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New offices satisfying present-day criteria for high-quality City space have been created within one of Sir Edwin Lutyens' most imposing buildings. Alongside careful retention of the facades and important original internal features, an open plan space surrounding a new atrium has been opened up beneath a new mansard roof, and the whole redevelopment serviced for high technology needs.

A short summary of landmark events from the last decade illustrates the growing strength of the practice. Three very different projects are described in more detail: the railway vibration isolation at Birmingham International Convention Centre, environmental noise assessment at the Wytch Farm Oilfield development in Dorset, and the acoustic consultancy for Phase 1 of Alexandra Palace's restoration.

Water levels in marinas and harbours have to be controlled for many reasons. The methods employed on three projects — Salford Docks, Port Pendennis, Falmouth, and The Crumbles, Eastbourne — are described and illustrated in this article.

A new multi-storey shopping centre has been built over the water of the disused Princes Dock in the centre of Kingston-upon-Hull. The foundations for this necessitated some of the largest CFA piling ever installed in this country, adjacent to the original dock wall works of the 1820s.

Natural ventilation is a notable feature of this refurbishment of a 1950s shopping arcade in Epsom, winner of a 'Shopping Centre of the Year' Award.

Front cover:
Lutyens House atrium
(Photo: Peter Mackinven)

Back cover:
Furzey Island site: BP Wytch Farm Development (see pp.12-13)
(Photo: Sillson Photography)

Lutyens House

Executive architect:
William Nimmo and Partners

Consultant architects:
Peter Inskip and Peter Jenkins

Martin Gates-Sumner
Rod Buchanan

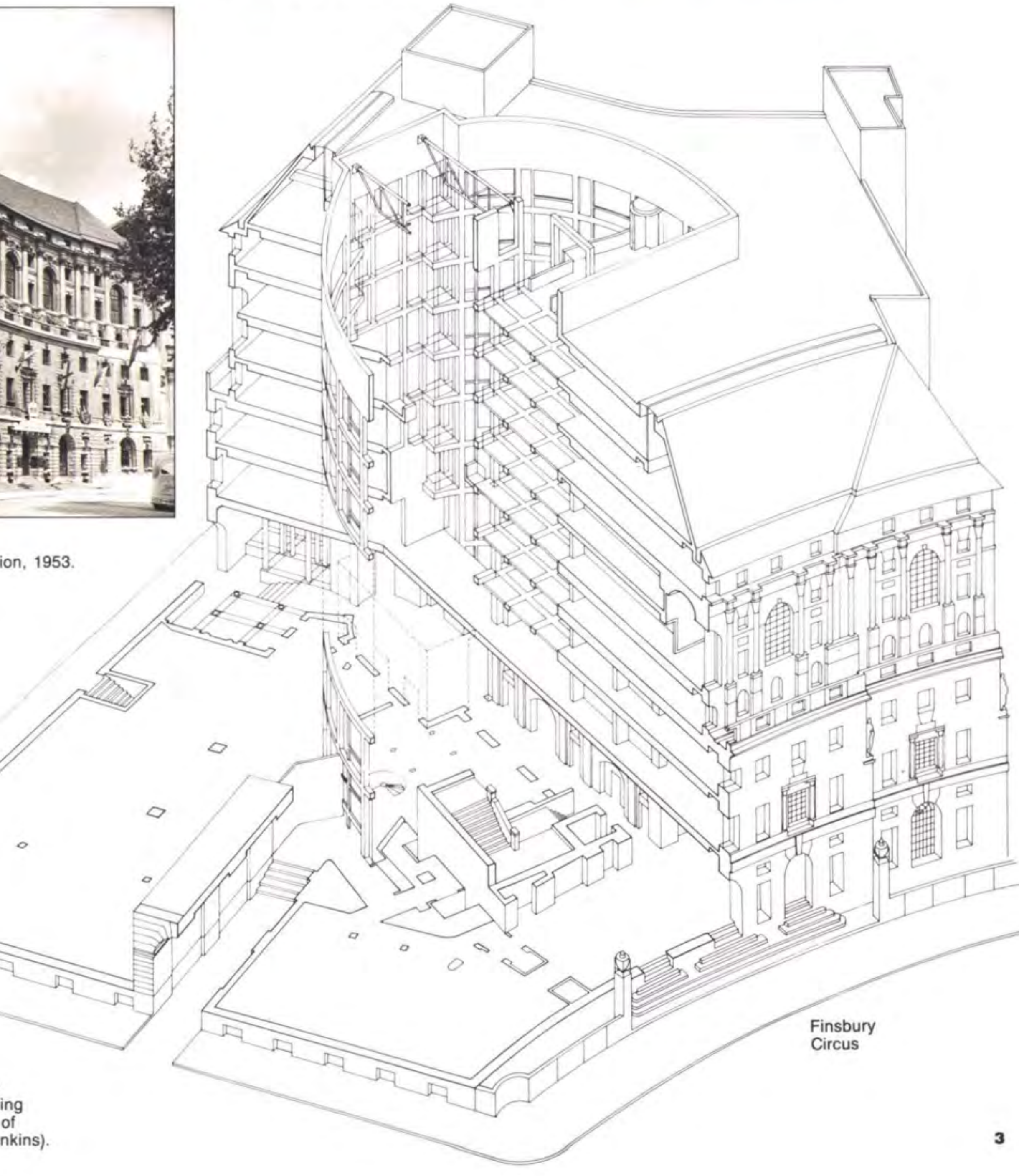
Introduction

The redevelopment of Sir Edwin Lutyens' Britannic House in London's Finsbury Circus has recently been completed following a three-year design and construction period. Some 19 500m^2 of functional, high quality office space has been created for the client, Greycoat plc, behind the magnificent retained facades and entrance halls of one of the City's most interesting commercial buildings of the 1920s.

The result shows how conservation of an historically important building can be successfully reconciled with the demands of 1990s office users and technology.

3. Restored entrance to Finsbury Circus.

1. Britannic House decorated for the Coronation, 1953.



2. Architect's perspective of the reconstructed building (Reproduced by courtesy of Peter Inskip and Peter Jenkins).

History

Lutyens designed Britannic House between 1920 and 1924 as the headquarters of the Anglo-Persian Oil Company, latterly British Petroleum. Built in two phases between 1924 and 1927, it was, and remains, a prime example of his development of the Classical language, drawing inspiration from Renaissance palazzi and the work of Wren, as reflected in the geometry of the Portland Stone facades with their varied and delicate carvings. *The Architectural Review,* May 1925, described the Finsbury Circus elevation as giving the impression of a 'palace built on a cliff, a very daintily and curiously disposed cliff . . .'. The building was listed Grade II* in 1950.

In 1966 British Petroleum moved to the nearby new Britannic House in Moor Lane (an early Ove Arup & Partners' project), since when the original building has had various occupiers, and become known as Lutyens House. Greycoat, in conjunction with William Nimmo & Partners and Arups, were successful in competition with other developers, and purchased the building in 1986. Conditional planning permission was granted in October of that year. Following the appointment of Peter Inskip and Peter Jenkins as consultant architects, detailed discussions were held with English Heritage, the Lutyens Trust and the City of London conservation officers over the form of the internal replanning, culminating in a revised conditional Planning and Listed Building Consent being granted in March 1987. At the same time Taylor Woodrow Management Contracting were appointed to undertake management of the reconstruction, while Arups were commissioned to provide a full multi-disciplinary service including an on-site design team supervising co-ordination of the engineering design. Enabling works started on site in June 1987 with demolition of the existing interiors being substantially complete by January 1988.

Brief

The essence of the client's requirements for the scheme was a new building satisfying present-day criteria for City office space, to be created within the restraints imposed by the restoration of significant retained sections of the interior and the three major facades. It is not a refurbishment. This is well-illustrated by the care taken to satisfy the requirements of the planning authorities in two major aspects of the exterior — the mansard roof and the windows.

The mansard roof has been totally reconstructed to the exact profile, and reslated using the same source of Westmoreland slate and pattern of diminishing courses as the original — which involved detailed surveying of the existing roofs and reopening the original quarry. Likewise, the various sized windows in the retained facades have been replaced by purpose-made aluminium double-glazed units, having the same external appearance as the original single-glazed, steel-framed windows, but providing the thermal and acoustic properties required by a modern office environment.

A challenge of a different kind was presented by a major branch of the National Westminster Bank situated on four floors in one corner of the existing building. This could not be relocated, and was to remain trading on site throughout the contract period while its present space was reconstructed. Similarly, the reconstruction had to leave unaffected an existing entrance to Moorgate Underground Station at basement level.

Concept

The planning consent required that the marble-lined ground floor entrance halls and barrel-vaulted central staircase were to be retained unaltered in any way. This effectively set the storey heights up to fifth floor, within which the new construction surrounding these retained elements had to be planned, ranging from a generous 5.68m at ground floor to a dauntingly cramped 3.35m at third and fourth floors. The developer's standard of a minimum floor to ceiling height of 2.59m, coupled with the requirement of a raised floor for underfloor electrical and communications distribution, determined that exceptional measures had to be taken in the floor design to provide relatively column-free, air-conditioned office space.

The need to introduce good quality daylight into the centre of the building was an equally important influence on the structural form.

The existing building, an irregular pentagon on plan, was dimly lit internally by two small lightwells, bisected by a section of the building containing the two-storey boardroom at fourth floor. Detailed investigation by the consultant architects into Lutyens' early studies for the building led to a proposal for a top-lit semi-circular atrium linked to the retained areas being accepted by the planning authorities. The one casualty of this scheme, the boardroom, was faithfully reconstructed in exactly the same plan location, but at basement level.

Retention of the existing facades presented further restraints.

 4. Typical floor plan.

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Setbacks in the facades at third and sixth floor level effectively prohibited an external system of temporary support. To minimize the potential disruption of a braced internal system supporting a freestanding wall, we adopted a scheme which retained the first bay of the existing steel-framed structure to stabilize the facades. This steel frame, together with its filler joist floor slabs, was then to be incorporated into the permanent works, although the clarity of this concept was compromised in areas where the existing slabs had to be removed to reduce loads on retained foundations.

The above factors influenced our decision to adopt a minimum depth steel frame for the reconstructed areas, but one where the structure and above ceiling services installations had to occupy the same zone. The location of plantrooms and the major duct and pipework routes emanating from them had to be integrated with the floor plate structure, and by an iterative process of design a fully-co-ordinated layout evolved providing as far as possible flexible and efficient systems within a minimum storey height.

This principle was extended to totally new floors constructed above the retained areas, where by adopting the same approach an additional floor was introduced behind the reconstructed mansard roof.

Foundations

The existing masonry-encased steel frame is supported by steel grillages embedded within mass concrete strip footings or pads founded directly on Terrace Gravel or London Clay, some 1.5m below the existing basement. Groundwater is present immediately above the top surface of the clay.

Where the existing frame has been retained in the perimeter bays, the facades and beneath the entrance halls, new loads coming down onto the existing foundations have been limited to allow their re-use. Elsewhere, cast in situ tripod bored piles support the new structure. The existing basement has been lowered over half its area to accommodate new central plant while reinforced concrete tanks have been constructed beneath these

5. Original Chairman's office
6. Original boardroom.
7. Boardroom relocated at basement level.

areas for sprinkler and domestic water storage. Existing foundations to retained columns in the lowered areas have been underpinned, and a new drained cavity floor and walls constructed.

Ground movements resulting from the demolition of the interior and subsequent reconstruction were a primary concern, particularly in respect of their effect on the masonry facades and marble-lined halls.

Calculations of the initial undrained and long-term consolidation displacements using the VDISP program showed that the centre of the site would experience a net heave in the order of 20mm relative to the perimeter, which would move little. The worst curvatures of ground profile would occur during the construction period after demolition. Subsequent settlement from reloading of the site approximately balanced the continuing long-term heave. The predicted curvatures were within published limiting values, suggesting that little or no damage would occur to masonry elements, but no such case histories or empirical data could be found regarding the hogging behaviour of tightly-jointed marble wall panels attached to backing masonry.

8. Temporary works to Moorgate facade.
9. New mansard steelwork adjacent to retained stair.
10. Temporary works showing propping.

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Physical restraint of the ground movements, using tension piles or anchors, was investigated but there was no guarantee of performance. Consequently the decision was taken to remove panels of marble at critical locations where the curvature was greatest, stitch-drilling the backing brickwork to create 'hinges' where movements in the structure could be concentrated. The marble could then be refixed at the end of the reconstruction period after the worst movements had taken place. This proposal was presented to the planning authorities and accepted.

Monitoring of the site levels at monthly intervals throughout the contract showed a remarkably good correlation between predicted and actual movements, giving a fair degree of confidence that the splendidly restored marble halls will not suffer damage from subsequent long-term movement.

Structure

The existing masonry-clad, steel-framed structure was designed and fabricated by Redpath Brown and Company using the shipbuilding techniques of plating and riveting to create composite sections for both beams and columns. A detailed site investigation of the frame carried out during the enabling works period showed the steelwork to be generally in sound condition with little evidence of significant corrosion. One exception to this was the eaves beams at the base of the mansard roof located adjacent to a secret gutter. This, coupled with the extent of temporary works needed to retain this structure, led to a proposal to reconstruct the mansard roof, which was successfully negotiated with the planners.

In the retained perimeter bays up to fifth floor, site trials had shown that some 100mm of existing screed and topping could be planed off the 300mm thick filler joist floors while maintaining their integrity.

This, together with replacement of existing concrete encasement to beams by sprayed fire protection, was essential in maximizing the available storey height and reducing dead load.

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11. Mansard cladding showing precast planks, timber battens and new Westmoreland slate in the foreground.
12. Mansard cladding giving clear view of timber battens
13. Steelwork for new mansard.
14. Demolition of original 6ft deep transfer beam.
15. Part elevation of atrium showing vierendeel frame spanning over existing structure.

16 to 18. Views of the atrium.

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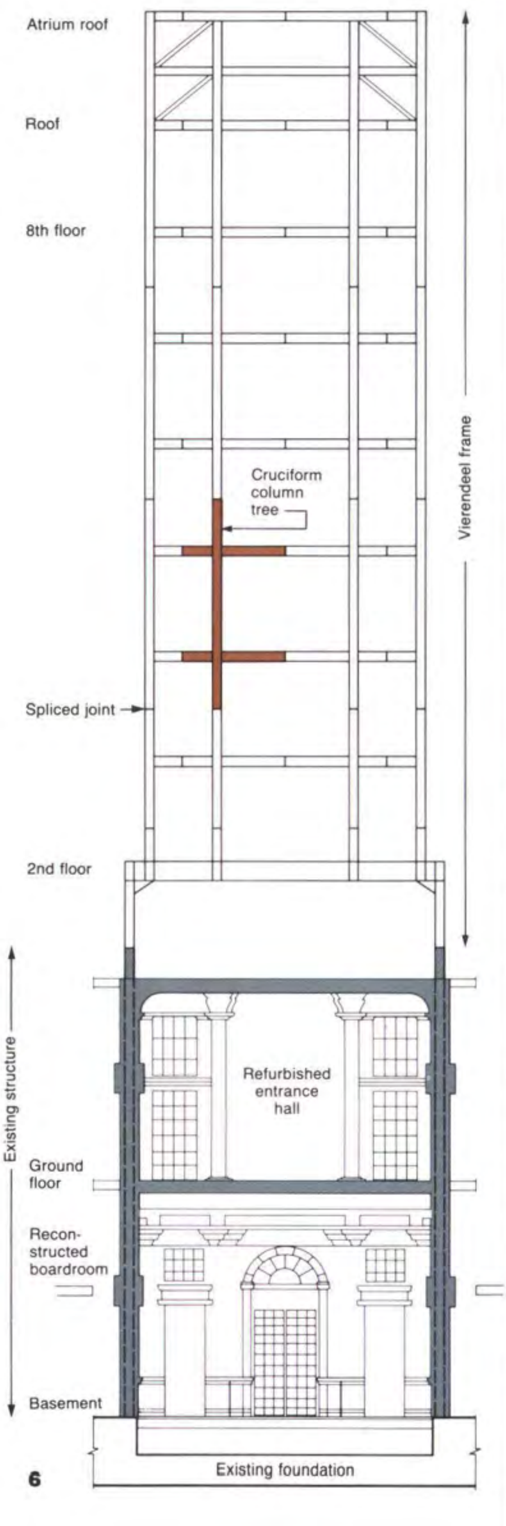

The resulting exposed top surfaces of the filler joists were accepted by the District Surveyor as not requiring fire protection, but main beam flanges are protected. The principle of dovetailing all services into a single zone within the floor structure, and use of the ceiling space as a return air plenum, required frequent openings to be cut in the webs of perimeter beams. Reduction in load and low stress levels adopted in the original design allowed holes up to 540 × 190mm to be formed within stiffened sections of the web.

The new structure is steel-framed with lightweight concrete floors cast on profiled metal deck permanent formwork. Generally the floor slabs act compositely with the main steel beams, but above primary duct runs, secondary beams are set up into the slab depth to provide sufficient clearance within the ceiling space. Grade 50 castellated universal column sections are used for the main beams to minimize steel depth and allow passage of services and return air. The services are planned such that the largest openings required for ductwork do not exceed two castellations joined together. The structural steel zone including firespray and an allowance for deflection is 538mm. In the office area facing onto Moorgate, column-free space up to 12m × 12m is achieved by utilizing plate girders within the same structural depth, again with preformed web openings.

By setting the ceiling tight up against the bottom flanges of the beams an overall ceiling and floor zone of 843mm has been maintained throughout the office areas. As expected, this integration of structure and services proved to be a major challenge, requiring the engineering-led resolution of ceiling layouts and detailed services coordination very early in the design to enable openings in the steelwork to be preformed as part of the programmed steelwork fabrication process. The semi-circular atrium enclosure is formed by eight-storey steel frameworks, some faceted on plan, acting as vierendeels spanning up to 10m to create column-free deep space at first floor. These frameworks are built up as a series of two-storey cruciform elements spliced at mid-points of the columns and beams to speed erection and minimize site connections. The main frames support a network of secondary steel-framed panels acting as a substrate for fixing the fire-rated glazing and Portland Stone cladding of the atrium facades.

Two primary roof trusses of welded circular hollow section construction support the fully-glazed, saw-toothed profile of the atrium

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roof, and its suspended maintenance equipment. The truss sizing reflects the consultant architects' requirement for the roof structure to unite the various elements of the atrium facades at roof level.

The steel-framed structure is again reflected in the new curved rear elevation which echoes the sweep of the Finsbury Circus facade and the proportions of the windows in the retained elevations. Here the columns are on a regular module with faceted or straight spandrel beams supporting a new aluminium rainscreen curtain walling system. The two-storey mansard roof, curved on the Finsbury Circus elevation, has been reconstructed using precast lightweight concrete planks supported by new steel portal frames to minimize load carried on the retained perimeter columns.

Services

Provision of building services within the constraints imposed by existing floor-to-floor heights, established in the days before the high technology needs of modern office users, was always going to be challenging. Early recognition of this led to the formation of a dedicated co-ordination team working alongside the discipline engineers throughout the design stage.

During construction, this co-ordination team moved to site to oversee the contractors' drawing production. The division of the building services under the management contract resulted in the appointment of nine separate services works contractors (excluding lifts, disabled hoist and toilet fit-out). These works contractors were greatly assisted in the development of their installation drawings by our own production of fully co-ordinated services design drawings. These were prepared for the whole of the shell and core works and selected floors of the fit-out works.

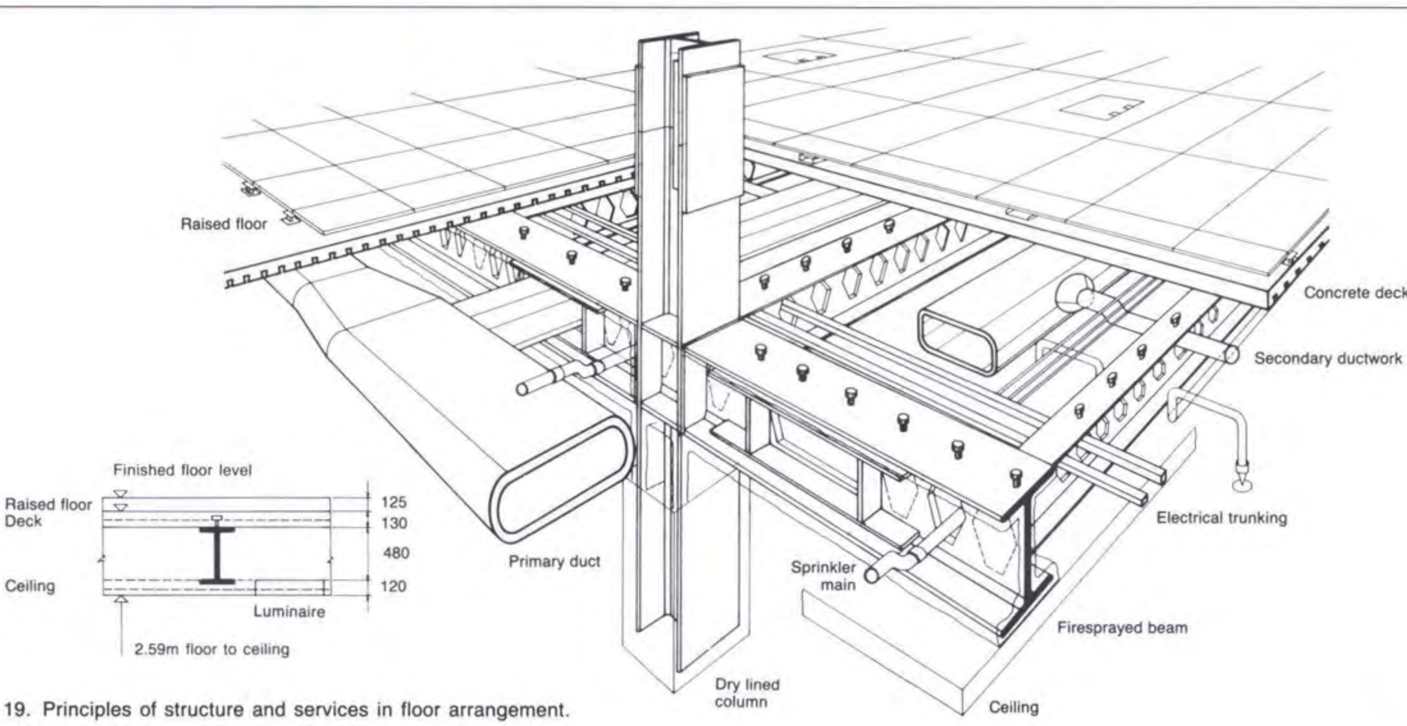
The services were tendered on the basis of a shell and core design, but during the course of the contract the client chose to extend the works to include office floor fitting-out, generally negotiating this as an addendum to the works contracts already let.

The principles of air-conditioning, plant location and horizontal and vertical services distribution established during the feasibility and scheme design stages resulted in solutions sensitive to the needs of both the retained and new architecture, the constraints of the existing and new structure and the client's wish to maximize the office space potential.

The remodelled basement houses central chiller, boiler and standby generator plant, substations and sprinkler plant, together with centralized variable air volume air-handling units serving the lower ground, ground and first floors. Three principal service cores connect the basement plant areas to the upper floors and roof. Cooling tower plant and toilet ventilation units are positioned at roof level, together with fresh air and exhaust air handling units serving floor-by-floor air-handling plantrooms between second and eighth floors.

Electrical distribution is fed from three packaged HV substations at basement level, each serving a riser containing separate landlord's, tenant's and communications compartments. Full lighting power and alarm installations are provided in the ceilings, leaving the tenant to fit power and data services within the raised floor.

An analysis of the most appropriate form of air-conditioning system established variable air volume air-handling in favour of ceiling-mounted fan coil units. Building heat losses are counteracted in the office areas by hot water re-heaters fitted to each perimeter VAV terminal box. In the absence of windows in the double-height perimeter mansard at the seventh floor, a four-pipe fan coil system was adopted.



19. Principles of structure and services in floor arrangement.

The use of perimeter radiators or below-floor convectors for perimeter heat were examined but discounted, based upon loss of floor area. To minimize the possible effects of cold radiation and downdraught adjacent to the perimeter, low emissivity double-glazing is installed throughout in the new windows.

The brief required an open plan office layout and a perimeter zone was fixed notionally at a depth of 4m. A continuous two-slot linear diffuser within 1.5m of the external facade serves this perimeter zone. Inside the offices, square supply air diffusers have been selected with a facility to respond to the lower supply air volumes experienced under part load conditions.

20. Facade to Moorgate, March 1990.

The irregularity of the existing building plan made a formal grid impossible to achieve. A system of modules was applied to each facade, dictated by the existing perimeter columns with ceiling-mounted sprinklers, lights and air diffusers set out along the window centrelines.

Lighting to the office floors utilizes specially developed 600mm square high efficiency fluorescent luminaires with low brightness louvres. Reproduction light fittings matching the originals of 1924 have been installed in the retained internal areas. In addition, dimmer-controlled cold cathode light sources have been introduced behind windows on the retained main staircase to create the impression of daylight, originally provided by the internal lightwells.

The central atrium required particular smoke control measures. Four smoke ventilation fans extract air from the highest point of the atrium. Make-up air is introduced via automatically opening doors at both the Moorgate and Finsbury Circus entrances which connect into the base of the atrium. Should smoke break into the atrium from an office fire, the cooling effect of the make-up air prevents the smoke from re-entering the offices at high levels via the atrium glazing. Operation of the atrium smoke ventilation system is triggered automatically by beam detectors spanning the atrium or manually under fireman's control.

During the development of the fit-out design a comparative analysis of the controls market-place led the client to opt for state-of-the-art fully addressable VAV box controls. Lutyens House became the first UK project to employ such a system and the ability to re-set the VAV box attributes, such as maximum and minimum set point, from the comfort of the central keyboard without the need to remove ceiling tiles, contributed to the timely keyboard completion of the airside commissioning.

Postscript

The project was completed to developer's fit-out standard in November 1989. Now, history is repeating itself with British Petroleum having taken a new lease on the building and fitting it out as their headquarters, allowing the 1960s Britannic House to be vacated for possible redevelopment.

Credits

Client:
Greycoat plc &
Associate Companies
Executive architect:
William Nimmo & Partners
Consultant architects:
Peter Inskip
and Peter Jenkins
Structural and services engineers:
Ove Arup & Partners
Quantity surveyor:
Davis Langdon & Everest
Services quantity surveyor:
Mott Green & Wall
Construction consultant:
Lehrer/McGovern
International
Lift consultant:
ACTS
Lighting consultant:
Lighting Design Partnership
Management contractor:
Taylor Woodrow
Management Contracting
Photos:
1, 5, 6: British Petroleum
9, 13: Ove Arup & Partners
11, 12: Ian Scott
8, 10, 14: Richard Baldwin
3, 7, 16-18:Harry Sowden
20, 21: Peter Mackinven
Illustrations:
Lin Bickford and
Luis Navarro

21. Facade to Finsbury Circus, March 1990.

ARUP ACOUSTICS: TEN YEARS

Richard Cowell

Arup Acoustics celebrates its 10th anniversary this year. Its beginnings and early development were described in *The Arup Journal*, December 1982. Since that time, and despite the sad death of Professor Peter Parkin, consultant to the practice, it has grown together within a continuously increasing spectrum of work; the range is best described by reference to a few important projects and developments.

Work in Hong Kong

The acoustic consultancy work for the Hongkong Bank included studies which developed Arup Acoustics' experience in many fields. The acoustic design of the Bank's atrium space (Fig. 1) with a mid-frequency reverberation time of 1.9 sec. achieves a careful balance, involving an aural sense of space and materials, awareness of 'busy-ness' and appropriate protection from distraction by external and occupational noise.

The boardroom sound enhancement system was a leading example of carefully controlled technology directed at the need for clearly intelligible speech of natural character. This was achieved by the use of voice-activated microphones, delay, equalization and automatic switching to feed gently enhanced voice signals to each board member. Loudspeakers and microphones were integrated unobtrusively, but effectively, with the interior design.

1. Hongkong Bank: Atrium (Photo: Ian Lambot).

The project also made advances in acoustic specification skills associated with packaged sub-contracts which combined to produce overall acoustic performance. Nine packages, for example, determined room-to-room sound pressure level differences at the perimeter of the building. The demolition, sea water tunnel, rock anchors and Mass Transit Railway operations called for extensive vibration analysis, monitoring and controls, as well as acoustic testing in Europe, the USA and Japan, which proved useful experience to the practice. We also contributed to the design of the acoustic isolation for the MTR Island Line rail track.

Other commissions include full acoustic consultancies for the Hong Kong Conference and Exhibition Centre, the Shanghai Hilton Hotel, and a wide range of commercial developments. The practice is currently providing advice for the Hong Kong University of Science and Technology.

Britten Opera Theatre

After early studies at the Royal Festival Hall and Barbican Concert Hall and a series of auditorium renovation projects, the Britten Opera Theatre (400 seats) for the Royal College of Music, London, commissioned in 1983, was the first new auditorium undertaken by Arup Acoustics intended primarily for the performance of music. The recognized success of the acoustic was achieved by determination to maintain adequate built volume, giving particular attention to detail in the auditorium's internal geometry, and a special study of seating absorption.

To achieve an appropriate teaching acoustic, the design aim was for a mid-frequency reverberation time of 1.25 sec. with the theatre full, rising to not more than 1.45 sec. under rehearsal conditions, and a controlled rise in bass response was introduced. Initial predictions showed the volume to be too low and consequently the roof was raised by 3m.

The auditorium's traditional horseshoe form and modest dimensions, together with a convex 'scroll' profile on the balcony fronts (Fig. 2), ensure strong early reflections. Effective control of services noise was of course essential, and the special sound insulation requirements and room acoustics for teaching music have been studied further through a range of later projects.

2. Royal College of Music, Britten Opera Theatre: detail of balcony scroll (Photo: Arup Acoustics).

Refurbishment and fit-out

Shell-Mex House on London's Embankment is an example of a recently-completed major refurbishment. A long-term programme of works involved the use of packaged internal elements to form new office, computer and support accommodation on 10 floors and also in basements. Comprehensive laboratory testing was carried out to refine the attenuation requirements of the suspended ceilings, air-handling, light fittings and internal wall linings. Typical airborne sound insulation between offices, although subject to the performance of many system components, was maintained at 33-35dB (mean level difference). Although building services sound output from fan coil units was used advantageously as masking sound to maintain aural privacy, a wide range of building services noise and vibration controls were required and a number of interesting areas required individual acoustic studies. These included acoustic treatment to a vaulted restaurant, controls on noise from a fitness centre and the protection of staff medical facilities from excessive noise.

Research and technical development

Arup Acoustics has made contributions to specifications for building services noise and vibration control equipment, and detailed guidance has been developed for design of common forms of public address systems.

Studies have been made with Arup Industrial Engineering of the dynamic response of suspended floors to footfalls, and to vibration from external sources, particularly railway vibration. More recently, practical examination of the effects of structural vibration on sensitive laboratory equipment and manufacturing processes (e.g., wafer fabrication) have been reviewed.

Recording/broadcasting facilities

Although early project work for the BBC Langham Place and Edinburgh buildings was not realised, the former included particularly useful studies of isolation from railway vibration. More recent commissions to provide the acoustic consultancy for the ABC Radio Centre in Sydney (Fig. 3) in 1987, and the BBC White City News and Current Affairs Centre in 1989 gave the practice an opportunity to provide new thinking in this area, particularly in respect of dry construction methods for studios and structural isolation.

3. ABC Studios: model (Photo: Arup Acoustics).

Building isolation and railways

Since 1985 Arup Acoustics has become increasingly involved with the control of railway noise and vibration. Work at the Birmingham International Convention Centre (described overleaf) and many sites in central London, including Broadgate and Charing Cross, Victoria and King's Cross stations, have involved extensive studies of vibration and structure-borne noise, and in some cases building isolation on natural rubber, neoprene, and metal springs has been developed. Isolation from underground railway noise has been arranged for parts of the Langham Hotel site, Portland Place, and for the main meeting room in the new British Library.

4. M42 (Photo: Harry Sowden).

Environmental work

We have been involved with environmental noise assessment, e.g. on motorways, for many years.

Two recent developments in regulations — the EC requirement that major projects must be subject to environmental assessments and the Noise at Work Regulations 1989 — have introduced far-reaching requirements for acoustic studies. Current work for the Wytch Farm oilfield development (described on pp.12-13) and for the new Toyota plant in the Midlands make use of well-established evaluation techniques, now used in a legal context which will bring new technical challenges for such developments.

Birmingham International Convention Centre: railway vibration isolation

Introduction

The siting of the International Convention Centre in Birmingham brings sensitive auditoria close to British Rail's Monument Lane tunnel, which carries Intercity and local services between Birmingham New Street and the North West. Within the Arup Birmingham Office engineering commission for the project (a full report is intended in a future *Arup Journal*), Arup Acoustics became involved in surveys and study of the implications of railway vibration. An American firm, Artec, were already commissioned for the acoustic design, Arup Acoustics' work being restricted to support for Ove Arup and Partners in finalizing engineering solutions for railway vibration isolation.

Some years before, the Birmingham Repertory Theatre (an earlier Arup structural project) had been built very close to the tunnel. Although limited measures were taken to attenuate structure-borne noise (in the construction of the auditorium envelope), the passage of trains is clearly audible as a low frequency 'rumble'. For the International Convention Centre, Artec were looking for very low background noise criteria, close to the hearing threshold. The first step was to evaluate whether the Concert Hall should be on the site at all. It is bounded by a major road (Broad Street) to the south and the Worcester and Birmingham Canal to the west, and is formed as fill over conventional Birmingham Rocksand. The railway tunnel is driven entirely within the rock and runs across the site as shown in Figs. 1 and 2. A first survey concentrated on vibration velocity measurements on the surface within and close to the Bingley Hall (previously occupying the ICC site), in the Repertory Theatre, and in a number of buildings more remote from the tunnel. At the same time, sound pressure levels were measured in the internal spaces including inside the Birmingham Rep.

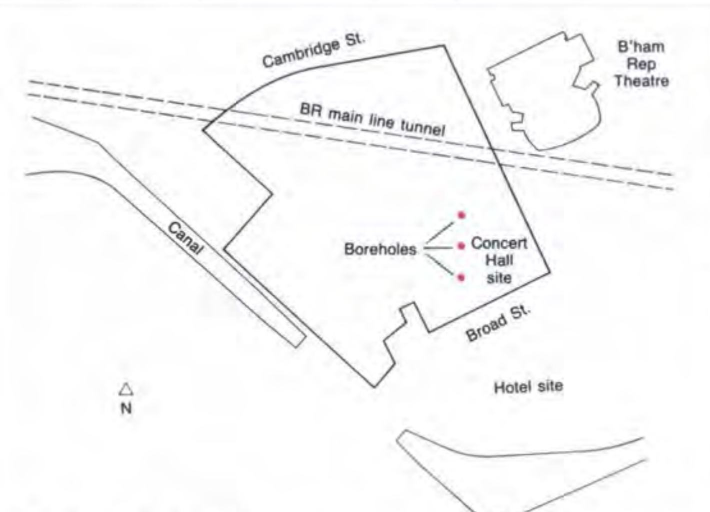
One particular feature from the first survey was the concentration of energy in the 63Hz octave band. This arose because of the spectral emphasis within the train vibration and also because of relatively high radiation efficiency in this frequency at the survey locations. A sound pressure level of 70dB was measured in the 63Hz octave in the Birmingham Rep at representative seating positions, but with the theatre unoccupied. Propagation losses in the form of Rayleigh (surface) waves were generally consistent with expectations. Vibration velocity levels (vertical and horizontal) and sound pressure levels were measured around the site (see Fig. 1). Of course, corrections were applied to measured data to allow comparison with likely exposure for a new Concert Hall.

The survey established helpful reference data as a basis for further, more detailed, survey work. It had already become clear that without major vibration attenuation (e.g. at source), construction of the proposed Concert Hall on that site using conventional methods was not compatible with the very exacting target noise limits. Substantial attenuation at source by track isolation could not be expected, although some might prove worthwhile if achieved at reasonable expense. Some form of building isolation was already envisaged if this siting were to be pursued.

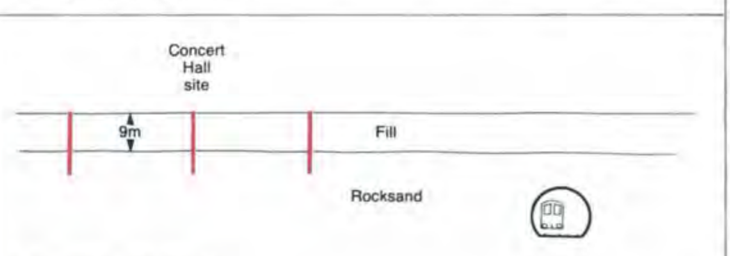
A second survey was arranged to improve understanding of the specific pattern of vibration propagation from this tunnel. The approach to the further assessment was discussed with Professor Peter Grootenhuis of Imperial College, London, and Dr. George Wilson, of the US acoustic consultants Wilson Ihrig of California, who was advising Artec. Arup Acoustics proposed and then developed a methodology for vibration measurements within boreholes. The low water table allowed scope for dropping accelerometers into them to sample ground response arising from compression and shear waves.

The tests were carried out in 250mm diameter, 9m deep boreholes at horizontal distances of 33m, 50m and 68m from the tunnel. The vibration measurements were obtained using Bruel & Kjaer *8306* and *4370* accelerometers mounted orthogonally in a steel cube by means of magnetic strips. The whole assembly was lowered into a borehole and firmly set in a bed of rapid setting grout to achieve good coupling between boreholes and accelerometers. Once the measurements had been obtained, the accelerometers were retrieved by breaking the magnetic bond.

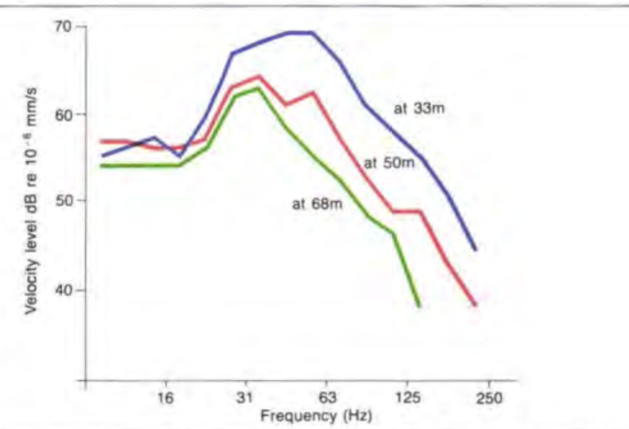
Examples of vibration velocity data from the three boreholes are given in Fig. 3. Although horizontal vibration levels were significant, the vertical component was found to dominate. From analysis of the data, it was agreed that use of 10Hz isolation bearings (with extensive controls over bridging via services, stiff air spaces or at access points) should allow sufficient attenuation to permit siting of the Concert Hall without unreasonable risk. Nevertheless, to achieve inaudibility of the railway, tolerances on estimates would need to be favourable and no certainty of inaudibility could be established. It was therefore agreed that Arup Acoustics would provide input to the design, directed at achieving the highest practical standards of isolation. In view of very stringent Artec noise targets, the Concert Hall and seven of the other halls within the Convention Centre were to be isolated as separate constructions. Exhibition Halls sited over the tunnel, foyers and much of the supporting accommodation, were not to be floated, being less sensitive.



1. Site plan showing tunnel line.



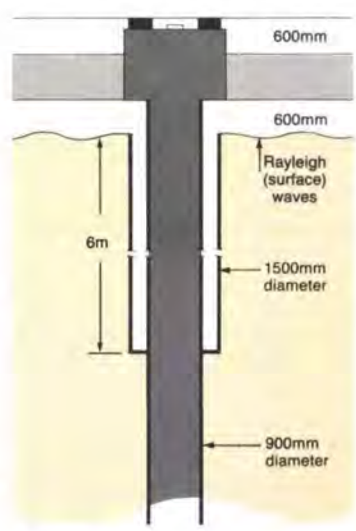
2. Section showing boreholes.



3. Borehole vibration data.

Pile design

At distances from the tunnel greater than 15m, the vibration transmission was dominated by Rayleigh (surface) waves. It was essential for energy transmission to be limited by using piles bearing on the Rocksand (where mobility was approximately 1/3 of that which would drive a raft at the surface). There was therefore advantage in using large diameter piles and decoupling the top of the piles from the surface waves. 6m was determined as an appropriate depth for the decoupling. Many materials were considered as sleeves at the top of piles to provide a mismatch against vibration coupling. To achieve the benefit (a few decibels only, but for this project every one counted), sleeving material needed to be highly compliant. It was eventually decided to use a void around the top of the pile. By using a second steel tubular outer case welded to the pile case 6m below intended ground level, a voided pile detail was achieved (see Fig. 4). Close to the railway, voided piles could not be justified, because compression and shear waves dominated the transmission into piles.



4. Pile design (section).

5. Undercroft showing the beams and bearings (Photo: Peter Mackinven).

Pile caps and tie beams

A second major influence on the design has been a tight control on the geometry of air spaces surrounding floated structures. In the past, the stiffness of large expanses of shallow air space has lifted the isolation frequency, or the build-up of resonances in the voids has aided transmission sufficient to have adverse effects on isolation (previous Arup experience of building isolation and research work on isolated studio construction for the unbuilt BBC Langham Project proved useful). A 600mm airspace has been provided between elements of substantial surface area facing each other across the isolation gap. Pilecaps are tied together by beams which are kept 600mm above the new ground slab and are also 600mm below the soffit of the floated structure. The undercroft space allows excellent access to bearings and the complex geometry prevents powerful resonances occurring. The area of pile caps was also limited (i) to avoid excessive local coupling through air across the bearing arrays and (ii) to allow good access to bearings (see Fig. 5).

Services

The high standards of isolation present a challenge to conventional flexible links in services connections, and research found little definitive work covering attenuation across such flexible links. The City of Birmingham, with the Arup Development Fund, provided money for laboratory research into their performance in various pipes from 50mm to 150mm under a variety of pressures, as single flexible links, or as two units separated by a loaded bend, with changes to patterns of local support.

As a result, flexible connections have been selected for maximum practical performance. In the case of groups of smaller pipes, some loaded bends have been arranged at RVJs by strapping bends to steel plate suspended on spring hangers with flexible connections either side (see Fig. 7). Electrical trunking was broken, and large cables suspended on springs for designated distances beyond the joint, subject to cable stiffness.

7. Services loading plates (Photo: Ove Arup & Partners).

Bearings

The main support bearings are steel plate-reinforced, natural rubber-based compounds manufactured and supplied by the Andre division of BTR Silvertown. They are generally 125mm deep and 250mm square, carrying approximately 300kN per pad, with static deflection close to 9mm excluding a few millimetres of creep. Dynamic stiffness is close to 1.5 × static stiffness. A full programme of static and dynamic testing has been carried out including tests at Malaysian Rubber Products Research Association in Hertford.

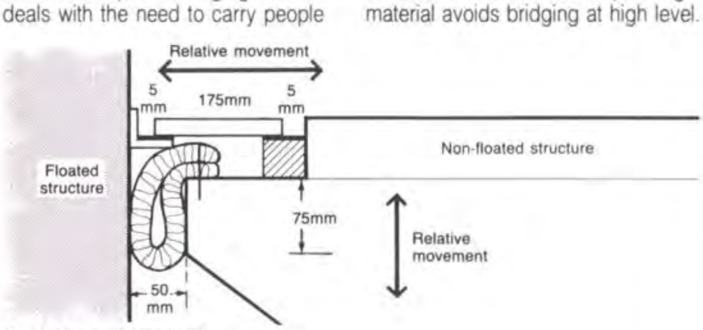
All bearings are numbered with individual static test certificates.

Creep, ozonization, shear and durability assessments have followed the guidelines of *BS6177: 1982*.

Bearings are set onto levelled epoxy grout beds around a steel failsafe block. Lateral restraint of floated elements is achieved using bearings which perform primarily in vertical shear but offer resistance to wind loads. However, a special case is the need for the Broad Street retaining wall to be propped by the bearings. This has been achieved in the design of the Concert Hall lower slabs (to transfer the load) and use of precompressed bearings being set in to replace temporary wedges.

Perimeter detailing

Where slabs meet floated structures, generally a 50mm airspace has been allowed. A theoretical ±12mm lateral movement under 50-year wind load is expected and relative vertical settlement of as much as 12mm has been allowed across railway vibration isolation joints (RVJs).
The elevational area facing the floated structure has been limited and slabs are generally chamfered to a 75mm deep nosing (see Fig. 6). A series of special bridging details deals with the need to carry people over the joint, achieve fire separation, and account for settlement and bearing creep without vibration bridging. Folded foam or ceramic blanket is used to achieve fire ratings within isolation joints. For waterproofing or facing, low modulus sealants or dry resilient seals have been included. At roof level, and at pavement junctions, cover pieces are fixed one side of the joint and bear on resilient material on the other side. Flexible weatherproofing material avoids bridging at high level.



6. Nosing and joint detail.

Isolation at source

At a late stage it was found that BR's plans to re-lay one of the tracks in the tunnel (as part of their maintenance programme) offered a chance for under-sleeper isolation to be added. A material manufactured by James Walker Ltd., which had been on trial in North Wales, had provided close to 10dB attenuation in the 63Hz octave band (see Fig. 8). It was felt that perhaps 6dB could be achieved in the tunnel. In view of the wish to minimize transmission to the site, it was agreed that the 'up' track should be isolated and the 'down' track could then be isolated in a second maintenance programme planned for 1991.

The 'up' track is now isolated. Arup Acoustics' measurements indicate that useful benefit has been achieved. More extensive tests are proceeding now.

8. Under-sleeper isolators stacked (Photo: Ove Arup & Partners).

Quality control

At the time of writing, surveys of residual vibration within the floated structures are becoming possible. As the project develops, isolation measures call for the highest standards of quality control. Although building planning has resulted in the pattern of isolation lines becoming more elaborate than proposed by Arup Acoustics, a strong awareness of the critical nature of the isolation process has developed amongst the site team, supported by Arup teach-ins to site staff.

Credits

Client:
City of Birmingham

Architect:
Convention Centre Partnership

Consulting engineers:
Ove Arup & Partners

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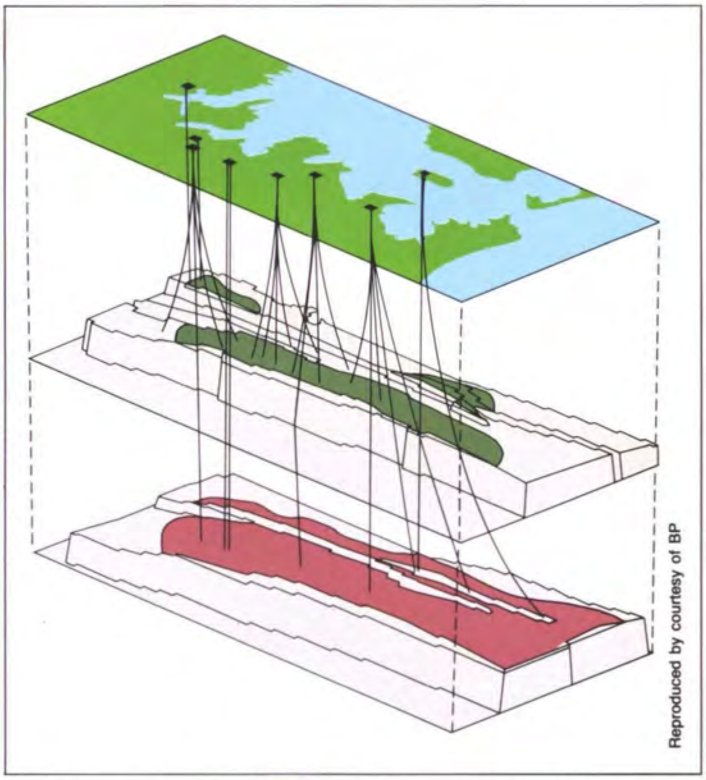

Introduction

The Wytch Farm Oilfield is the largest known onshore field in the United Kingdom and lies beneath the southern shores of Poole Harbour in Dorset. The whole of the Harbour is designated as a Site of Special Scientific Interest and is bounded by nature reserves, bird reserves, heathland and other areas of outstanding natural beauty (see Fig. 1).

Oil was first discovered in the Harbour in 1974 in the Bridport Reservoir and has been produced from a gathering station on Wytch Heath. Crude oil has been transferred via a pipeline to a rail terminal at Furzebrook; liquified petroleum gas (LPG) is exported from the gathering station by road tanker, and gas piped into the British Gas network. The deeper Sherwood Reservoir was discovered in 1978 but not fully appraised at that time (see Fig. 2).

In 1984 BP Exploration announced plans to develop the oilfield with new wellsites, expanded process plant and new export facilities. A full Environmental Impact Assessment was carried out by them, this being their policy for all major developments where significant environmental issues are involved.

Appraisal drilling on Furzey Island

Initially, planning permission was sought to carry out appraisal drilling from Furzey Island, which is within Poole Harbour and in BP's ownership. The purpose of this was to provide more information about the reservoirs to enable the requirements of the whole development to be better defined. Permission was granted subject to detailed conditions, among them specific limitations on noise, including proving tests to show that the noise limits (as measured on the adjacent Brownsea Island) could be met before drilling was allowed to proceed.

A permanent noise monitor was installed on Brownsea Island and noise levels continuously recorded throughout the drilling programme.

When the first appraisal well was finished an Environmental Review

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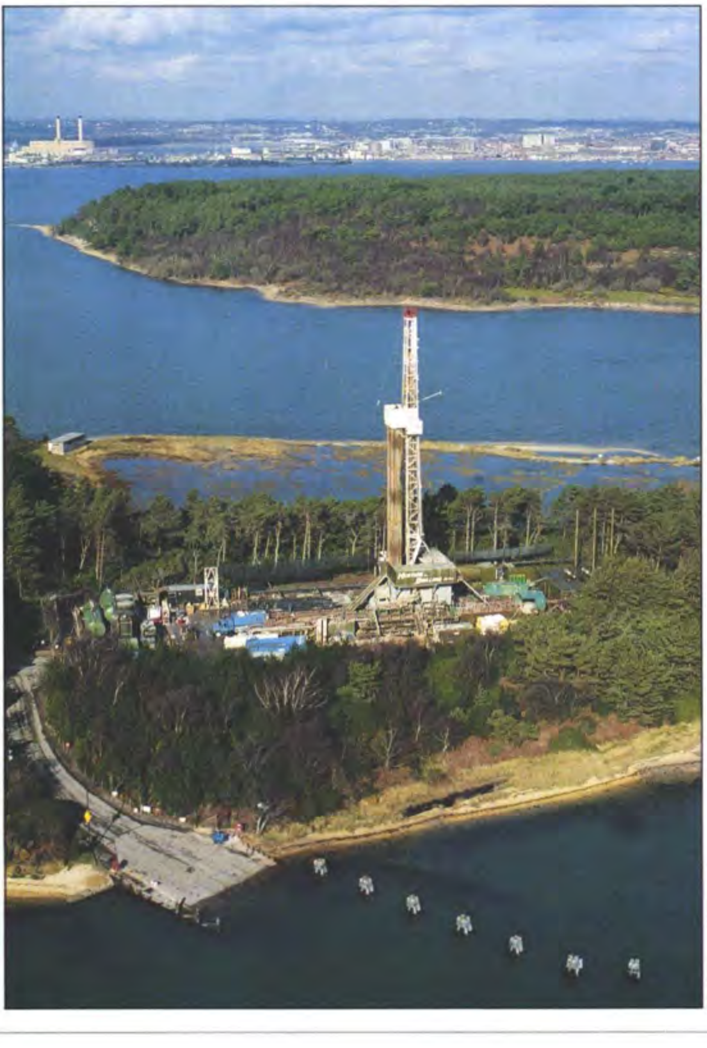

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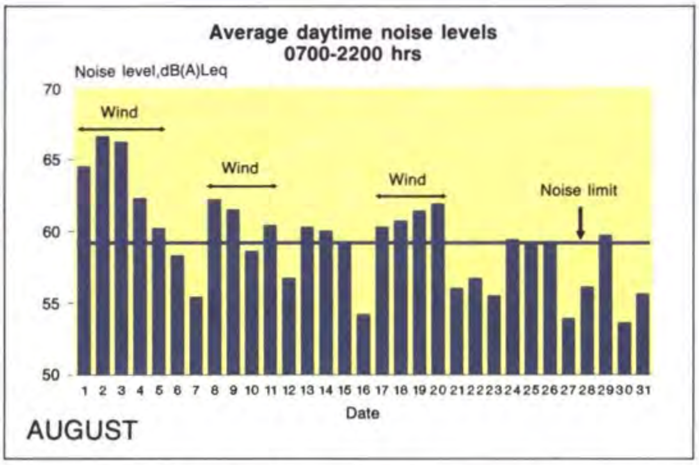


1. Plan of oilfield.
2. The Bridport and Sherwood Reservoirs.
3. Drilling rig on 'L' site.
4. Noise monitoring station.
5. Histogram of noise output.
6. Gathering station under construction.

was carried out to assess the validity of the original Assessment. The results from the noise monitor confirmed the original predictions and the acceptability of the noise levels in the surrounding environment. Difficulties were encountered with the measurements, however, due to the lack of power supply for the equipment, access being only by boat, and the noise levels monitored often being below the ambient noise from wind in trees, waves on the shore and birdsong.

The early appraisal exercise proved useful in the development of a reliable automatic monitoring system, gaining the confidence of the planners and community and providing technical data for use in the assessment of the main development.

Automatic noise monitoring

The lessons learned from the appraisal drilling led to the view that noise monitoring for the production drilling would be better carried out under controlled conditions closer to the source of noise. Four activities on Furzey Island were covered by numerical noise limits: 40dB(A)L_{eq} between 2200 and 0700 hrs and 45dB(A)L_{eq} between 0700 and 2200 hrs when measured at St. Mark's Lodge on Brownsea Island. BP had therefore to agree with the planning authorities on equivalent noise levels at an alternative monitoring position on Furzey Island itself for each of the key activities: drilling on 'L' site (see Fig. 3), drilling on 'K' site and horizontal drilling for the island-to-shore flowlines. The latter technique is an interesting one, consisting of drilling a pilot hole from Furzey Island at a shallow angle under the sea bed using directional drilling techniques, to the surface on the mainland more than a mile away. The previously prepared pipe bundle is then attached to a reaming bit at the end of the drill string and the whole assembly pulled back through the pilot hole to connect the island to the shore. This was one of the most difficult crossings in terms of the complexity and distances involved that had ever been made using this technique and pullback under load had to be completed in a single continuous pull.

The monitoring equipment comprised a microphone, wind speed and direction indicators at a remote shoreline location, with cables leading back to a small hut on the wellsite where the processed data was dumped in the form of three-minute average samples onto a data logger (see Fig. 4). BP personnel collected the tapes at two weekly intervals for analysis at their Sunbury Research Centre and onward transmittal to Arup Acoustics for interpretation. Tape collection proved an unpopular task since the hut had been inadvertently located next to a nest of wood ants!

Quarterly and annual noise monitoring reports were prepared by Arup Acoustics for the duration of these activities, concluding at the end of last year. The windspeed and direction data were incorporated to determine which wind-induced noise affected readings and also to assist in identifying the direction from which noises were coming. A sample output format for the noise data is shown in Fig. 5.

Environmental management

As part of BP's environmental commitment, a team of environmental inspectors has been employed on the development to deal with all such matters as they arise. Arup Acoustics showed them how to use sound measuring equipment techniques, and in addition to looking after the automatic noise monitoring equipment they have been undertaking measurements regularly on all aspects of the development. A standard survey format was discussed, and survey sheets collated and sent to Arup Acoustics for interpretation and comment. This has provided valuable data on noise from construction activities, support information for response to any complaints and a database for future developments.

In practice, considering the size and location of the development, there have been few noise problems. Development of trained personnel in the field has certainly helped to identify and resolve any such noise issues as soon as they arise.

Project status

Commissioning of the main gathering station is imminent, with start-up due this summer. The planning consents also contained numerical noise limits for operation of the gathering station and the water pumping station at Cleavel Point, on the southern shore of Poole Harbour.

Design of the gathering station (see Fig. 6) has been a rigorous challenge since the allowable noise output is the same as the original process plant — half the physical size and $^1/_{10}$ of the throughput. Foster Wheeler Energy has been responsible for the design and procurement of this equipment to meet the noise limits.

In parallel with the development of the known oil reserves, exploration has continued both onshore in Dorset and immediately offshore in Bournemouth Bay. Onshore drilling has been subject to similar noise limits and these have proved extremely onerous to meet at some locations. Whilst all onshore drilling rigs have been fitted with high standards of noise control, careful selection has been necessary at critical locations. Additional on-site screening has been provided, normally plywood barrier fences, on a number of these sites.

We are currently carrying out a study of work over rigs for use on a critical drillsite and evaluating noise from well test equipment and flaring.

The future

Noise from commissioning and production has still to be evaluated before it can be said that the project has been entirely successful. Events have already overtaken the original development proposals with additional oil discoveries. BP still face considerable environmental challenges, not the least of which will be the means of winning the oil from the known reserves beneath Poole Bay and tying in future production from these wells to the main development.

Credits

Client:
BP Petroleum Development Ltd.
Photos:
Silson Photography

Alexandra Palace renovation Phase I: acoustic consultancy

Introduction
In a major fire in summer 1980, a large part of the Victorian Alexandra Palace in North London was severely damaged. The Great Hall, the venue of many historic events, including recitals of considerable repute on the renowned Willis Organ, was destroyed. The massive walls for the most part remained, but the roof and interior were lost. The rebuilding of the Palace is being tackled in several phases, the first of which includes the Great Hall and the west end of the building. Arup Acoustics became acoustic advisors. The task of the Alexandra Palace Development Team was expanded to include the rebuilding of the fire-damaged areas. This included a new arrangement for the Great Hall, developed around a brief for its primary function as an exhibition hall, but with capacity for other uses. A clear spanning roof was to replace the previous structure, which had relied on a pair of colonnades to limit the span.

The Great Hall
The Great Hall is 118m long and 56m wide. The new roof section (Fig. 1) has a height close to 30m along the central axis. The volume of the hall including the coupled volume above the lightweight ceiling is approximately 150 000m^3, with capacity for 5000 people.

Records of measurements of reverberation time in the Great Hall before the fire of 1980 indicated mid-frequency values exceeding 6 sec. (unoccupied). Although highly responsive for organ recitals, this reverberation had proved very limiting for other activities needing less 'bloom' on the sound. In the new Hall, exhibition requirements suggested substantially reduced reverberation time targets. A value of 2 sec. or less would be ideal for exhibition use, but a wish remained to allow for musical events and occasional organ recitals. Two other factors influenced the choice of values, the first being the substantial cost of the extensive acoustic treatment which would be necessary to achieve ideal conditions for exhibitions. Secondly, there was the opportunity to develop effective public address signals within a live acoustic. Arup Acoustics have particular expertise in achieving high speech intelligibility in very reverberant spaces, arising in part from recent experience of cathedral sound systems. Reverberation time at mid-frequencies was designed to fall in the range 3.5-4.5 sec.

Acoustic treatment to roof soffit
The interior design for the Great Hall offered little scope for acoustic treatment to walls. Limited areas of absorptive material were integrated into the formal pattern of the wall elevations but most attention needed to be at high level in the form of ceiling or roof soffit treatment. A major feature of the interior design was the use of daylight from the roof. A separate ceiling was at one stage in doubt and it was necessary to find ways of introducing absorption at the roof soffit without a significant conflict with daylighting. A series of panels was designed to fix to the framing of the glazing, hanging down to form linear baffles running at an angle with the slope of the roof. Simple aluminium framework contained mineral wool slabs faced in a white weave to achieve high light reflectivity (see Fig. 2). This treatment was extremely cost-effective, exposing both sides of the panels to sound, much like the suspended baffle absorbers often used in noisy industrial workshops.

△ 1. Axial view of Great Hall (Photo: Peter Mackinven).

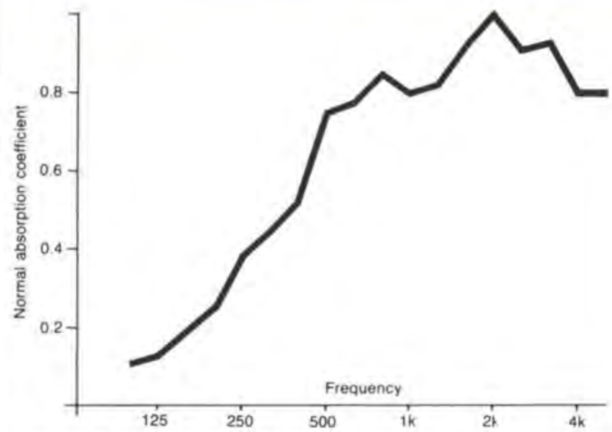
△ 2. Suspended absorbers and ▽ 3. ceiling (Photos: Arup Acoustics).

Lightweight fabric ceiling
The architects proposed the use of a lightweight structural fabric suspended ceiling, with substantial light transmission (Fig. 3). Previous experience of the acoustic performance of structural fabrics (including work with Arups' Lightweight Structures Group) indicated three possible consequences. Firstly, if it was unperforated, most high frequency sound would be reflected. Long reverberation at mid/high frequencies was undesirable and absorption of sound in the air was helpful only at very high frequencies. Elements of concave curvature in the ceiling form might also have resulted in underside sound focusing. The fabric takes up a two-way curvature, part concave, part convex, limiting the potential for focusing. Nevertheless, an unperforated construction was unwelcome.

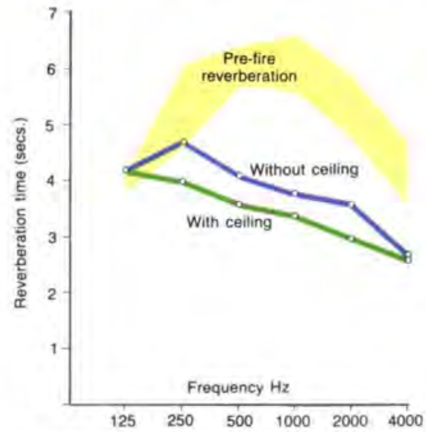
The second possibility was an acoustically transparent arrangement with sufficient perforation to allow the sound to pass to the upper volume for absorption by the powerfully absorptive baffles, the preference from an acoustic viewpoint.

The third option was an interim condition whereby with controlled porosity, broadband absorption (approximately 50%) could be obtained. The relative benefits of the upper baffle absorption and the inner liner absorption could be reviewed if this option was followed.

The quality of light transmission was a major influence on the choice of fabric: very open fabric would give too clear a view of the various elements above the ceiling, whilst fabric strength and the effects of air movement were other considerations. There was also concern that variations in coating geometry might adversely affect the controlled porosity option. Small samples of fabrics (proposed as suitable for non-acoustic purposes) were subjected to normal incidence absorption tests in an impedance tube, those reasonably transparent to sound at mid-frequencies being preferred. To avoid too much vision through the fabric, some high frequency reflection (<20% above 2kHz) was accepted (Fig. 4).

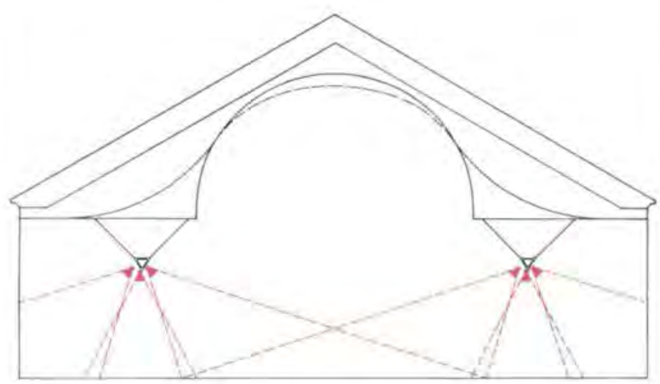


4. Sound absorption at lightweight fabric.



5. Measured reverberation times in the Great Hall.

On completion, measurement of reverberation time (unoccupied) demonstrated that target conditions had been achieved (see Fig. 5). Fund-raising for rebuilding of the Willis Organ enabled a small (first stage) organ to be set on a new organ platform. The natural acoustic has proved to be appropriate for a wide range of uses including choral music, school examinations, exhibitions, and sporting events.



6. Loudspeaker coverage, Great Hall section.

Public address

The intelligibility of speech from the public address system in such a 'live' acoustic depends upon:

(1) Direction of sound onto the listening zones, with minimum unnecessary dispersion from the source to excite the reverberant response of the hall.

(2) Reflection of any sound from unoccupied hard floor surfaces towards absorptive material (in this case the ceiling), again to reduce excitation of reverberation.

(3) Careful alignment of elements of loudspeaker arrays to avoid coloration caused by phase interference.

(4) Appropriate quality of specification for the system components.

Constant directivity horns (*Altec* units were selected) are suspended from two lighting and servicing gantries which run the length of the Hall. By careful orientation of the horns, sound projection is arranged to cover the flat floor condition and perimeter raked seating (see Fig. 6). There is sufficient vertical emphasis to the distribution for floor reflections to be directed back up to absorptive treatment at high level, thereby limiting excitation of lateral reverberation. A wall-mounted system or a central cluster would have enhanced reverberation and resulted in uneven coverage and substantial interference by exhibition stand screening.

Low frequency units operate in tandem with the horns, through an active crossover to extend the system frequency response and provide high quality music reproduction. When only part of the Great Hall is in use, selected circuits may be switched out. Mimic panels at the control panel are arranged to give a quick visual picture of the circuits in use. Control is from the Hallmaster's Panel, although local control for a fixed coverage pattern can be arranged via microphone panels in the Hall. An audio induction loop (for hard-of-hearing listeners) is installed within the floor void.

Automatic noise sensing is included to allow compensation for occupational sound levels.

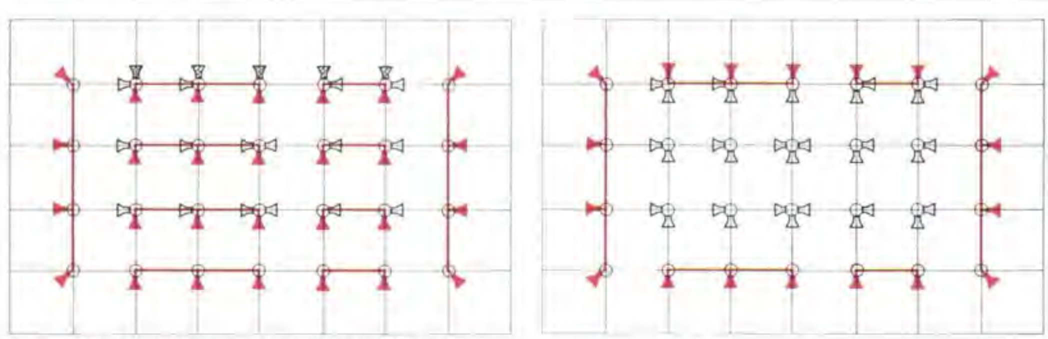
The Great Hall PA system forms part of a 12-zone installation for the Palace Redevelopment Phase I. The overall strategy allows for a cascading priority system with fireman's override (Priority 1), security control (Priority 2), Hallmaster's control (Priority 3) and local control (Priority 4). The priorities, zones, loops, variety of loudspeaker arrays, noise sensing and switching make the Palace system one of the more sophisticated of recent installations.

Reliability and the required emphasis on priority for fire control are also key characteristics.

The system provides clear intelligible speech throughout.

West Hall

The West Hall is a simple rectangular space (63m × 43m × 12m high), formed by roofing over what were the Italian Gardens in the West Court. A new metal deck roof was constructed with sound insulating smoke vents set into it (the sound insulation being required to control disturbance to adjacent users by occupational sound leakage). The perforated roof soffit is designed as a broadband sound absorber. The mid-frequency reverberation time of the Hall is close to 3 sec. (unoccupied). Without an absorbent roof, this value was expected to exceed 4.5 sec. Again the PA system provides for sound coverage from overhead, this time using Philips column loudspeakers set amongst the open roof structure. These achieved controlled coverage more easily than with horns, due to the limited height and the intended use of temporary raked seating. By system switching, coverage can deal with an arena format and various conditions of distribution from a side wall stage location (see Fig. 7). Audio induction aid loops and local input were again allowed for.



7. Examples of loudspeaker switching, West Hall (plans).

Palm Court

The Palm Court is an exceptionally live space with large areas of glazed roofing, and no significant areas of sound absorption. Two particularly interesting aspects of the acoustic design are of note. Firstly, the public address system needed to have minimum total output (to avoid exciting reverberation) but be adequate for listeners. By directing sound from a large number (26) of *TOA TZ301* columns, coverage was controlled and excitation of reverberation minimized. The Palm Court has fountains, the noise from which might have disturbed the West Hall, so guidance was given by Arup Acoustics to limit the sound power by restriction of water drop heights and conditions of water entry into the pools. The Alexandra Palace project provided an opportunity to apply experience of room acoustics and sound system design in an integrated fashion to the overall benefit of the listener. The PA system design has allowed a 'live' acoustic to work well and the Arup role in the control of the room acoustics has allowed the effective deployment of funds for the public address system.

Credits

Client:
London Borough of Haringey

Architects & Engineers:
The Alexandra Palace Development Team

MARINA LOCK WORK

Paul Lacey

General

Water levels in marinas and basins have to be controlled for many reasons, particularly where a large tidal range occurs. Some of these objectives and constraints, which will affect the selection and control of water levels, are as follows:

- Maintenance of sufficient depths for moored boats
- Improved access to the marina for craft
- Amenity, safety and visual concerns
- Environmental interests
- Flood protection from both sea and river
- Economic factors in marine structures and dredging
- Reduction of siltation
- Maintenance of water quality by provision of a barrier.

The control of water level involves the prevention or restriction of flow into and out of the marina. A simple fixed sill might be all that is required, but normally a moving structure is needed to maintain water levels whilst still allowing navigation.

In most marina projects, each feature must be justified in terms of its capital cost, operating and maintenance costs, and the benefits it brings either to the users of the marina or to others, including of course environmental gains. All possible options need to be looked at to determine the optimum range of water levels to be permitted in an impounded marina (i.e. one in which the water is entirely contained), taking into account relevant physical, environmental and financial factors.

Planning the water level regime inside a marina must take into account the depths outside it, which are controlled by seabed level (which can be altered) and by tide levels (which cannot). The size of marina and intensity of boat traffic are also important; normally only large marinas can justify the provision of a lock.

This article looks briefly at three marina projects with which Arups have been involved: the Port Pendennis Harbour in Falmouth, Cornwall; The Crumbles Harbour Village, Eastbourne; and Salford Docks. Fig. 1 shows in schematic form the water level arrangements made for each.

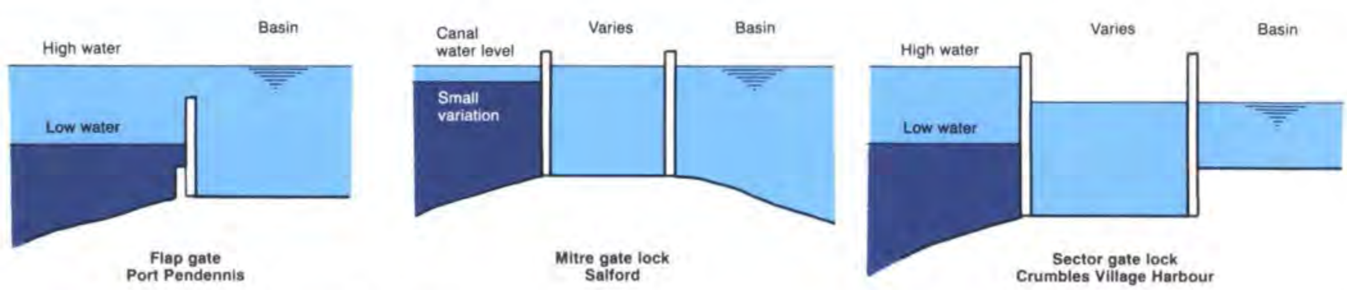
The approach channel depth is the key factor affecting access to the marina. Nothing is achieved by setting the level of the marina entrance deeper than the approach channel level. The 'tidal window' when the marina can be entered will be equal to or less than the window when the access channel is deep enough, the precise time depending on the type of control structure at the marina entrance. Periods of free access associated with various types of lock are shown on Fig. 2.

Many marinas are now of the 'marina village' type, and have housing around much of their perimeters. This type is much more attractive if the tidal range within the marina is less than about 1m, with houses and gardens very close to the water. A small tidal range also reduces the need for floating pontoons. A large drop from quaysides to the latter is not a safe feature where houses surround a marina, although of course precautions would have to be taken to keep children out of the water, whether it was tidal or static.

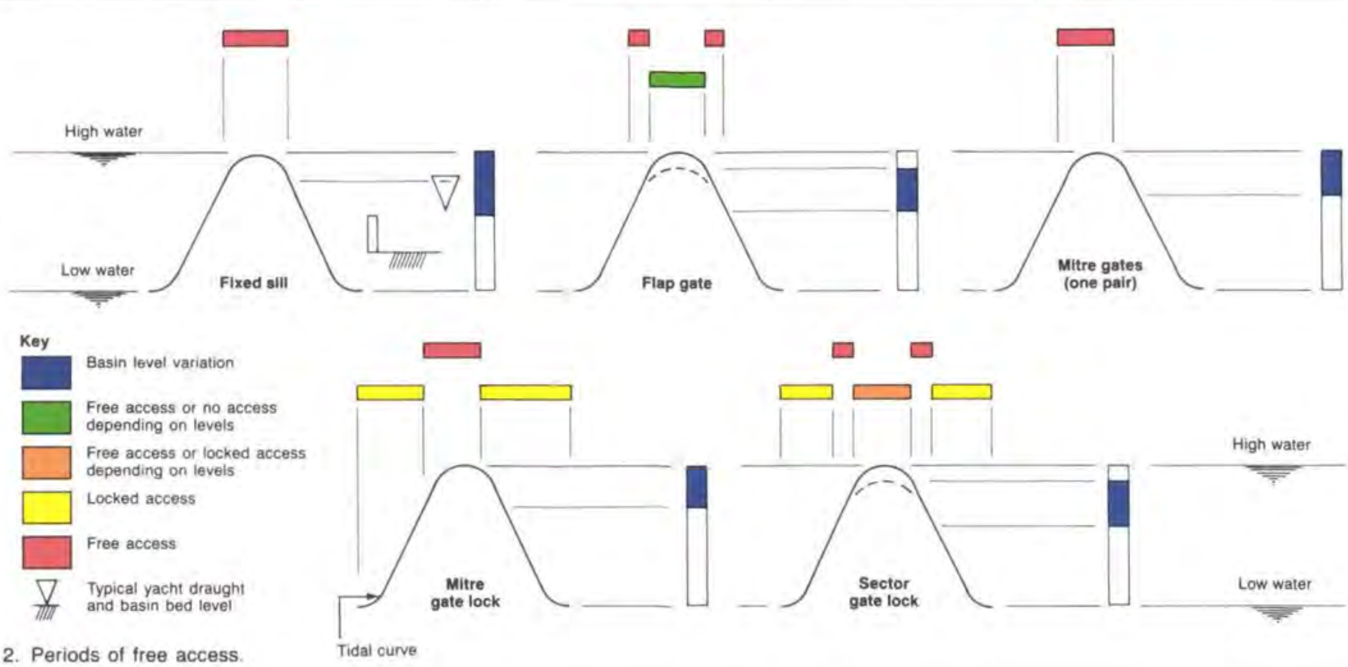
An impounded marina generally requires construction of enclosing breakwater bunds, which can provide improved protection against flooding due to high tides, surges and waves. This is important in areas vulnerable to flooding, and government grants can be made available to fund such protection.

Maintaining a constant water level inside a marina means that to provide a given water depth, the quay wall structures can be built to a minimum overall height equal to water depth plus free-board (the distance between a boat's deck and the water level). If the water level varies, then the height of the quay walls will be increased by the amount of the variation. Re-use of existing dock basins generally fixes the water level relative to the existing quay edge coping level.

The lack of strong water movements inside a dredged tidal marina can result in sedimentation, which is a costly problem. A large inflow of silty water on every tide can be substantially reduced by impounding the marina; water and silt inflows then being limited to the flows arising from use of the lock. A small flow of water is essential through a marina to maintain water quality, which generally requires a limited variation of water level either tidally or at least for several days every fortnight during spring tide periods. How often the water in the marina should change depends on the quality of the sea-water, and of any freshwater inflows (streams, etc.), as well as the presence of biological matter in the seabed, which can lead to problems of de-oxygenation of the water. Yachts can be a major source of contamination, which must be minimized by regulation and also by the provision of good, convenient lavatory and waste facilities throughout the marina.



1. Schematic water level arrangements for projects.



2. Periods of free access.

Table 1: Water level control in marinas (after S. de Turbeville and P.D. Hunter 1989[1]).

Control structure	Water level regime	Advantages	Disadvantages	Suitability	Cost indication[1]
Lock with sector gates	Fixed (or within narrow range)	Entrance at all times (subject to access channels) Provides flood protection	Generally needs operators Uses water from marina	Shallow site Deep tidal channel Large marinas	1.0 (0.8) [2]
Dock gate (single or single pair of gates)	Tidal only while gate is open	Provides flood protection	Restricted entering periods Needs operator Needs power supply	Acceptance of restricted entering times	0.6
Rising sill	Tidal while still submerged	No operator needed No power supply needed	Restricted entry periods	Acceptance of restricted entering times	0.4
Fixed sill [3]	Tidal while still submerged	Very simple Maintenance-free	Long periods of restricted entry	Acceptance of restricted entering times	0.2
None	Fully tidal	Ideal on suitable site	Possible large level variation	Low tidal range or very deep site.	—

To give some idea of the advantages, disadvantages, suitability, and costs of the various water level control methods described, the essential facts are given in Table 1.

Much effort is required to assess the water level requirements which can achieve the boat usage criteria together with capital and operating costs which are within acceptable limits.

Notes

1 The costs have been expressed as a proportion of the cost of a lock with sector gates. That cost at mid-1989 prices, for a lock 40m long, 8m wide and 6m deep, would be approximately £1 500 000.

2 Cost indication for a lock with mitre gates.

3 Estimates are based on a common entrance width; in practice the optimum width for sills may be greater than for locks or gates.

Salford Docks

This project has been the subject of several papers presented in *The Arup Journal* [2] and the *Proceedings of the Institution of Civil Engineers* [3]. The need for gates has arisen for two reasons:

(1) To protect the retained water basins from the grossly polluted Manchester Ship Canal, and

(2) To allow pleasure boat access (this latter requirement envisaged the Canal being cleaned up sufficiently for pleasure cruising).

These two needs made a lock arrangement essential, in that although the Salford Quays basin water level was almost static, the outside canal water level fluctuated as stormwater input was regulated by opening lock gates along its length.

The solution was to provide two sets of mitre gates in a classic pleasure canal layout, the difference being the size of the gates and the design requirement for the gates to take a reverse head: a somewhat unusual requirement for mitre gates. The layout is shown in Fig. 3 and the gates under construction in Fig. 4. Due to the advent of environmental impact study requirements, water quality behind locked basin systems or within basins with restricted access has become an important issue.

3. Salford Dock layout

4. Lock gate under construction at Salford

(Photos: Ove Arup & Partners)

Port Pendennis, Falmouth

The marinas we have designed vary from the small 60 to 80 berth size up to the 2000 berth village harbour marina. Port Pendennis Harbour Village at Falmouth was constructed for Land Leisure plc; the aerial layout is shown on Fig. 5. The main civil works are now complete at a cost of £4.5M.

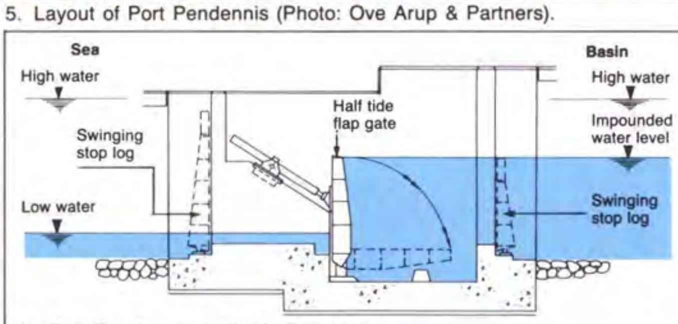
Port Pendennis has been constructed on what was semi-derelict land adjacent to Falmouth's commercial docks. The project consists of land reclamation, dredging and construction of a 65-berth locked marina to be enclosed by a development of 200 residential units.

Ove Arup & Partners, through the Bristol Office, were commissioned to design the land reclamation and marina basin that formed the centre of the complex. This was created by dredging 10 000m^3 of unsuitable material from the shoreline and retaining 35 000m^3 of imported fill behind 10 000m^2 of anchored steel sheet piling. A study of the likely vessel traffic indicated that a 10m wide automatic half-tide flap gate would be required to retain a minimum water depth of 3m during all states of the tide. Provision has been made to maintain the water quality within the basin. The development also includes the provision of a launching ramp for the Royal National Lifeboat Institution, a dinghy park and an exhibition centre.

The maximum draught of the yachts likely to use the basin was taken to be 2m. The minimum retained water level inside is 3m (+0.35m OD to −2.65m OD), the extra 1m being allowed for siltation, dredging tolerance and wave action.

The tidal range is MHWS +2.39, MLWS −2.31, MHWN +1.29 and MLWN −1.01 OD (mean high and low water at spring and neap tides). The flap gate opens automatically as the rising tide approaches +0.35m OD, thus affording free passage of five hours per high tide during spring tides and two hours during neap tides. The gate is shown in Fig. 6. The restriction of access/exit during these times will provide minimum inconvenience to the permanently moored vessels, with a maximum capacity of 20 vessels per hour in either direction during peak traffic periods.

5. Layout of Port Pendennis (Photo: Ove Arup & Partners).



6. Port Pendennis: half tide flap gate.

Crumbles Harbour Village, Eastbourne

This, the largest marina in the United Kingdom, is situated on the South Coast and is being undertaken in the London Office. It is now under construction by Tarmac Construction Ltd.

The Eastbourne Harbour Act 1980 granted permission to construct a harbour and breakwaters. For several years the economic climate was unfavourable to such a project getting under way, but eventually outline planning permission for a comprehensive mixed use development and harbour works providing 3000 residences and berthing for 2000 yachts was given by Eastbourne Borough Council on 20 May 1988.

To protect the new outer harbour, two breakwaters totalling 410m in length are to be constructed. Beach improvement and replenishment will be carried out on the full 1.5km long boundary of the site, in accordance with an agreement reached with Southern Water Authority. Basic statistics convey some idea of the scale of the infrastructure works for this development. They are:

Outer and inner harbour

- 500 000m^3 of excavation
- 47 000m^2 of concrete block revetment
- 2200m^2 of rock rip-rap
- 42 000m^2 of plastic filter sheet
- 2600m of concrete step and retaining walls varying from 2m to 5m
- 50 tonne capacity shiplift
- 30m × 15m steel piled concrete slab jetty
- Twin locks with 45m × 15m barrels, 65m long between sector gates
- Three double bascule footbridges of 10m span (one capable of carrying emergency vehicles).

Roads

- 3750m of estate roads including road junctions of which nine are roundabouts, plus the provision of surface water drainage and street lighting.

Services

- Five foul water pumping stations ranging in capacity from 181 to 146 litres/sec.
- 4000m of pumping and gravity mains
- Provision of main gas, water, electricity and telephone.

Certain areas of the site were known to contain domestic rubbish dumped in the past. These were tested and the groundwater and refuse qualities monitored, so that methods for dealing with the problem could be produced for the client.

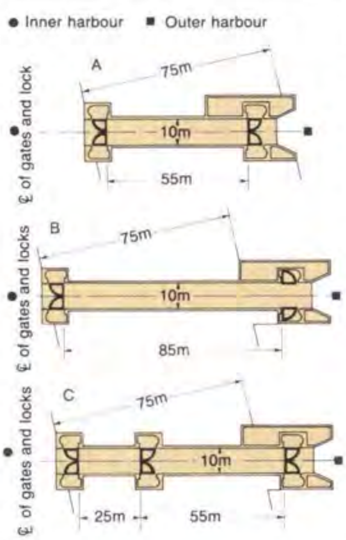
Up to the time of writing, 600m of the estate road have been constructed, together with one foul drainage pumping station, surface water drainage, road lighting, etc., out of a total civil works value of £30M.

Key:
A. Hotel for possibly 200-250 beds.
B. Area for fishing fleet (18 boats).
C. Customs, marine facilities, harbour master.
D. Double locks.
E. ASDA superstore.
F. Other large stores.
G. Parking for 1200 cars.
H. Recreation/shopping area with bars, bistro, boutiques and other shops.
I. Tent-shaped chandlery with boats for sale.
J. Green area for conservation purposes.
K. Shingle area for conservation purposes.
L. Martello tower for use as a conservation interpretation centre.
M. Public viewing area of construction work.

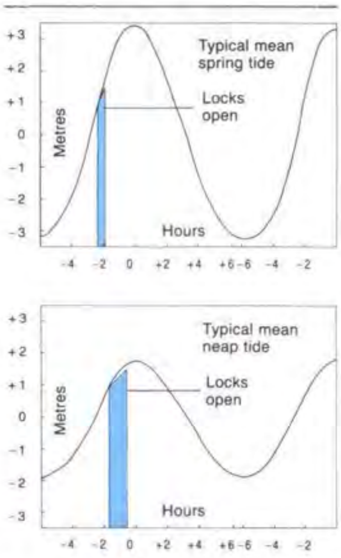
The entire site measures 1 mile × ½ mile. The houses are marked in red on the islands in the harbour.

7. Layout of Crumbles Harbour Village (Courtesy of the architect).

Much effort was spent on consideration of the Inner Lakes water level, and the number and size of the locks. With such large potential peak numbers needing access to the sea, large locks were the obvious choice, but the fact that construction was to be phased over several years meant that initially only one lock was needed.



8. Lock types A B and C



9. Tidal record showing possible free flow periods at the Crumbles.

The design throughput was based on the assumption that 1700 boats would be behind the lock in the basin, producing a maximum peak flow of 119 boats per hour.

It was decided that, apart from operating reasons, no free flow would be used unless sea water was needed for topping-up processes. The number of hours a free flow situation was possible is small (Fig. 9). Various configurations were assessed and the final lock layout was settled at two, with 65m between the sector gates and a main barrel clear width of 15m. The gate width access size was kept at 10m clear on economic grounds.

The assessment of the lake sizes and shapes indicated that the arrangement and configuration will have a major influence on the water quality. Experience also indicates that the greater the depth of water the better the quality.

The following parameters were used wherever possible:

(a) Minimum water depth in the lake system to be 5m.

(b) Maximum lake lengths and lake widths to be used, especially in the prevailing wind direction.

(c) All lakes linked and individual pond type areas avoided.

Surface water run-off from paved areas and especially roads is usually sufficiently contaminated to make direct discharge into the lake system or Inner Harbour unacceptable if good water quality is to be maintained. The operations of the lock, especially at peak boat movement times, will naturally affect the water regime of the Inner Harbour and the Lakes. The impounded water levels are taken to be a maximum of +1.5m OD and a minimum of +1.0m OD.

The tidal curve shown in Fig. 8 indicates that the majority of the profile is below +1.6m OD. This shows that during most locking operations water will eventually be lost to the sea. During the summer months this will be the case especially as the natural groundwater recharging will be at a minimum and, as would be expected, the peak lock usage is in the same season.

The impounded system could be recharged by two methods:

(1) Tidal replenishment using a controlled free flow system which will ultimately result in a mostly saline regime behind the lock.

(2) A pumping system which replaces the water losses from the Inner Harbour with water from the Outer Harbour.

Both methods allow saline intrusion. The overall effect can only be assessed by monitoring the impounded water and the groundwater systems over a considerable period. The impounded water may become unacceptably brackish, due to part saline or saline conditions, sufficient to affect the water quality and therefore the quality of the development.

A pumped water circulation, however, between the lock and Outer Harbour prevents the discharge of water from the Inner Harbour or lakes. This will allow the recharge of these areas by the natural groundwater, resulting in non-saline conditions in the lakes.

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Princes Quay Shopping Centre, Kingston-upon-Hull

Architect: Hugh Martin Partnership

Ken Knowles Andy Woodland

Introduction

In common with many other cities in the UK, the city centre docks in Kingston-upon-Hull have become progressively disused and available for redevelopment. In 1985 the Hull City Council held a limited competition for development proposals for Princes Dock, located in the heart of the city; although it had not been used as a dock for many years it was, nevertheless, still intact. Its status as a listed building was an indication of its quality, and a body of opinion in Hull wished to retain it as an open dock. The competition was won on the basis of a design by the Hugh Martin Partnership of Scotland as the architect and Ove Arup & Partners Scotland as consulting civil, structural, mechanical and electrical engineers. The client is Land Securities plc, in association with Balfour Beatty Developments Ltd. The development proposals put forward were for a multi-storey shopping centre to be constructed over the existing dock with shop-lined malls linking the centre to Carr Lane and Victoria Square. The design, elevated on piles above the water surface, avoided any requirement for large-scale transport of silt through the city centre and also went some way towards satisfying those who wished to preserve the dock intact. It is located between the two established shopping areas in Hull. Integrated with the shopping centre to give direct access to each shopping level is a multi-storey car park with space for some 1000 vehicles, the location of which is such that it will be very easily accessible from the dual carriageway in Castle Street which links directly with the M62 to the west.

The shopping centre has three retail floors with a fourth floor of leisure facilities above, all grouped around a central atrium. At the east side of the lowest shopping level there is a public terrace looking out over the existing dock and the attractive East Dockside buildings beyond. Above this level the structure is essentially a conventional steel frame. However, the geometrical complexity of the roof has required a substantial co-ordination exercise to reconcile all the requirements of building services together with cleaning and maintenance. The building is clad in glass and profiled metal sheeting. The car park is a reinforced concrete flat slab structure with recesses in the soffit to accommodate the lighting and maintain headroom. The light fittings themselves had to be specially manufactured to match the profile of the structure. The structural form is largely determined by the basic requirement that alternate levels match the main building floor levels, dictating a 2.5m floor-to-floor height.

The two malls linking the development to the city centre lead into the middle shopping level. The East Arcade is single-storey and spans across the dock water on circular concrete columns which are direct extensions of the piles under the water. The West Arcade runs overland and is linked to a multi-storey extension of the existing Allders department store. The development is also linked to land by the East Bridge which provides both pedestrian and fire engine access to the lowest deck level.

In addition to the main shopping centre development the project includes a major extension to the existing Ferens Art Gallery, restoration of the only remaining original dock warehouse, and a footbridge over Castle Street. We have also been involved in making recommendations for the control of the level and quality of the water in the dock.

1. Competition model.

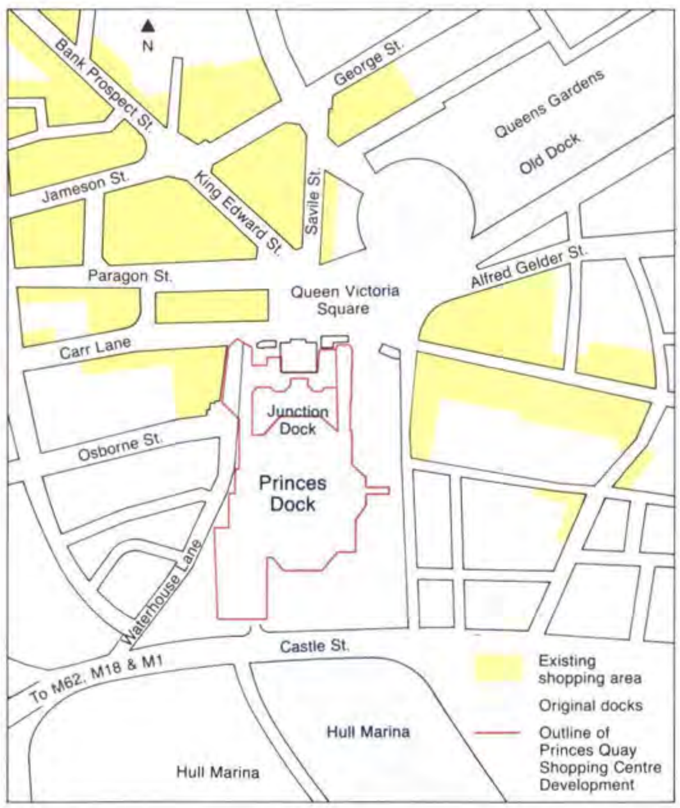
Historical background

In common with redevelopments of other former dock sites, a detailed knowledge of the form and dimensions of the dock walls and foundations of quayside buildings is crucial if expensive delays and special measures to deal with unforeseen obstructions are to be avoided. At an early stage in the design of Princes Quay, the usual sources of historical information were researched and we were fortunate to locate several technical papers about Hull's Docks.

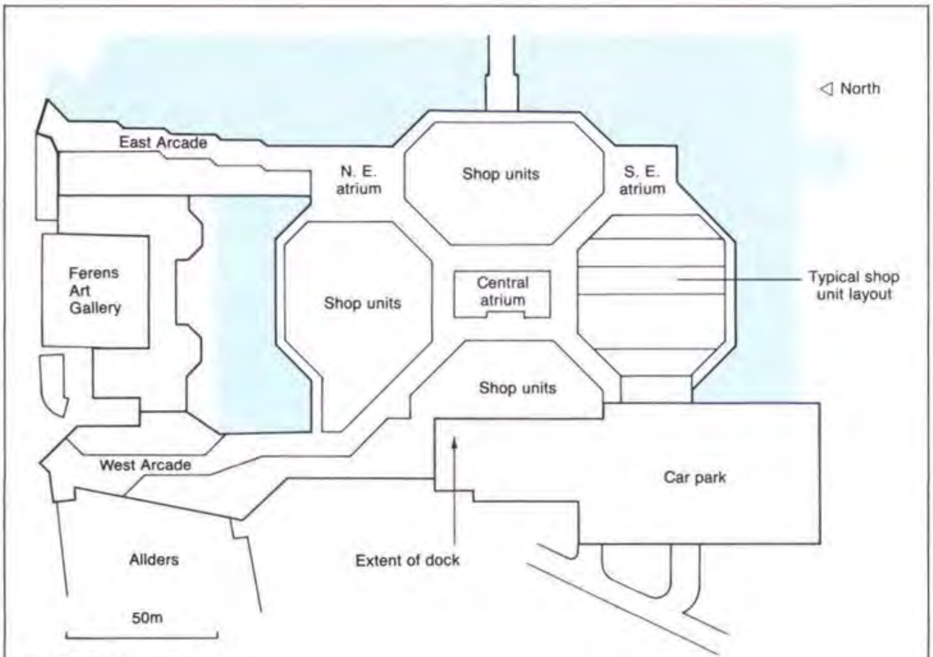
The most important of these, 'An Account of the Harbour and Docks at Kingston-upon-Hull' is in Volume 1 of the *Transactions (Proceedings) of the Institution of Civil Engineers,* dated 1836. The paper contains authoritative detailed information about the Docks, written by John Timperley who was resident engineer for the Hull Dock Company from 1827 and was awarded the inaugural Telford Gold Medal.

Princes Dock, originally called Junction Dock, was constructed between 1826 and 1829 at a cost of £165 000, and was the last of three docks connecting the Rivers Hull and Humber outside the line of the Town Wall and 'Town Ditches' around Kingston-upon-

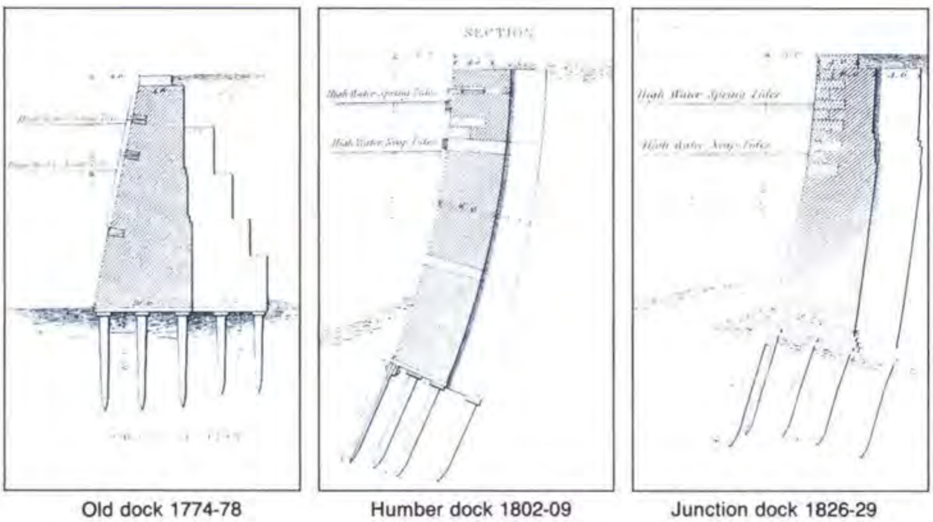
2. Historical plan (from Timperley's paper in the *ICE Transactions,* Vol. 1 (1836)).



3. Location plan.



4. Development plan.



5. Dock wall sections (after Timperley).

Hull. Old Dock was infilled many years ago to become Victoria Gardens whilst Humber Dock is now a marina. The engineer for Junction Dock was James Walker who had previously worked on the East and West India Docks in London. His design of the dock wall was developed from experience with Old Dock and Humber Dock, where failures had occurred, and it received the approval of Thomas Telford himself in 1826. Generally, the construction proceeded without serious mishap and it is reported that 'Walker's respect for the variable nature of the ground was well developed; he had pile-driving records kept to enable softer areas to be identified and the foundation design adjusted accordingly', although Timperley astutely observed that: 'Much irregularity prevails in pile-driving; sometimes a pile will go down at the last stroke more than it did at the third or fourth, though the fall of the ram and the density of the ground may be nearly the same, and the friction of course greater. Hence we perceive how uncertain all theories must be which profess to ascertain the actual weight a pile will bear, by having given the weight of the ram, the fall, and the depth driven at a stroke'.

Foundations

The design and construction of the piled foundations to support loads of up to 8000kN were a particular challenge due to the constraints of working over water, in conjunction with the poor ground conditions prevailing in the area.

The site is underlain by more than 15m of soft clay and loose sand (alluvium), an intermittent peat layer below −15m OD, glacial sand and gravel (absent in the north) and glacial till, overlying Upper Chalk of Cretaceous age. Up to 4m of silt had accumulated in the dock before closure, whilst up to 5m of fill existed behind the dock walls beneath the quays.

Steel or precast concrete driven piles were considered but were rejected due to noise and vibration considerations, particularly in respect of the adjacent housing and the dock wall, which is a listed structure.

Bored piles, socketed up to 9m into the hard chalk, were therefore designed. Single piles per column, up to 1.2m diameter, were adopted in the dock and it was envisaged at pre-tender stage that all piles would be conventionally augered, under bentonite. However, the successful piling sub-contractor proposed innovative construction techniques both for the piles in the dock and also those on the quayside.

The dock piles were constructed from floating pontoons. A permanent casing was first installed into the top of the chalk by high frequency vibrator. The pile was then bored under water using a *Wirth* drill, the spoil being removed by reverse circulation through the hollow drill stem. Reinforcement was placed, the pile socket was cleaned by air lifting, and the pile was concreted by direct pumping through a 100mm diameter tremie tube. Each pile typically took two working days to complete. The integrity of every pile was checked by sonic coring via access tubes attached to the reinforcement cage.

A trial pile had been previously constructed and load-tested on the quayside. This performed extremely well under load and the design rock socket length was reduced for the contract piles. The combination of reverse circulation water flush drilling and air-lifting resulted in a very clean rock socket, entirely free of remoulded putty chalk.

Progress was relatively slow at the start of the contract due to relatively small objects, buried in dock silt, being driven into the soft ground by the vibrated casings until stiffer soils were reached and further casing penetration was prevented. Divers went down to remove the offending objects, such as pieces of wire rope, a bent ship's lantern, wellington boots, a parking meter, etc., all artistically drawn in detail on the divers' reports.

The piles on the quayside were constructed by continuous flight auger (CFA) methods. Because of the required pile lengths, in excess of 30m, the piling contractor imported a very impressive, brand new, rig from Holland capable of installing piles at diameters of 0.75m and 0.9m, to depths of up to 38m. At our requirement, instrumentation and data loggers were installed to monitor all aspects of the boring and concreting process, and proved very reliable.

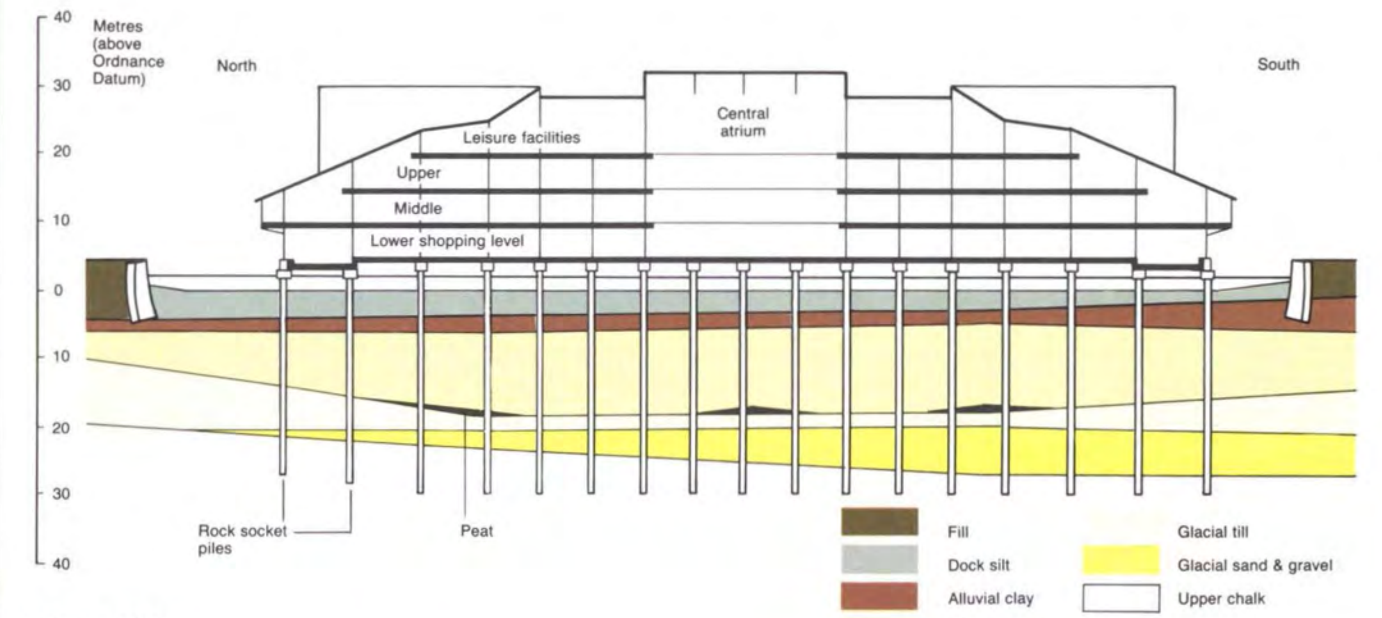
The power of the machine was sufficient to bore a pile in 30 minutes, with no significant loss of penetration rate in the hard chalk. The longest pile was 35m and is believed to be the longest CFA pile ever constructed in the UK.

Lower deck design

The development of the structural concept for the lower deck over the water presented the greatest engineering challenge, particularly in relation to construction. We adopted simple objectives such as minimum alterations to the existing dock, which ruled out infilling to form a working platform; adequate durability, since the deck is exposed to marine conditions; and, not least, ease of construction, given the relatively unusual requirements of building over water. A system of prestressed concrete beams and slabs spanning onto pile caps constructed on the individual large diameter piles was adopted as best meeting those criteria. It was not clear at that stage whether the lifting into place of the beams would be done by dock-based plant or cranes sited on the already constructed deck or indeed whether the piling equipment itself might be supported from the partially-constructed deck.

There were other constraints on the deck design. The level of the lowest deck was fixed by the maximum acceptable gradient of the East Arcade heading into the shopping centre. It was undesirable, if water quality was to be maintained, to lower significantly the level of the water because extensive silting of the dock had already reduced the water depth.

The combination of these constraints meant that the spans had to be limited to control the depth of the beams. Deep beams would have been partially submerged preventing air circulation below the deck and giving rise to concerns about durability. Where the lower deck crossed the existing west quay wall, a 10m span was unavoidable and therefore this was adopted as the maximum span. By permanently lowering the water level by about 200mm it became possible to design



6. Cross-section.

7▽

7. Dock piling in progress.
8. Continuous flight auger rig.
9. Rock drill head.
10. Pile cap construction.
11. Lower deck construction.

Photos: Ove Arup & Partners except where otherwise credited.

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10▽

11 ▷

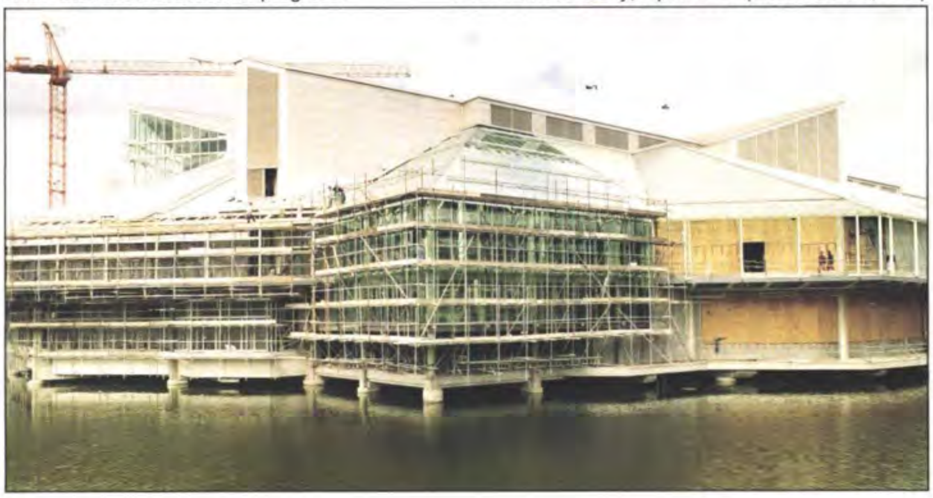
a precast scheme for 7.5m and 10m spans and still maintain a minimum clearance between the water and the lowest precast beam soffit of a nominal 100mm. This was considered to be the minimum acceptable when wave height, air circulation and storm-water run-off were taken into account.

Temporary lowering of the dock water level was restricted to a maximum of 1m, both by the need to safeguard the stability of the quay walls and the draught requirements of floating piling plant. It would not be economic to strengthen the deck sufficiently to support the piling equipment. Pile caps had therefore to be constructed partly below water level.

Despite the apparent obvious advantages of the precast scheme, it was decided to re-examine the possibility of constructing an in situ flat slab reinforced concrete deck which eliminated the need for pile-caps. In conjunction with the contractor a scheme was developed for suspending the formwork by wire hangers from a framework above the deck. Following casting of one section of slab, the formwork could be dropped onto floating pontoons and towed into position for the next bay.

This in situ scheme, as well as the precast scheme was put out to tender by the main contractor. The result of the tender was that the precast scheme proved cheaper, particularly since the successful piling contractor offered to join forces with the lower deck sub-contractor to erect the deck using the floating plant already mobilized for the piling. The construction sequences for the piles and lower deck were tightly linked.

△12. Steelwork erection in progress.



▽13. Princes Quay, April 1990 (Aaron Studio, Hull)

Building services

In the building services design, special care was given to the external lighting effect, especially from the old dockside nearby. Inside the building, smoke ventilation posed a particular challenge, solved by the use of roof-mounted hydraulic flaps as a non-mechanical smoke exhaust. These also act as a cooling device, drawing fresh air from the arcades out through the roof in a natural chimney effect, jointly with a mechanical smoke extract at roof level.

Conclusion

The creation of a retail development built on an architectural concept which relates to the surroundings whilst preserving the existing dock presented our Scottish team with an engineering challenge which we have enjoyed. Work started on site in April 1988 and the centre will be opened within three years of this date.

Credits

Client:
Land Securities plc, *in conjunction with* Teesland and Balfour Beatty Developments Ltd.

Architect:
Hugh Martin Partnership

Structural, civil & services engineers:
Ove Arup & Partners Scotland

Quantity surveyors:
CBA

Project managers:
Project Management Services *and* Balfour Beatty Developments

Main contractor:
Balfour Beatty Building

In the Autumn 1990 edition of The Arup Journal

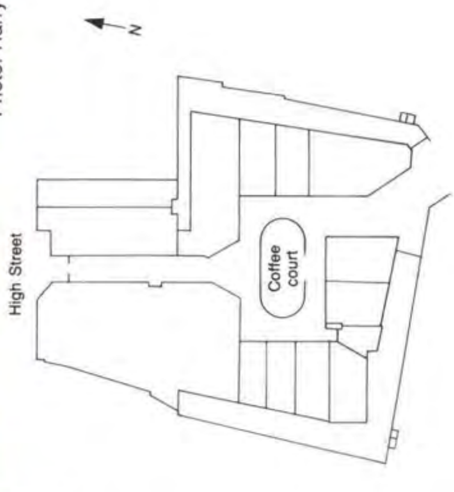
M. Sekiya

Bari Football Stadium

KING'S SHADE WALK

Architect:
Renton Howard Wood Levin Partnership

Photo: Harry Sowden



Site plan.

Roger Olsen

Introduction

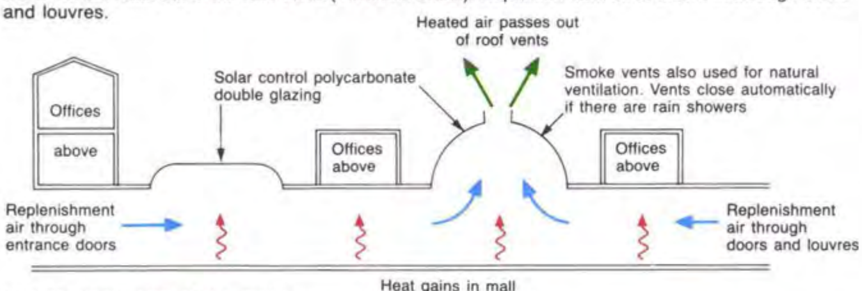
King's Shade Walk is in Epsom High Street, and was originally a small 1950s shopping arcade, built largely around an open courtyard. (It was built on the site of a pub of the same name, and according to local tradition the 'King's Shade' was the ghost of Charles I.) The arcade has been refurbished, with the courtyard roofed over, and it now forms a link from the High Street through to the Ashley Centre (another Arup job) which was completed in 1986. A number of offices on the first floor were also refurbished.

Planning permission was initially turned down because of concern about roofing over the courtyard. The local authority thought that the roof would be detrimental to its character, and that it would become a 'greenhouse'.

Planning permission was finally granted, and the refurbishment proceeded, with five shops trading throughout the construction period. It was completed in 1989 at a cost of £2M, and after completion the Planning Department had no reservations about the scheme:

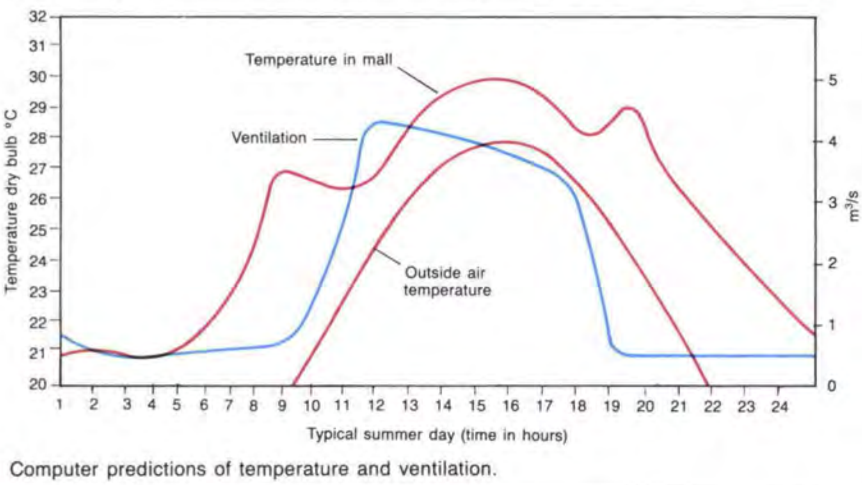
'A very successful venture — well worth doing — a natural extension to the Ashley Centre — nothing but praise'.

The mall is not air-conditioned, but is kept cool by natural ventilation. Heat gains in the mall warm the air which rises out of the roof vents (the stack effect). Replenishment air is drawn in through doors and louvres.



Natural ventilation of the malls.

Computer analysis predicted the temperature in the malls to be no more than 2°C above the hottest outside air temperature. The ventilation rate was predicted to rise to 4.3m³/s (6.5 air changes per hour). During the heatwave in July '89, the temperatures in the mall were measured as 1° to 2°C above the maximum outside air temperature, i.e. within the predicted limits.



Computer predictions of temperature and ventilation.

Engineering

The modifications to the structure consisted of the removal of various walls, relocation of columns, and the addition of the structure for the courtyard roof. Fortunately a number of drawings from the 1950s were available.

The public health engineering included rationalizing the existing drainage, which was excessively complicated. The client said he would pay us £5 for every manhole we managed to remove! Sprinklers were installed in the atrium, and connections were provided for each shop unit.

The electrical engineering included provision of an interface unit in each shop, connected into the Ashley Centre management system for connection by the shopfitting contractor. Connections were provided for fire alarm, security alarm, sprinkler flow switch and internal telephone.

The mall area lighting consists of low voltage luminaires, fluorescents concealed behind a bulkhead and specially designed luminaires within the courtyard.

Smoke control in the mall is achieved by natural ventilation. If smoke is detected in the malls the doors and the roof vents open automatically. The system is also used to provide fresh air and cooling throughout the year. This was considered acceptable by the client (and by the Planning Department) and saves the considerable expense of a mechanical ventilation system with cooling plant. The system is illustrated left.

Credits

Client:
Friends Provident Managed Pension Funds Ltd.
Architect:
Renton Howard Wood Levin Partnership
Structural & services engineers:
Ove Arup & Partners
Contractors:
M J Gleeson plc
Abrey Garland Group

Shopping Centre of the Year Award
(Joint first, Refurbishment Category)
British Council of Shopping Centres

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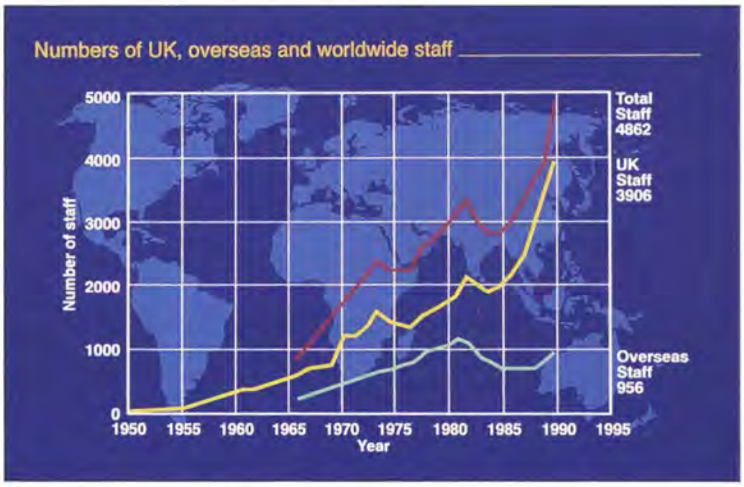
Keeping the Arup world together

Jack Zunz

This paper is drawn from Jack Zunz's opening address to the Arup Gemot, held in May 1989 at the Belfry Hotel, Wishaw.

1. Showing the spread of Arups worldwide.



2. Illustrates the firm's growth since the early beginnings.

My task is to talk to you about 'Keeping the Arup world together', about cohesion, about the glue which binds us. In a way it is easy because you could say that it's all been said before and all we have to do is to refresh our memories; to some extent this is true.

It would not be unreasonable to ask 'why bother keeping the Arup world together, what's so special that it merits a Grade 1 listing?'. Of course the short answer could be that if you have to ask the question, you shouldn't be in the firm. But that's too easy and in a way glib and it is right and proper that we should stop and reflect on what we are doing and why we are doing it. Because, make no mistake, we may all admire one another and appreciate what it is we are trying to achieve, but to foster and nurture the cohesion, the glue which holds us together, doesn't just happen — it has got to be made to happen and requires a great deal of effort on the part of many of us.

Our firm has grown a great deal since it was founded. Figs. 1 and 2 show the spread of Arups — where we are located. There are now 48 offices in 20 countries while the extent of our work now is such that we are actually working in 71 countries. Fig. 2 shows the growth of our firm over the last 40 years as well as the ratio of UK to total staff in Arups worldwide. But growth isn't everything — growth for growth's sake is not worth pursuing — indeed there is something inherently wrong with it.

Our firm has also altered a great deal over the years. We started off being mainly structural engineers to architects. We were successful because we opened a new dimension in the way we tackled our work — we were skilled in what we did but we also immersed ourselves in the whole, not just the part, and by words and deeds we contributed to a greater understanding of bringing all the special skills together to bear on a building project. This naturally led to a greater involvement into total building including architecture and then into civil engineering in its widest sense and so on. So that today this firm of ours practices its skills on a wide front on matters concerning the built and, for that matter, the unbuilt environment. Our skills have spilt over into industry and telecommunications — but these could of course be included in a broad definition of the built environment.

All this has happened in a relatively short time. It has been built up on shared ideals so ably articulated by Ove in his 'Key Speech', given at the first Arup Partnerships meeting at Winchester in 1970. Much of what we have achieved has been done by *not* following the herd. In our designs we have questioned the established procedures. In the way we have organized our affairs, we have done our own thing in accordance with our own philosophies.

When the managerial revolution took place in the United States and spread to the rest of the Western world, we decided that it was not totally relevant to professional practices which were large and whose aims and objectives were just that little more lofty than producing the largest profit in the shortest possible time. We realised early on that if we wanted to have a big ongoing professional practice of quality where a large number of talented designers were willing to commit their professional lives, a different arrangement from the generally accepted management structure would have to be invented. The traditional pyramid would have to be adjusted — so we flattened it. Just how flat it should be is a matter for continuous debate and reappraisal.

We decided that the traditional concepts of ownership were wrong. Our firm depends on shared ideals which have little to do with its value as property, as a commodity which could be bought and sold in accordance with the rules of the market. Recently here in Britain there has been a flurry of firms seeking listings on the Stock Exchange. These moves are often accompanied by explanations which purport to show that the reasons for going to the market are nothing short of altruistic. We reject them totally as being wholly inappropriate to the aims and objectives of a professional firm which has aspirations to achieving excellence in its endeavours — both human and professional. In most instances going to the market is allegedly aimed at injecting capital into an otherwise illiquid organization and to allow some of its members to take a part in the fortunes of the organization. It does not require a great deal of imagination to find the flaws in the argument — the money comes in, the bank manager and the principals are happy, but the reckoning is around the corner in that there are now outside shareholders who have to be satisfied.

We guard our independence jealously. Our firm — and we have different arrangements in the various partnerships — is not owned by individuals, but by trusts or entities which ultimately control our underlying assets. The leaders are the temporal keepers of these assets so that when they die or retire they pass into the control, but not the ownership, of their successors. The control is in the hands of a self-perpetuating oligarchy — an arrangement which many of you may find less than satisfactory, but until we can think of a better way that's the way it is going to be. Democracy is all very well but design excellence cannot be subverted by the antics of the hustings. Our best leaders are not going to be asked to make election promises and go around kissing babies — not in the foreseeable future anyway.

When one talks about a 'generation' one should strictly speaking, refer to a 30-year span because this is the time (it is generally thought anyway) that it takes for a person to become a parent, thus creating another generation. But like so much language the word has come to be used more loosely to describe appropriate succession. In Arup terms we, here in London or more accurately today in the UK, are coming to the end of the third generation of leaders. In most of the other partnerships you are well into the second generation. The fact that there appears to be one more generation in the UK is not really due to the few extra years that the London office has been in existence, but that Ove was a generation on his own! His first partners were the second generation, and so on.

The fourth generation leaders are in place, at least some of them. So you might say we have done all there is to be done to continue what has been started, but have we?

Nothing endures but change

Heraclitus (circa 500 BC)

Of course we haven't — if we want this firm to continue to flourish and hang together we have to continue to make considerable efforts to bring this about. 'Nothing endures but change' is an old saying and this is as inevitable as night following day. Change is not made without inconvenience — even if it is from worse to better. Succeeding generations in our firm, therefore, have to accommodate inevitable change. But the essential issue surely is that we must not lose our aims, our ideals, our attitudes. We must try and view Arups as a balanced ecological system — where some things are being born and flourish, while others wither and die, but the system lives on.

A healthy disrespect for the impossible

Much of what we have done has come about through a healthy disrespect for the impossible. We have, as I have indicated, rewritten the rules about ownership and have established a unique framework within which talented professional people can express themselves fully with almost total independence. They can earn a good living, have the added advantage of opportunities for exchanging experiences with their peers, as well as having some security in their hour of need should this ever arise. We have incorporated our firms in different ways in the countries in which we practice, conforming to differing legal and institutional requirements without vitiating the underlying principles which we have established.

Can these principles of ownership be stated simply? Possibly — so I will try:

(1) We want to govern ourselves, that is we want to be totally independent of outside shareholders, banks, controllers of any kind.

(2) We want the best technical professional people to lead the firm whether they are partners or directors or whether they have a title at all. We do not want to compromise in being able to select the best possible talent.

(3) We want, in general, our leaders to come from within the firm. We do not want individuals, however good or important they are to us, to own any of the assets of the firm, particularly our name, including its goodwill, our work in progress or any of the reserves we have built up.

(4) We want the members of our firm to be well rewarded for what they contribute and share in its fortunes. We consider our staff to be the shareholders in that they participate in the profits in accordance with an appropriate formula. The shares are income, not equity shares.

(5) We want to make provision for our members' retirement, so that they can live out their advancing years in relative comfort without being unduly concerned about money.

(6) We want to be able to care for our infirm if they require help and generally give aid and assistance where necessary.

(7) We want to be financially strong.

(8) We want these principles of ownership to be enshrined in such a way that successive leaders, having joined and worked under this regime, accept and develop these concepts in accordance with an externally changing social, legal and fiscal environment.

These ideas which have evolved over more than 25 years are not yet strictly speaking implemented or embraced in *all* our partnerships. There are historical or legal reasons why in some cases it has not been possible to abide by them but we in the Arup Partnerships must at least accept them as objectives to be achieved whenever possible. If we cannot share the objectives, then with the changing circumstances and the decreasing involvement of the original London partners in the non-UK partnerships, the relationships will inevitably wither. Incidentally I have desisted from referring to the non-UK partnerships as 'overseas' partnerships, because I have always felt that referring to 'overseas' was slightly parochial. The world does not stop at Dover — nor incidentally in Perth!

You might say why all the fuss about ownership — it has nothing to do with our work and its quality so why take all this trouble? Actually it *is* very important in that it removes a common irritant, a cause for abrasion and dissent in a partnership and if we have removed this potential obstacle, particularly in the context of being in charge of our own destinies, it makes it that much easier for our members to get on with their work objectively and deal with their technical and associated problems. Human interaction is sufficiently fraught with potential points of friction that anything which can be done to remove unnecessary irritants must be good.

We have introduced as much equality in our leadership as possible. Even our chairman is an equal amongst equals with certain particular responsibilities. It is only by exposing each of our leaders as top professionals in their own right that we will continue to succeed. There is also the question of wielding power. Power like so much else in life has two sides — it is both a menace and a necessity. We have tried to strike the right balance.

There is potentially a negative side to our attitude to the ownership of the firm which I should touch on. The founders, and to some extent those who follow, could argue that, having started an enterprise or at least contributed to its development, they have a right to expect to capitalize on their enterprise — an argument which is particularly encouraged in the current political climate in Britain.

The argument is by no means clear, particularly in the context of a professional practice. But that is not to gainsay the validity of a particular point of view. Our short answer is that for better or for worse and after many years of development, discussion, heart-searching, experience and evolution, we decided more than 20 years ago to go down the route which I have described, that it was best for Arups, best in the sense that if we wanted to establish a technical institution which had as its main objectives quality and excellence and continuity of leadership, then this was an essential ingredient of the means whereby these objectives could be achieved. The years have not dimmed our perception of the wisdom of this decision — indeed it has, if anything, been strengthened by the growth and development of our firm and its people as well as by what we see outside in the marketplace amongst our colleagues or competitors or whatever you wish to call them.

But enough about ownership; the ownership issue is only a means to helping achieve our objectives — means and aims can merge and overlap but what are these objectives which make us go to so much trouble and create frameworks whereby we can continue to work together in as positive and as frictionless a manner as possible?

It takes a long time to bring excellence to maturity

Here, not surprisingly, precision eludes me as much as it did Ove in his 'Key Speech' nearly 20 years ago. But let me try a few pointers. We want to excel in what we do. But someone said a long time ago that 'it takes a long time to bring excellence to maturity'. Excellence, like art and quality — all very important to us — cannot be defined and is whatever you want it to be. How can one judge whether one succeeds?

Reluctantly I confess that one pointer (and it is *only* a pointer) is the judgement of our peers both inside and outside our firm. If the normal criteria — honours and awards both corporate and personal — are anything to go by, we have done pretty well. Most, if not all our partnerships, have acquired recognition and respect in the countries in which they practise. And the leaders in those offices who have not so far received their fair share of peer recognition should have a serious look at their work and how they do it and if they want help they should ask. Our collective resources are such that we are capable of giving considerable assistance to one another. In fact this should be part of our way of life.

But awards and honours are indicators to be used like all indicators and under certain circumstances to be ignored. Indeed I believe they can be potentially, like power, the most corrupting influences in our lives. When we start believing other people when they heap praise on what we do, we are facing the slippery slope towards degeneration. It is a fine balance between receiving recognition for one's endeavours and beginning to believe in one's excellence and ultimate infallibility. But all-in-all we are quite well thought of in some, if not all, the disciplines in which we practise. If we are willing to recognize our shortcomings then at least we must take steps to improve and continue to aspire to the highest possible standards.

As an aside here (it ought to be obvious, but sometimes needs to be restated), standards of excellence are in this context not universal — we must relate what we do to the country and sometimes the location in which we work and the context in which the work is carried out. A major interchange in a European urban environment will demand different solutions from a rural crossing in Papua New Guinea — again an obvious comment but not always understood. Both, in their totally different ways, can be examples of excellence in design and construction. So that quality and excellence, those hackneyed but so important issues, must forever be foremost as our objectives; always viewed in the appropriate context; always being questioned and reviewed critically; never accepted as achieved; always refined, improved and looked at afresh. This is what is at the core of our existence. Without that quest, that crusade, that mission, we might as well not make any effort to keep this firm afloat. Because just to run a business to make profits (which are of course essential if we want to be financially strong), to make money and keep people in employment is not what The Arup Partnerships are all about. We are a firm of designers — and here I am using the word in the broadest possible sense, whether we are designing an artifact which has been commissioned by an external client, whether we are designing a system whereby this artifact can be built, whether we are designing the best organizational network for people to function, or whether we are planning our future strategy — all is included. And in this quest for excellence we must include all aspects of the design — animate and inanimate.

An issue of *The Arup Journal* in July 1981 contained a monograph on Brunel's design for a 1000-bed hospital in the Crimea — it was initially meant to be erected in Scutari where Florence Nightingale performed her wonderful works, but was eventually erected in Renkioi. Quite apart from the extraordinary achievement in being asked to design and erect a hospital on 16 February and having the whole thing erected and open to receive patients on 12 July the same year, which included a sea voyage of about 3-4 weeks to transport the prefabricated units, Brunel's detailed instructions and attention to every possible contingency are nothing short of breathtaking. In a letter to Dr. Parkes who had been appointed as Medical Superintendent of the hospital he wrote his instructions which said *inter alia* '. . . I have added twenty shower baths, one for each ward and six vapour baths. You will be amazed to find also certain boxes of paper for the water closets — I find that at a cost of a few shillings per day the WC's will be much influenced by this. I hope you will succeed in getting it used and not abused. In order to assist in this important object I send out some printed notices or handbills to be stuck up, if you see no objection, in the closet room opposite each closet exhorting the man to use the apparatus properly and telling them how to do so. If you do not approve of such appeals the paper can be used for other purposes and perhaps impart information in its exit from this upper world . . . *et seq.*'

I have quoted this extract not just for its light relief or its quaintness, but for an insight into the mind of a brilliant designer whose passion for excellence did not stop with giving instructions to manufacturers or contractors, but who almost obsessively pursued every detail to its intended conclusion. So that when we talk about excellence and quality and using current technical jargon we mean through-thickness quality — which is not surface-wrapped with little beyond.

When I asked the question as to whether all this effort to keep Arups together is really worthwhile I know there is only one answer, but it is only right to question one's aims and objectives from time to time so that they don't turn into meaningless dogma. We have built up a firm of hundreds of exceptionally talented people. We have allocated an increasing proportion of our resources to investment — to training and retraining and to research and development. We have carried out some good work — even our best and most acclaimed projects are never good enough; they are inevitably flawed but by all the accepted yardsticks we haven't done too badly. We have established leadership arrangements which, although subject to constant review and adjustment in the light of changing circumstances, have served their purpose in creating a framework whereby our work can be done in a reasonably cheerful and creative environment. We have in most but not all our partnerships achieved an element of financial stability to enable our objectives of caring for our members to be met. So all-in-all there is enough on the credit side for us to stand up and let ourselves be counted, to go on developing on what has been built up so far.

I say 'so far' deliberately because the danger of the 'God's in his heaven, All's right with the world' syndrome is particularly real when you have enjoyed the measure of success which we have been fortunate enough to enjoy. But while so much more remains to be done, the answer to the question as to whether it is all worthwhile must be a resounding 'Yes'.

But on the assumption that the majority if not all of you share my enthusiasm to move forward together, what can we do individually and collectively to help bring this about, to further the objectives which are part of Ove's legacy to us?

I have already indicated that first and foremost we must each, in our respective corners of the Arup world, put our own house in order — an ongoing process. By practising in accordance with our common principles of fair dealing and our very special attitudes to our work, each of us by example should try and demonstrate to others in Arups, whether in the office or country in which we work, or thousands of miles away, that at least on our own patch in our own way each one of us tries as best as he/she can to adhere to our ideals.

Corporately we in The Arup Partnerships have taken a number of initiatives which, although never enough, are beginning to show some results. We have established Regional Committees in South East Asia and in Africa which meet to co-ordinate our affairs in those regions. There are signs that these annual meetings, apart from providing a forum whereby interested parties meet to discuss common problems and to pool resources, are making it possible for personal relationships to be established, which are ultimately the only means whereby we will continue to hang together. There are encouraging signs that the third, fourth and potential fifth generation leaders are beginning to get to know and respect each other and on occasions to work together, which ultimately is the most promising framework within which to establish enduring relationships. The key here is people, people, people, their meeting one another, being exposed to one another's cultures and problems and learning from one another's triumphs and failures. We have therefore encouraged the activities of the Staff Committee whose aim is to stimulate interchange between our partnerships at all levels. This is proving to be very difficult. When we are busy we need our good people more than ever and it is of course our best people who ought to be exposed to these experiences as part of their training. And the very word 'opportunity' implies that it just happens — it doesn't, the opportunities have to be created and you have to help create them. And as an aside it may be timely to remind you in the context of what I have said before about our founding fathers having created something, hopefully a force for good, to continue beyond their lifetime for the benefit of others and hopefully for the community at large.

We are of course very lucky in that not only do we have within our firm the most interesting group of people imaginable, but they also come from many different cultures, races, creeds and religions which, added to the many different locations where Arup offices are to be found, could and indeed should make life for a bright young man or woman in Arups a very challenging and interesting experience.

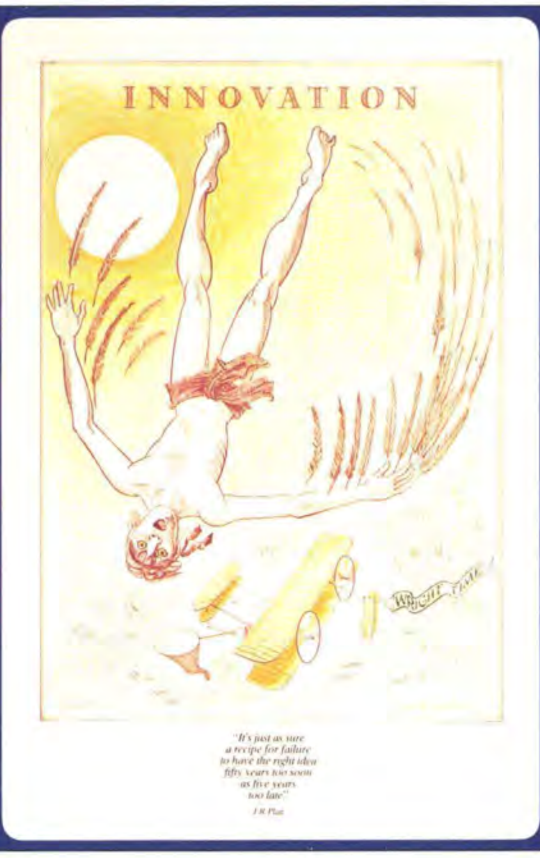
I have already referred to the personal relationships which have to be established, renewed, re-established and constantly fostered if we are to remain united. The Committees, Regional and functional, all play their part. The seminars which have been held, not only in the UK, have brought people of similar technical skills and interests together. They have proved to be a fertile field for creating new relationships and networks for exchange of technical information. There are usually one or two seminars annually held under the auspices of The Arup Partnerships — it is not as much as we wanted to do but is about as often as time and money allow at present.

But the framework which we have created for holding together this great firm of ours is only a means. It will be reviewed/adjusted as necessary so that it provides the best possible means whereby people can meet/interchange ideas, adhere to common objectives and so on. Ultimately, however, what will hold us together, what will prove the glue, will be our work — what we do, where and the way we do it. Everything else flows from this. And here is one of our basic weaknesses or strengths — depending on how you look at it. We have no written constitution — our society is fairly permissive, we have a broad church or whatever metaphor you wish to attach to one of our basic tenets. This is to select talented leaders who we believe understand our ethos and want to work within the concepts of our firm. They then go away and get on and do whatever they think best within, of course, prior agreed financial and other constraints which are as loose as possible. To let people do their own thing has worked more or less well so far — we have had one or two mishaps and a few close shaves, but by and large our very success has been based on good people doing their own thing under the Arup umbrella. They in turn have spawned and helped other younger people follow a similar trail.

When then we ask what work we should do, the answer is very simple 'Only that which we think we can do very well!'. We must never take on work which we can't excel at. I know that it is often tempting to pretend that each office has all the capabilities available to the whole partnership. Surely we must try and harness the total resources of our firm — particularly in Civil Engineering, Industrial Engineering and some of the specialist skills we have acquired. But some skills, particularly those associated with building, are or should be indigenous. Equally, developing into new fields must be carried out with circumspection. We are respected in most of the disciplines in which we practise, but it would be self-delusion to pretend that everything is rosy and there are few aspects of our work which can't do with some improvement. So we must be vigilant to maintain if not to improve our standards. We must do that without a police force. Self-discipline is the most difficult discipline to sustain but that's precisely what we in our firm have set out to do. Peer relationships and reviews help to exercise self-discipline and that is yet another reason why meeting and exchanging ideas and reviewing one another's work is so important.

Where we work, our geographical spread, is also the result of enlightened pragmatism. Initially we took opportunities when they presented themselves — our presence in Ireland and West Africa and later in Australia and Malaysia and some other places came about that way. Then we started backing individuals who wanted to go to particular towns or countries, often for personal reasons. Of late our geographical development has had more to do with particular work, opportunities or deliberate choice. With improving communications, international working has become easier if not essential for a major consulting group such as ours. Here again while our pragmatism has clearly been successful, our inherent permissiveness often requires careful consideration and consultation. Take the typical dilemma — a very interesting project comes up in a country a large number of people don't really wish to work in, but our workload at home is thin; we want to keep our good people together and our society, but our government is encouraging us to export our services. There may even be a middle man who, depending which end of the telescope you are viewing from, is either an expediter, a translator who provides services for the fee he receives or simply an agent effecting contacts at best and engaging in nefarious activities at worst — we never know which.

Fortunately these situations hardly ever arise, but when they do they can be divisive and we have to be sensitive to the views and feelings of our colleagues to ensure that by taking an expedient decision we don't damage the fabric of our firm irreparably. We must remain vigilant, particularly since standards change — I mean here that we cannot isolate ourselves from the world around us which is ever-changing. We must try and influence events in a way which suits our purpose, but this is not always possible. An interesting example is the current situation concerning the attitudes towards advertising our services to the public. 15 years ago — in some countries even more recently — it would have been inconceivable for us to advertise in a paper or a magazine, however tasteful and relevant the advert to the general tenor of the article or publication. Today here in Britain at least it is illegal *not* to be allowed to advertise and while we continue to be restrained and to act with what we perceive to be good taste and decorum, we must recognize that changes which we cannot ignore are going on around us and we must adapt as best we can without losing the essential qualities which make us what we are.



Innovation

I said earlier that much of what we have done has been by questioning established systems and procedures. I suspect that at the root of our success, or whatever you want to call our having built up what we have, lies a simple concept, namely *innovation*. I use the word innovation here in its broadest sense in that it means to renew, to alter, to produce something new. And in that context innovation is at the core of everything we do. Whether we introduce new arrangements whereby a large number of highly talented technical people can work together, which I have already discussed; whether it is new ways of arranging contracts in the construction industry; whether it is new or different ways of designing buildings or parts of buildings, or bridges or highways or whatever we design — it is the fresh approach, the unfettered enthusiasm, the lack of hang-ups, a certain irreverence; it is all or some or a combination of these activities and factors which make Arups what it is, makes it just that little bit different from other organizations working in the same field.

Now what is important is to recognize these sometimes delicate and barely perceptible attributes which distinguish our firm from others. And it is in the nature of human activity to sow the seeds for its own decline and destruction. We must be vigilant because our very success breeds complacency, self-satisfaction, institutional inertia — need I go on? I am not suggesting that we are suffering from any disease or indeed the first symptoms of the common diseases which can inflict much damage on enterprises such as ours. But every now and again there are danger signals and we must be on our guard.

So, 'keeping the Arup world together' implies preservation, renewal, rehabilitation and so on. While it may well need all these and more I would put it to you that the key to keeping the Arup world together is innovation. Innovation in our work, in the way we do our work, in the way we organize our work, in the way we arrange for the work to be carried out, and not least important in the way we arrange our own affairs for the benefit of ourselves and society as a whole. It is only by being, and making sure we continue to be, innovative that we will be sure to foster those guiding principles articulated by Ove and which have stood us in good stead so far.

There are many forces which could easily blow us off course. I have already mentioned the natural tendencies of a large, successful firm to solidify. But there are also potent negative forces outside. The increasingly litigious climate is a powerful anti-innovation force, not to speak of fee competition, the demotion of the professional advisor to a commercial contractor, and the difficulties in attracting and training the most talented young people into our industry. We have to keep our feet on the ground and our eyes on the stars. I am immensely heartened by the wealth of talented, dedicated, young men and women in our firm who have all the right attributes. It is your job, your duty to ensure that their talents are nurtured and encouraged for their, the firm's, and ultimately society's benefit.

> ***To prophesy is extremely difficult .....especially with respect to the future***
>
> **Chinese Proverb**

'To prophesy is extremely difficult, especially with respect to the future' — but I believe that if we stay together, if we continue to stand by our beliefs and ideals we can't go far wrong and will continue to flourish.