, Robert Warren (environmental)
Photos:
4, 7, 8: Olympia & York
5: John Mitchell
Panels: Ove Arup & Partners

Ludgate Railway Works and Development

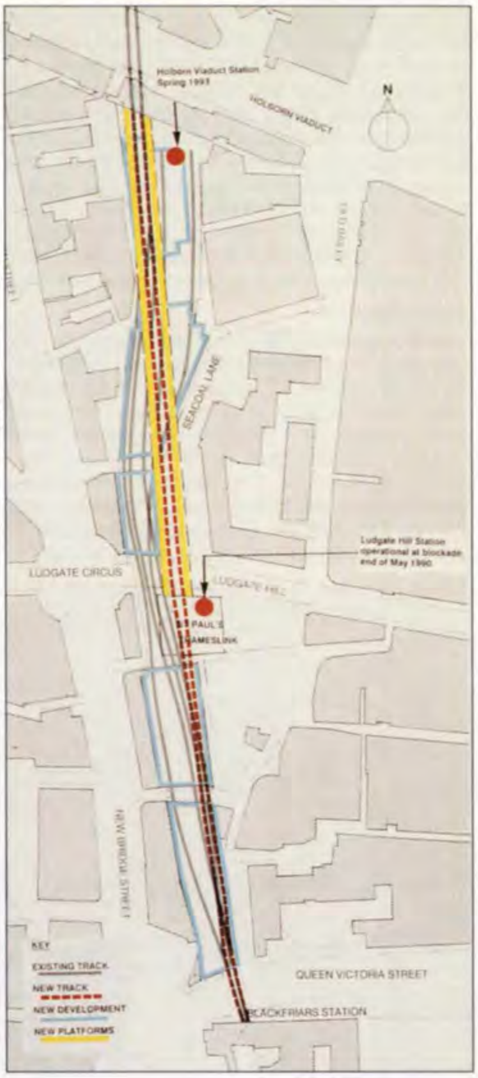
Naeem Hussain

Introduction

In the 1870s a high level railway brick viaduct between Blackfriars and Holborn Viaduct in the City of London was constructed, together with Holborn Viaduct terminus station, carrying the only main line through the City linking the networks north and south of the River Thames. The through line, latterly used for goods traffic, was closed down in the '60s, but Holborn Viaduct terminus continued to service Southern Region network. This area was subject to intensive bombing during the War and large areas of City-owned land south of Ludgate Hill had since lain derelict, being used mainly as car parks (Fig. 1).

The brick arch structure, whilst providing lettable space for small businesses, wine bars and car parks, was in a run-down state and acted as a barrier between the City and its western environs around Fleet Street. Significantly, in the 1980s the newspaper industry was moving out to Docklands and this coincided with the potential need for modern office space generated by de-regulation of the City, and as a counterbalance to the Docklands development. What had since the War been perceived as an uneconomic area now became potentially attractive. Following their successful collaboration with British Railways Property Board (BRPB) on the Broadgate Development, Rosehaugh Stanhope Developments (RSD) asked Arups in January 1986 to report on the feasibility of realigning the railway between Blackfriars and Holborn Viaduct stations with a view to releasing land for development. At this time BR were implementing the decision to re-lay the cross-river track to operate Thameslink through services between London Midland Region north of the river and the Southern Region south of the river.

The feasibility study identified that by realigning and lowering the railway to the east of its existing alignment, Holborn Viaduct terminus could be replaced with a new Underground station on the through line, serving both Southern Region trains (Fig. 2) as well as providing a modern station in the City for both Thameslink and future InterCity trains. The former was specially attractive, with potential for providing fast services to Luton and Gatwick airports. Realignment of the railway also made possible the complete removal of the old viaduct, thus allowing for major air-rights redevelopment of the area and removing the physical barrier between the City and Fleet Street. A masterplan for the redevelopment was prepared by the architects Renton Howard Wood Levin (RHWL) (Fig. 3). One of the major benefits of the scheme was the restoration of the view of St. Paul's from Fleet Street, obscured for over 100 years (Figs. 4 & 5).



1. Holborn Viaduct in May 1988.
2. Existing and proposed track alignment: April 1990.
3. Ludgate masterplan: April 1990.
4. The old railway bridge over Ludgate Hill.
5. View of St. Paul's from Ludgate Hill restored, March 1992.

Parliamentary Bill

Following presentation of the feasibility report and its acceptance, BRPB with the tacit blessing of the City decided to seek Parliamentary Powers to re-align the railway. Arups prepared the deposited plans and sections which also defined the 'limits of deviation' for land to be temporarily or permanently acquired for the works, and parts of four mediaeval City streets to be closed. Royal Assent was given on 23 March 1988, just in time for some temporary track re-alignment on the existing viaduct prior to the opening of the Thameslink service in May.

Concept

The construction of the new railway in this historic and congested part of the City had to be undertaken in a manner that did not disrupt essential services such as the railway itself, road traffic, sewers and statutory services provided by LEB, Thames Water, British Gas, British Telecom, and Mercury. The design was therefore governed by the logistics of construction and the need to meet the disparate requirements of the various services. A typical interface was the gradient of realigned Ludgate Hill Road and the railway itself, which resulted in a 1:20 gradient for the road and a 1:29 gradient for the railway, the steepest in Britain.

As the railway had to be realigned and relocated underground, new street patterns were created and essential services in its path relocated. Principal services were realigned and four major underground routes were selected to divert them across and below the railway at Apothecary Street, Ludgate Hill, Seacoal Lane and Fleet Lane (Fig. 6). A major services tunnel and an LEB tunnel were built at Ludgate Hill and Seacoal Lane (Fig. 8).

As this services diversion was the enabling works for the railway, so the latter itself constituted the enabling works for the six major development buildings and the new city plaza and street pattern above. This required railway construction suited to its own needs and to the particular needs of the individual buildings and streets. In several instances this resulted in combined foundations and structures for railway and buildings.

The principal civil engineering elements of the railway works itself are:

- Lowering of the railway bridge over Queen Victoria Street to suit the new vertical alignment.
- A prestressed concrete viaduct structure, approximately 105m long between Queen Victoria Street and Apothecary Street (Fig. 9).
- A reinforced concrete cut-and-cover tunnel c.100m long between Apothecary Street and Pilgrim Street. The sides of the tunnel founded on piles also support the new building at 100 New Bridge Street.
- A station building between Pilgrim Street and Ludgate Hill. Provision has been made for a possible future LUL link at this location. The structure has also been designed to carry future buildings above.
- A prestressed concrete double-deck bridge at Ludgate Hill. The lower deck carries the railway and platforms over the new multi-services tunnel and other statutory services, whilst the upper deck carries Ludgate Hill Road (Fig. 10).
- A prestressed concrete cut-and-cover tunnel c.100m long between Ludgate Hill and the Old Fleet Lane. The top of the tunnel carries the re-aligned Seacoal Lane (Fig. 11).
- A composite cut-and-cover tunnel approximately 50m long under the new 10 Ludgate Place building. The composite girders act as transfer structures for the 10 storey structure above.
- Platform structure between 10 Ludgate Place and the station building at Holborn Viaduct.
- A station building at Holborn Viaduct which also carries the 1 Ludgate Place building.
- Stabling sidings under Smithfield Market.

6△

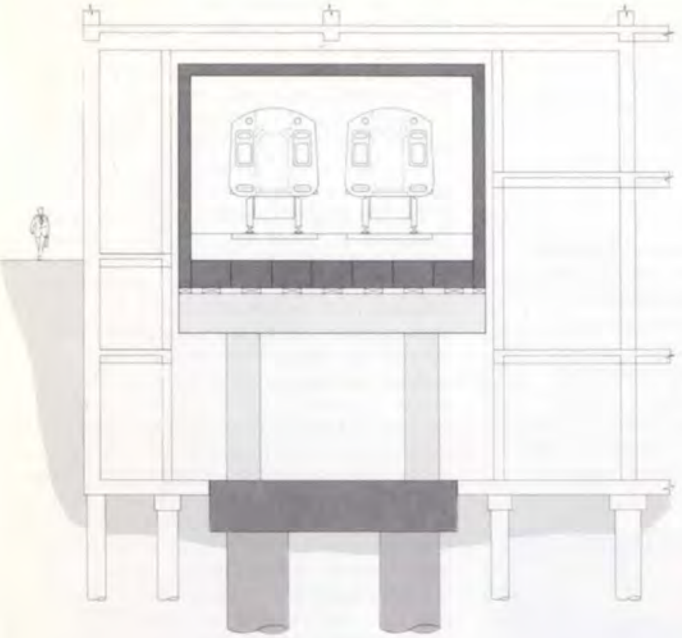
7▽

8▽

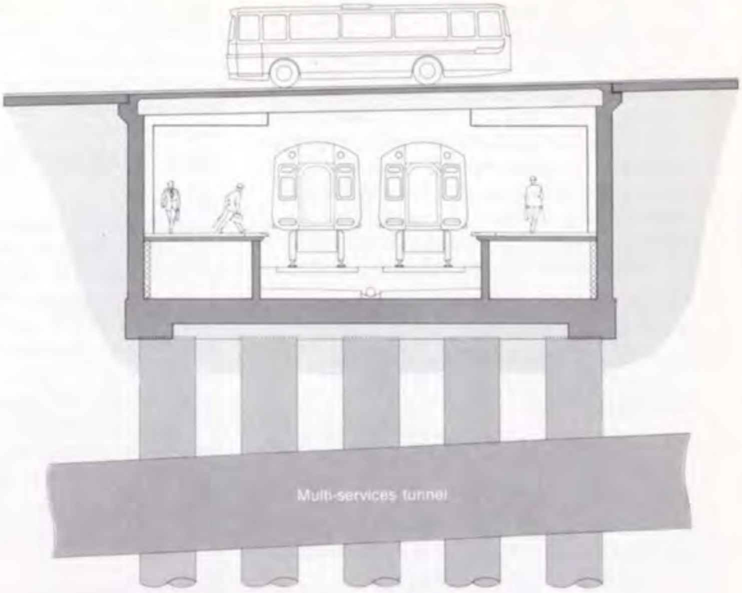
6. Major services routes.

7. Ove Arup & Partners are structural engineers for 100 New Bridge Street.

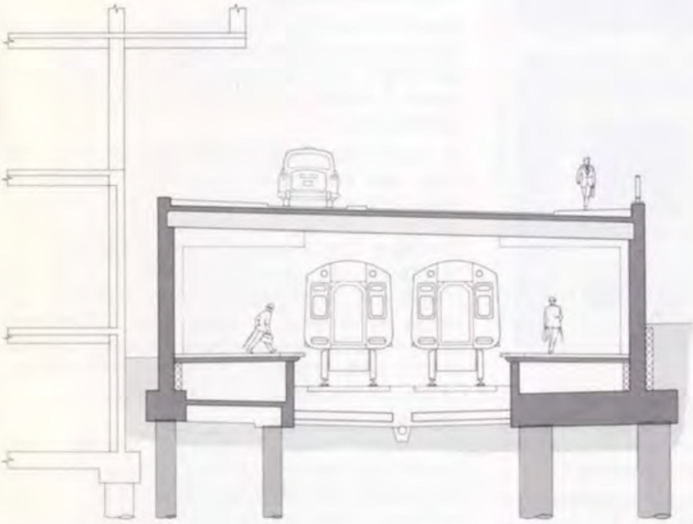
8. Major services tunnel.



9. Railway viaduct: Apothecary Street to Queen Victoria Street.



10. Ludgate Hill crossing.



11. Station box: Fleet Lane to Ludgate Hill.

12. Acoustic isolation of new offices.

The Railway Works

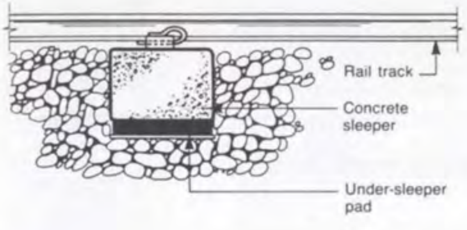
Noise and vibration

Noise and vibration were first raised as issues at the time of the Parliamentary Bill. The re-aligned railway brought the tracks closer to the foundations of existing buildings, and the occupiers were concerned that increased noise and vibration from its construction and operation would affect use of their offices.

Vibration and structure-borne noise levels were identified as the primary concern. As no significant new mainline railways had been constructed in similar circumstances in recent years and the new dual voltage rolling stock were yet to be built, criteria for assessment, measurement and predictions were all 'new ground'.

Initial estimates were made based on measured data Arup Acoustics had obtained from other sites in London. It was agreed that continuously welded track would be used throughout, but because of a scissor crossover which might produce a characteristic wheel/joint noise, detailed measurements were carried out at London Bridge Station where a similar crossover was identified, with Network South East commuter rolling stock travelling at similar speeds to those proposed for Ludgate.

A second series of measurements was carried out adjacent to a rail joint near the end of the platform at East Croydon.



13. Positioning of under-sleeper pad.

Based on this data the conclusion was reached that whilst vibration would not be felt in the adjacent buildings there would be sufficient energy for re-radiated structure-borne noise to be audible and clearly identified as train noise. The need for attenuation of the order of 10-15dB at 63HZ and 125HZ octave frequency bands was identified as the performance requirement for attenuating features.

A number of options were considered, culminating in a minimum 300mm concrete 'box' structure surrounding the railway, physical separation of the box structure from adjacent buildings, continuously welded track, and under-sleeper anti-vibration pads (Fig. 13).

Noise and vibration also had major implications for the office developments over and around the railway, RSD required that occupants should be unaware that a railway ran through the building. This necessitated a comprehensive expansion of the initial study, which recommended isolation of the new offices (Fig. 12).

Communications systems

These serve three main functions: information to passengers; information to staff, Police and the London Fire and Civil Defence Authority (LFCDA); and voice communications for one or more of these groups.

The Fennell communication requirements led to a period of weighing and sifting undeveloped and often incompatible requirements, leading to a series of development meetings to reach rationalized conclusions. In the event, development meetings continued throughout the construction period to meet the demands of the new requirements for Underground stations.

The principal requirements became:

- Reliable voice communications over the whole project area (effectively 900m from Blackfriars to Farringdon) for BR staff, BT police and LFCDA.
- Rapid public voice communications to the Station Control Room (Fig. A).
- Effective CCTV monitoring of all public areas.
- Continuous recording of every communications channel and every camera-view, un-erasable at the station.
- The use of fire-resistant cables, capable of operating at 950°C ambient temperature, for all emergency-related systems.
- Protection from fire where necessary of equipment and circuits by diverse routing, isolation or thermal insulation.
- Un-interruptible power supply (UPS) back-up for all communications equipment.

Some of the more interesting features of the system are:

Public assistance

The public areas are served by assistance points (Fig. B) set into walls at which the public can gain almost instant voice contact with the control room supervisor on a hands free channel by the operation of a push button. The supervisor can maintain control of multiple incoming calls, transfer from one to another, and make outward calls to any assistance point.

UHF/FM radio

These two-frequency simplex channels provide separate facilities for inter-communications using handsets for BR staff, BT police and LFCDA. The individual base-station signals are combined into a common antenna system consisting of yagi arrays covering the platforms and leaky-feeders (radiating co-axial cables) covering other parts of the station and the tunnels to Blackfriars and Farringdon.

CCTV

Visual monitoring of public areas of the station for normal passenger flow and any abnormal incident is aided by the closed-circuit CCTV system. Approximately 40 cameras, most having pan, tilt and zoom functions, are operated from the Control Room where six monitors give full colour displays of camera views in automatic sequences. When any fire or public assistance alarm in a public area is operated, a designated camera will automatically move to view the alarm point.

A. Station Control Room.

B. Public Help Point.

Fennell requirements and safety features

The fatal King's Cross Underground fire in September 1987 resulted in a public inquiry and a re-appraisal of the design of Underground stations, culminating in the Fennell Recommendations and Statutory Instrument 1401: The Fire Precautions (Sub-Surface Railway Stations) Regulations 1989. This meant a complete review of materials used in the construction of the station to minimize fire hazard, study of the effects of fire in train coaches, smoke flow and smoke extract systems, and evaluation and upgrading of life safety communications.

This has resulted in this project becoming the first major Underground station to be purpose-built to incorporate the latest state-of-the-art fire prevention, safety and communications systems.

Fire and smoke control

Following the King's Cross fire, Class 0 materials were specified for use on the station. The main fire hazard was posed by the Class 415 (slam-door) trains themselves which operate on the Southern Region, as their carriages have wood side and ceiling panels. The fire scenario assumed an arson attack in a carriage some time before the train entered the station. On arrival at the station the fire was considered to be fully developed and at the point of flashover (the term used to describe the stage in the fire when the heat inside a compartment becomes so great that all of the combustible material starts to burn at the same time). This was a departure from the normal BR fire scenario that assumed that the fire would be extinguished before it reached flashover conditons; the decision to consider flashover was a direct consequence of Kings's Cross. In the event of such a fire an extract system was needed to keep the level of the smoke at a safe height of 2.2-2.5m above the platform level during the evacuation period from the station.

As insufficient data were available on the heat output from fire in the coach, seat and lining fire tests were carried out at BRE. Based on the fire test results, computations were made to evaluate the speed at which the fire would grow and the total heat output from ignition through to complete burnout. These showed that after flashover the carriage fire would grow to 16MW heat output in only four minutes. The computation for passenger movement and excavation showed that passengers would still be on the platform. This led to the study of smoke movement and extraction.

Early on in the fire the windows in the carriage would break and smoke would flow through the openings. The buoyancy of the smoke would cause it to flow along the station ceiling in a stratified layer.

At peak heat output the smoke flow rate in the layer was calculated to be 60m^3/second. To keep the base of the smoke layer at 2.5m above platform level required mechanical extraction at 65m^3/sec with at least 23 extract points evenly distributed throughout the station. As it was not possible to control spread of smoke over the tracks by screens or drop curtains, 'slit-type' extract ducts were placed across the tracks at the two ends of the platforms to limit the spread of smoke and keep the exits clear.

Station Interior

The station finishes' architect, RHWL, were faced with the task of designing the platform environment to avoid the relentless feel of a low-ceilinged 275m-long space. They cleverly introduced tapered pilasters at 6m intervals along the platforms, combined with uplighting to produce what appears as a series of bays along each platform (Fig. 15). The pilasters also house vital communications equipment and fire hydrants.

The platforms are covered with white terrazzo tiles and the walls lined with white vitreous enamel panels, behind which are housed the multitude of essential services. Colour is provided through the blue and red of Network South East picked out on lights and other furniture.

The station concourse features the same materials as the platform including the uplighting — a comparative innovation for BR station design.

14. (above) Street level booking hall; and 15. (right) Station platform.

16. Temporary track alignment: Stage 1.

17. Temporary track alignment: Stage 2.

Construction

Archaeological excavation
In a carefully programmed and systematic manner to allow construction work to proceed without delay and disruption, the Museum of London with funding by RSD carried out a multi-million pound archaeological dig (Fig. 18), which provided a unique opportunity to add to knowledge of London's history. Important finds include the remains of substantial 12th and 13th century buildings and the medieval wall along Pilgrim Street and New Bridge Street adjacent to the culverted River Fleet. The medieval wall under the development has been preserved by surrounding it in sand, and permanent access provided for examination and study by future generations.

Civil engineering works
As is evident and explained earlier the construction of the railway works and development not only had to contend with the archaeological dig and the multitude of underground statutory services but also had to ensure that all essential services including road and rail traffic were not disrupted during construction. Before the railway works commenced, the underground services in Fleet Lane, Old Seacoal Lane and Seacoal Lane — high voltage feeder cables from the LEB substation in Seacoal House and a City Corporation main sewer — were diverted through new tunnels constructed under and alongside the line of the new railway. In parallel with these operations the four tracks on the existing viaduct between Queen Victoria Street and Ludgate Hill were replaced and realigned with two tracks on its west side to serve both Thameslink through services and Southern Region trains to Holborn Viaduct. A composite steel bridge recently completed as part of the viaduct was slid over to the west side. In close succession the railway tracks and platforms at Holborn Viaduct station were realigned to provide three platform faces on the west side (Fig. 16).

Realignment of the railway to the west at Easter 1989 allowed demolition of the eastern part of the viaduct and railway structure construction to commence. Construction of the double-decker bridge at Ludgate was done in two halves to maintain a constant 7m carriageway along Ludgate Hill. The southern half was first constructed and then bridged over with a temporary structure to carry traffic whilst the northern half was built.

In order to allow further construction to proceed, the tracks and platforms at Holborn Viaduct were realigned immediately above the Thameslink tracks below the station. This allowed demolition on both east and west sides of the platforms to take place and construction of the new Holborn Viaduct entrance to the new station to commence (Fig. 17).

In January 1990 the Southern Region train service to Holborn Viaduct terminus ceased and construction along the whole length of the new railway alignment was taken as close as possible to the remaining part of the old brick viaduct. This was the prelude to the all-important Blockade at Easter 1990.

18. An 11th century three-seater toilet seat under excavation in the Fleet Valley.


19. First day


20. Second day


21. Third day


22. Fourth day


23. Fifth day


24. 12th day

Blockade

This was a 17-day suspension of railway services, during which the remaining part of the viaduct was demolished, the new viaduct completed, and tracks laid along the new alignment culminating in restoration of the Thameslink services and commencement of services at the partly-completed new underground City Thameslink Station. The Blockade was meticulously planned for 24-hour working. The 17 days were divided into two periods, the first a seven-day activity commencing at midnight on 12 May 1990 to remove existing tracks and complete demolition, lower Queen Victoria St Railway Bridge, complete the new viaduct and create new formation for the railway tracks along the demolished part of the remaining Holborn Viaduct Station. 10 days were reserved for BR to lay new tracks, install signalling and traction power, and complete vital testing for train services to recommence at 5am on 29 May. The operation based on the Arup masterplan was fully programmed and implemented by Bovis acting as construction manager. Bovis, in close and pro-active co-operation with the trade contractors produced a series of two-hourly programmes for each and every activity and every trade contractor. Both design and construction identified problem areas, and contingency plans in terms of design change and materials were built in. Virtually nothing was left to chance, and the trade contractors, in particular Griffiths-McGee (who had the major task of demolition and track formation) and British Rail, responded to the challenge and successfully completed the works on time.

The statistics give an idea of the operation. There were over 4600 truck movements during Blockade, shifting 85 000 tonnes of spoil and rubble as well as four structural steel bridges in this congested and busy part of the City. This was a highly mechanized operation in which 28 excavators of various sizes were employed, along with seven cranes.

Conclusion

The railway works are now complete and handed over to British Rail and the buildings are well on their way to completion.

Credits

Client:
Rosehaugh Stanhope Developments
(Holborn Viaduct) plc
British Rail Property Board & Network South East

Architect:
Renton Howard Wood Levin Partnership

Construction manager:
Bovis Construction Ltd.

Cost consultants:
Gardiner & Theobald

Photos:
1, 5, 7, 8, 12, 14, 15, 19-24, A, B: Peter Mackinven
4: Ove Arup & Partners
18: Museum of London

Principal consultants:
Ove Arup & Partners

Major contributions to the project were made by the following:
Parliamentary Bill + construction management:
David Snowball
Civil engineering structures:
Steve Dyson, Peter Knight
Building structures:
Adrian Falconer
Tunnels, sewers, roads and services diversions:
Bob Barton
Geotechnics: Alain Marcetteau
Vibration + acoustics: Chris Manning
Building services:
Gregoir Chikaher, Mark Hann
Fire engineering:
Margaret Law, Andrew Gardiner
Communications:
Kirwen Phillips
Site services:
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Sussex Grandstand Goodwood Racecourse

Architects: Arup Associates

Sir Philip Dowson
Terry Raggett David Thomas

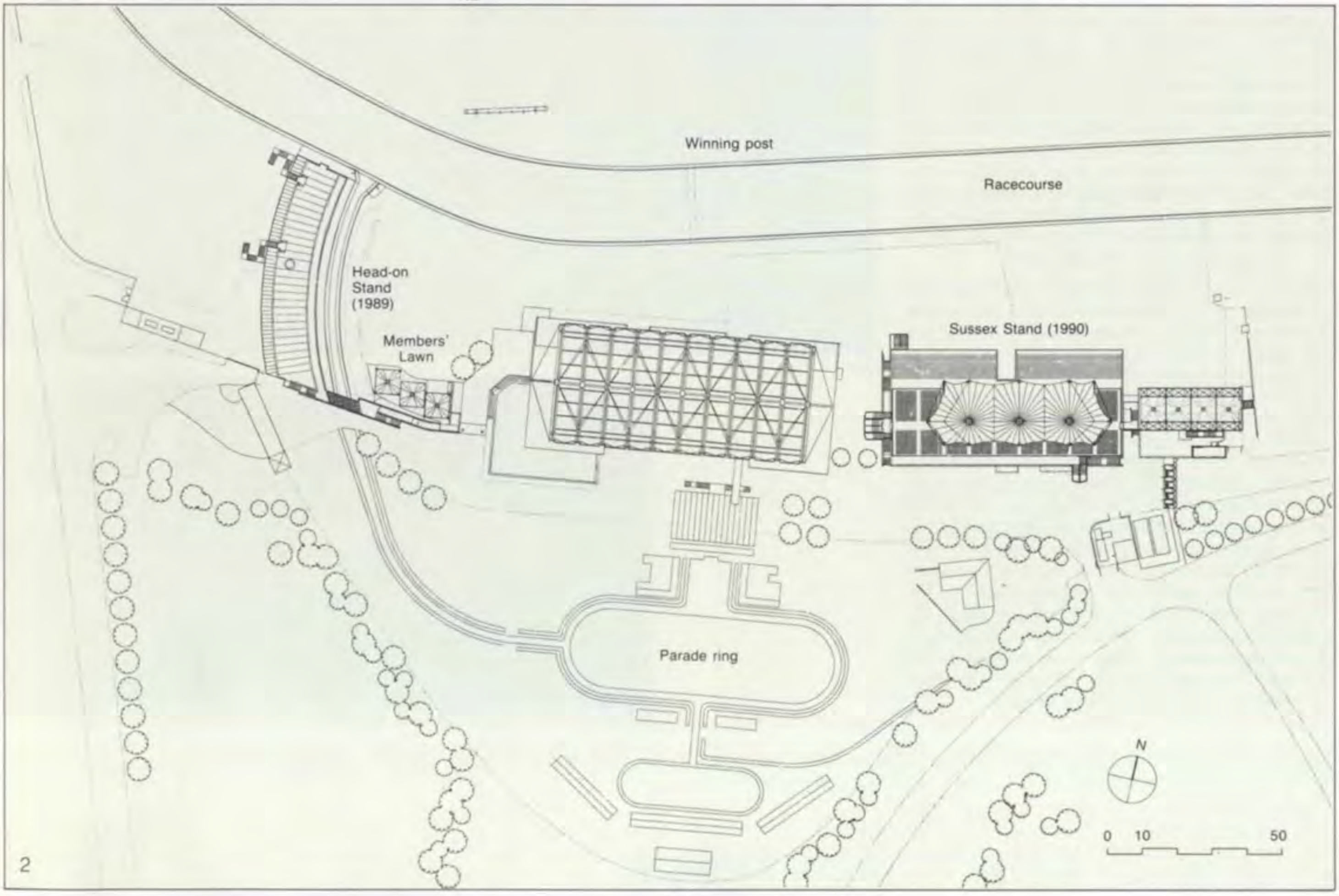
King Edward the Seventh, on a balmy day in July 1905, remarked that 'Goodwood is really a garden party, with racing tacked on'. In 1987 Arup Associates were appointed to prepare a masterplan for Goodwood Racecourse, and this attitude was taken as the starting point. In July the Downs near the racecourse are crowned with a profusion of tents and marquees, and the design intention was to extend this theme to both the permanent as well as the temporary buildings, to enhance this 'garden party' atmosphere and make it more available to all racegoers. Certainly, there is no other racecourse in England which enjoys such a magnificent setting. However, the economics of horse racing, as with most other sports, relies heavily on the revenue received from corporate hospitality. Goodwood Racecourse has been criticised by both the racing press and its membership for having favoured the corporate racegoer, so priority in the masterplan was given to the grandstand and paddock racegoers (Tatts). A new stand with a high viewing position was required, and also there was to be a new Members' Restaurant with a view of the course. All enclosures were to be extended and improved, and additional hospitality boxes constructed; a major race meeting presents a complete spectrum of English society and so whether Whelks + Whitbread or Beluga + Bollinger, it was determined that Goodwood should offer the finest facilities and live up to its reputation as 'Glorious Goodwood'.


1△

The masterplan locates the new Sussex Stand and 'Head-on Stand', an extended Members' Lawn and provides for improved access for circulation within the public areas. There are also landscape proposals which will mature in the future and will recover some of the 'green' with new trees to replace those so tragically lost in the last few years in storms.

There was a pregnant silence when it was suggested that the winning post be moved back to a more convenient position: sacred ground was being trodden on. However, this was eventually done, thereby placing it more centrally between the two stands, and moving it back from the acute bend in the course beyond the finishing line. The bookies' forecourt is now planned between the two stands, and an improved access with turnstiles was provided to the course.

The new Head-on Stand and the extended Members' Lawn are planned as one. The latter is built up as a grass bowl so that the rear of the lawn is just below the level of the members restaurant terrace, providing a clear view from both with the horse walk in between. In future, trees will cast shadows across the grass. The new Members' Restaurant has perhaps the most spectacular view at Goodwood, looking in one direction across the Downs and straight down the course, and in the other over the Solent to the Isle of Wight. With one sweep it embraces the landscape to the north and to the south from the ridge.



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The panoramic windows are screened with green and white striped awnings and sunblinds and this theme has been taken right through all the new stands, which is a further detail to help bring cohesion to the whole development.

The Sussex Stand draws a great deal from its predecessor, built in 1830. In principle, it has a mound of standing steppings rising from ground level, with boxes at the back, and with the main public seating above at high level, requiring a smaller canopy. In Goodwood, the main meetings are in the summer, and the sun is from behind the stands. Protection against the wind is more relevant here, rather than the rain and the sun. Unlike spectators in most other sports, racegoers are very mobile and are on the steppings only for the short duration of the race. Accordingly, circulation is all-important, and people usually dress for the weather. So, as with the 1830 Stand, the covered seating is at high level and the canopy small.

This canopy, however, gives the Stand its main character. It is a permanent 'tent' and translucent, and in July becomes the largest of the canopies around which the many other marquees congregate; soft in silhouette, it is light in structure. The clear glass windshields round the high level seating and below the canopy give a feeling of openness to create an atmosphere intended to be festive. Together with white painted steelwork, the building provides a light and airy spot in which to enjoy the racing and its magnificent landscape. The lower steppings give direct access to lawns, paddock and bookies' forecourt, and the comprehensive support facilities within the ground floor. In the building itself there is generous provision for catering, as well as extensive tote facilities and a betting emporium, with direct access to the course. The south facing terraces with their spectacular views are also a feature.

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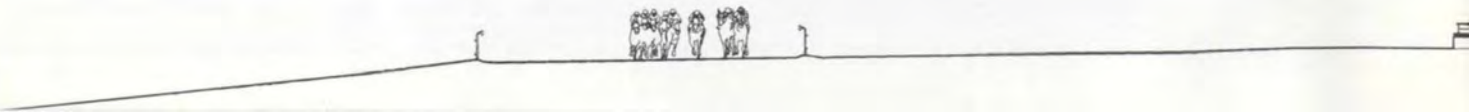

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Programme and structure

The very short design lead-in time effectively ruled out the use of precast concrete for the main frame, which is instead constructed as two levels of in situ coffered slab.

The upper tier and roof skeleton are of steelwork and precast units, which are used for the steppings at both levels. The roof framework combines tubular booms, mast and compression stays with solid round tie bars having rolled on threads to receive the connecting forks. The boom ends are complex arrangements of profiled plates to suit both the geometry of the primary structure and the perimeter cables. A polyester reinforced PVC fabric is used for the roof, connecting to zinc-impregnated perimeter cables, and the whole membrane is erected and stressed from the three mast heads. Assembly and erection took about a week. In common with the existing stand, the new Phase I and II buildings are constructed with a brick base to the first storey. This is to provide a continuity of building, walled enclosure and landscape which is unusual for a major racecourse.

The construction programmes for both Phases were strictly defined by the racing programme:

July 1987: appointment to prepare masterplan.

October 1988 – June 1989: completion of first phase — new members' and sponsors' restaurant, kitchens and viewing terraces with panoramic view of track and the paddock.

August 1989 – July 1990: completion of second phase — demolish existing buildings, extend and re-grade members' enclosure, build new entrance and the new Sussex Grandstand with low level steppings and covered high level seating, with hospitality boxes in between.

Refreshments, washrooms, tote betting facility and course administration centre are all provided within the Grandstand.

A racecourse and a grandstand need to be highly functional, as they have to absorb both intensive and heavy use for the few days a year that there are race meetings, but also they have to celebrate these events. Many interests and people are involved in their design, and the professional bodies, the client, the designers and the contractors are further constrained by the racing calendar. So both brief and programme require a close and combined operation on the part of all those concerned. In this case the contractor was Longley, who completed their contract on time and between the critical race meetings. There were, of course, moments of anxiety for us all, as in any ambitious undertaking, but the commitment and the co-operation of all concerned is now self-evident in the result.

Credits

Designers:
Arup Associates
Architects + Engineers + Quantity Surveyors

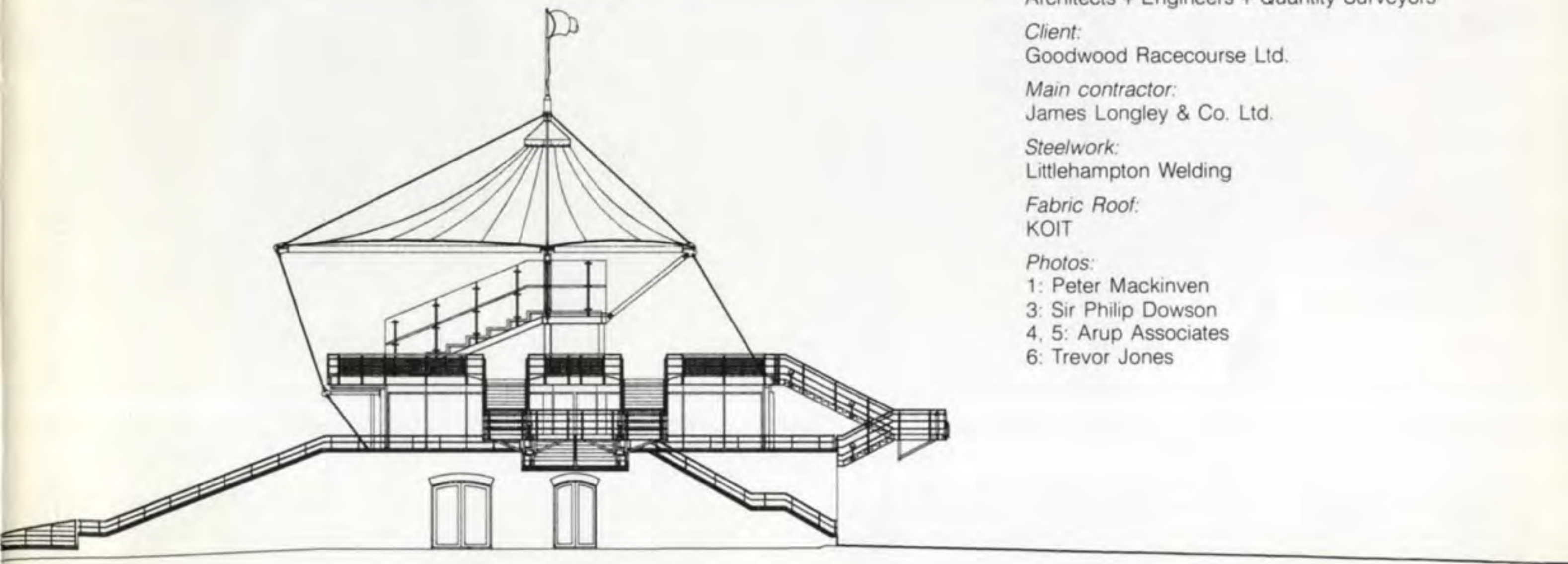
Client:
Goodwood Racecourse Ltd.

Main contractor:
James Longley & Co. Ltd.

Steelwork:
Littlehampton Welding

Fabric Roof:
KOIT

Photos:
1: Peter Mackinven
3: Sir Philip Dowson
4, 5: Arup Associates
6: Trevor Jones



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