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Front cover: World Cup third/fourth place play-off match: England v. Italy, San Nicola Stadium, Bari, 7 July 1990 (Photo: Shuji Ishida)

Back cover: Models of proposed business parks at Villebon-sur-Yvette (top left/bottom right) and Hallbergmoos (top right/bottom left) (Photos: Arup Associates)

The San Nicola Stadium, Bari

Architect: Renzo Piano

Peter Rice   Alistair Lenczner   Tristram Carfrae   Andrew Sedgwick

1. Western side, showing press accommodation on upper tier with TV gantry above: note translucency of membrane roof

Introduction

The city of Bari (population 370 000) is an industrial port located on the 'Achilles' tendon' of Italy, facing north into the Adriatic Sea. With the 1990 World Cup Football Championships taking place in Italy, Bari was chosen as one of the 12 venues at which the tournament's matches would be played. For the occasion, the city decided to build a brand new stadium at a greenfield site on its flat southern outskirts (thus fitting into an urban masterplan scheme for future expansion). The existing football ground within Bari, the 30 000-capacity Stadio della Vittoria, built in 1934, was considered too small and not worth refurbishing. Renzo Piano was chosen as architect for the project; Ove Arup & Partners were invited to collaborate in the design from the outset. The new stadium, called the San Nicola Stadium after the patron saint of Bari, was one of only two completely new stadia to be built for the World Cup, the other being in Turin. All of the others were either refurbished or rebuilt for the occasion.

The brief

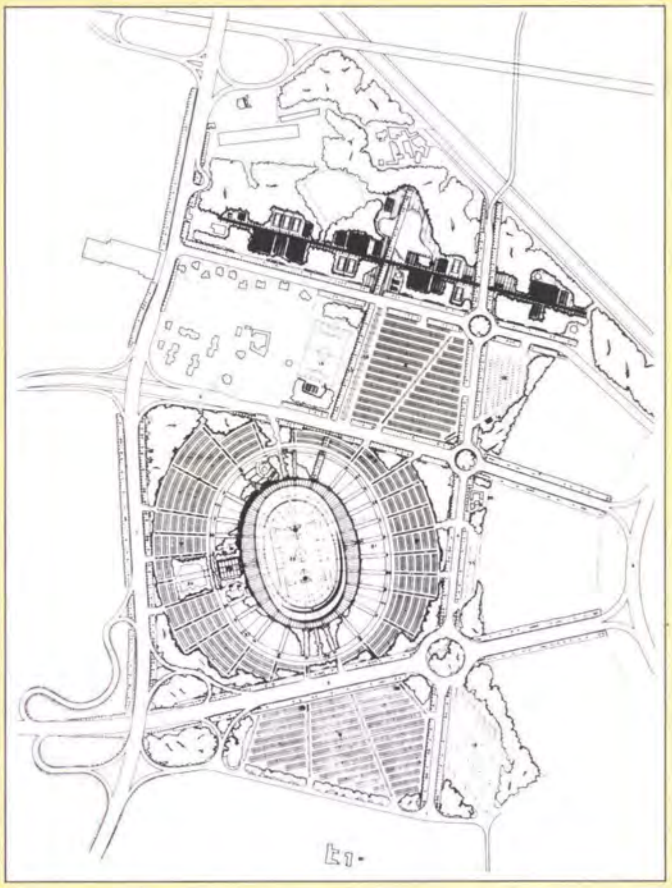
The initial project was for a stadium purely for football, with an all-seat capacity of 58 000 spectators. Later on, it was decided that it should also incorporate an eight-lane athletics track. The athletics facilities will expand the number of sporting events that can take place in the stadium, and it is now expected to host the next Mediterranean Games in 1991. It being a wholly new stadium, the design had to comply fully with all the rules and regulations set down by FIFA (Féderation internationale de football association — the international governing body of football) for new World Cup match venues. Thus standing accommodation was ruled out and security provisions such as a moat surrounding the arena were mandatory. For the World Cup tournament itself the stadium had to provide places for hundreds of journalists and suitable positions for cameras as dictated by the Italian television companies. The means of access for VIPs was also an important consideration.

2. Location

The concept

The architect's concept for the stadium was to have an upper tier floating like a spaceship above a man-made crater containing the arena. The crater was to be created by building a gently sloping mound all around the stadium, leading up to the top of a lower tier. The exposed underside of the upper tier was to be rounded and as uncluttered as possible. Thus most of the accommodation for changing rooms and offices was placed under the lower tier and hidden from the outside by the earth mound. An underground orbital road circuit beneath the lower tier provides vehicular access to this accommodation. The upper tier's flying saucer shape is surmounted by a lightweight canopy roof to provide shade and some rain protection. The roof, which continues right around the stadium without any structure to obscure spectator vision, was also to be used to support floodlighting; hence separate lighting pylons could be avoided.

From this initial concept, Ove Arup & Partners worked alongside Renzo Piano's Building Workshop in Genoa to develop the ideas to scheme stage. Arups' particular involvement at that time was to study the geometry for the stadium and at the same time devise a structural scheme consistent with the desired aesthetic and compatible with the established geometry.



3. Site plan

Geometry

In setting out the geometry for the stadium the following aspects had to be considered:

(1) The distribution of spectators around the arena

(2) Viewing distances

(3) The stand profile

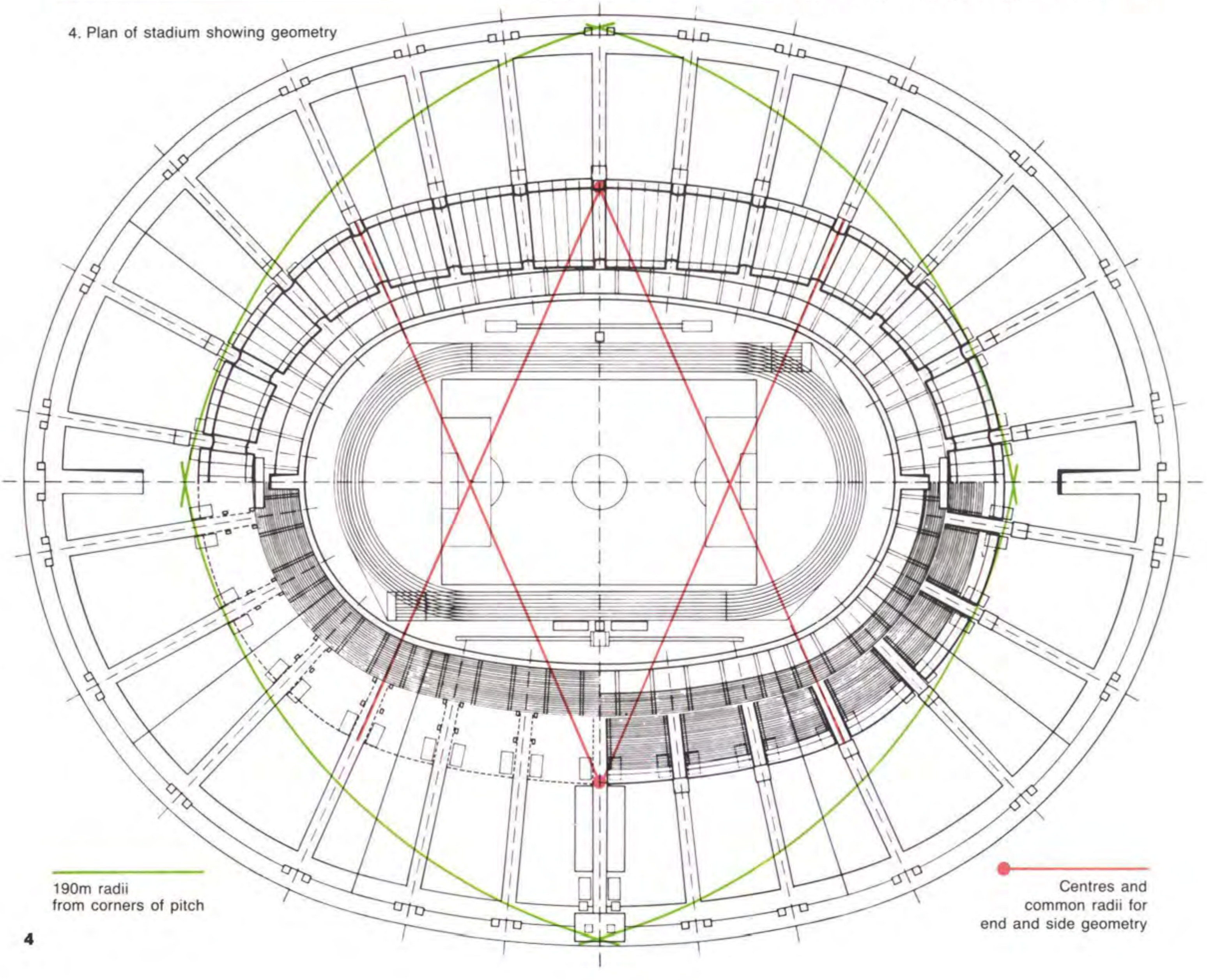
(4) Construction system.

Generally speaking, the preferred viewing positions for football are along the sides of the pitch, with the optimum normally considered to be opposite the half-way line. Similarly for athletics the preferred viewing positions are from the sides, particularly the finishing straight side. The special stand accommodation for VIPs, the press and television is best located exactly opposite the half-way line on the side facing away from the sun, since events usually occur during the afternoon or evening. This means that VIP and TV positions face eastwards.

For large stadia, the distance of the spectator from the furthest point of the arena can become a limiting factor. For football the absolute limit for visibility is considered to be 190m. Thus the 'squircle' shape formed by drawing arcs with 190m radii from all four corner points of the football pitch defines the outermost bounds for the plan shape.

Despite the addition of the athletics track which inevitably pushed the stands further away from the pitch than would otherwise have been the case, all the spectators could fit within the maximum viewing distance for football. By building an upper stand which

4. Plan of stadium showing geometry



partially overhangs the lower, maximum viewing distances are improved all round. Varying the number of seating rows in the upper stand from a maximum opposite the half-way line to a minimum at each end of the stadium further reduces maximum viewing distances, whilst also improving the distribution of spectators for watching football.

The stand profile should be designed so that spectators on successive seating rows can see over the heads of the people in front to the nearest point on the arena which should be seen without obstruction. The ideal profile which maintains a constant sightline clearance is concave. If a straight profile were chosen which satisfies sightlines from the back seating row, then the overall height of the stand increases compared to a curved profile, thus necessitating more construction work. However, to build the stand to a profile with a constantly varying slope is expensive. Therefore, in a compromise solution the ideal curved profile is approximated to a series of straights. At Bari the constant-width lower tier is built with a constant slope whilst the steeper upper tier has three slopes approximating to the ideal curve. The seating rows are 0.8m wide and a maximum row step of 0.6m is reached at the very back of the upper tier.

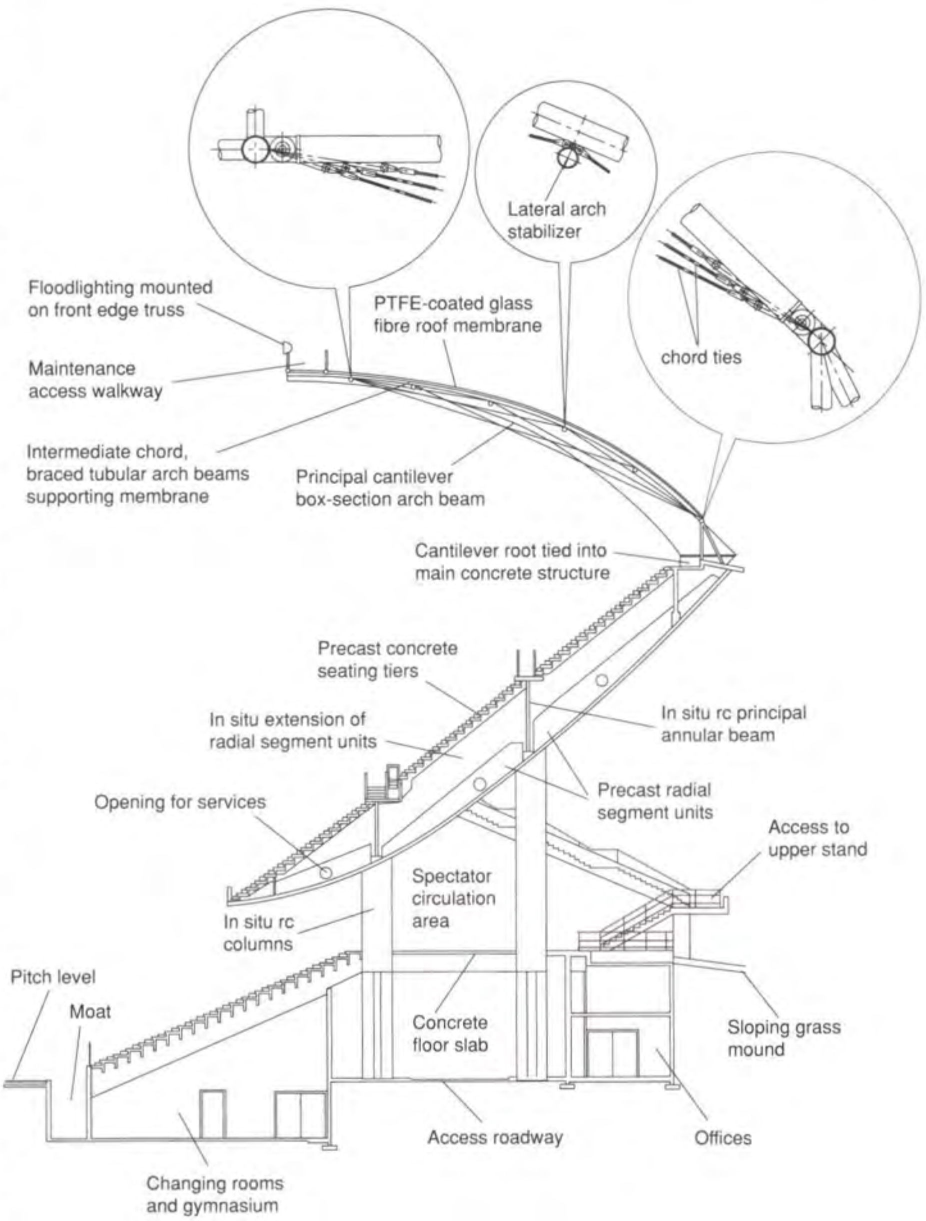
Viewed on plan, the Bari stadium is symmetrical about both long and short axes and a compound circular geometry is used to set out its stands. The end sectors of the stadium have a circular geometry concentric with the end bends of the athletics track (whose dimensions comply with international athletics requirements). Sightlines of the stand are designed to give unobstructed views of the outside track from any seat. The side sectors of the stadium have a circular geometry tangential with the end sectors but with a much longer radius. The bulges of arena space created between the straights of the athletics track and the fronts of the lower stand are used to accommodate long jump and pole vault runs. The variation in size of the upper stand to give the required distribution of spectators was achieved by defining the top edge of the stand by the intersection of the conic surfaces containing the seating with a curved plane chosen to give the necessary change in height of the stand.

The entire ring of the upper stand is sub-divided into 26 distinct bays. The upper parts of these are separated one from another by a slot deliberately created to provide access to the seats in the upper stand. Each bay thus becomes a 'petal' of the upper stand structure, a feature which gives Bari a unique appearance among stadia with concrete bowl constructions.

Each petal is sub-divided into 10 radial segments, which are concrete structural units forming part of the upper stand structure. The constant radius within the side and end sectors of the stadium means that the geometry of the radial segments has a high degree of repetition. The curved profile given to the underside of the precast units creates a 'sea shell' effect to the soffit of the upper stand structure.

The upper stand structural scheme

With the established aim of supporting the upper stand with the minimum of columns and to give its soffit an uncluttered appearance, the design of the structural system was of paramount importance.



5. Cross-section through stand opposite half-way line, showing precast and in situ concrete work: inset are details of stainless steel braced tubular arch-beam supporting roof membrane

6. Under the canopy roof, showing stainless steel tubular arch-beam with stabilizing chord-ties

7. Precast radial segment unit to upper stand being hoisted during construction

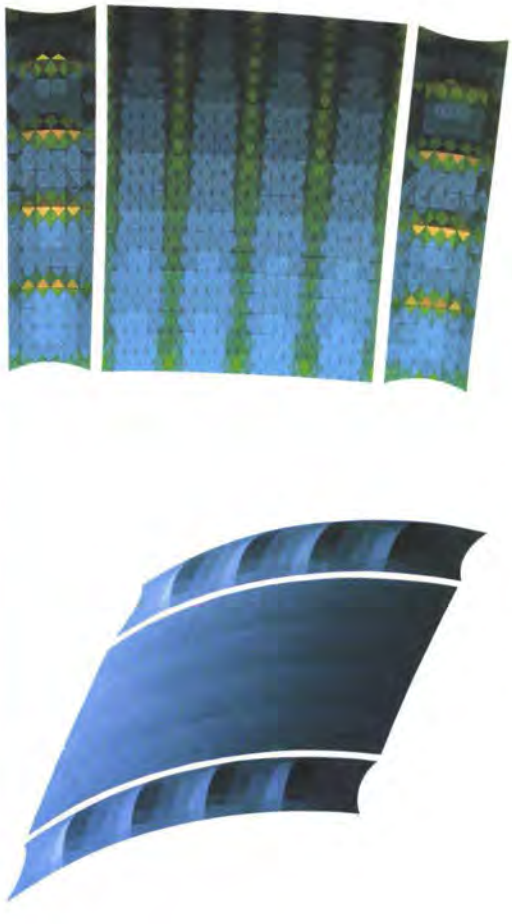
8. Cantilever canopy structure with membrane roofing during construction: the infill roof zone to the left has yet to be covered

9. Computer graphic images showing stress distribution within membrane roofing as found by computer analysis using FABLON

10. Quadrant showing main elements of roof structure

11. Construction, showing petals of upper stand structure before erection of canopy roof

12. View through slot between petals of upper stand structure showing infill roof structure. The curved segmental soffit to the upper stand made by the precast units is clearly visible.



The desired visual quality was thought to be best provided by precast concrete. For the main structural system, both all-concrete and mixed steel/concrete solutions were considered, tender documentation eventually being based on the latter as at the time it was thought to offer time advantages for construction. Post-tender, the engineers Studio Vitone (working for the consortium Bari '90) proposed an all-concrete solution using both in situ and precast. We approved this, and they went on to develop their system within the context of Arups' scheme.

Each of the upper stand's 26 bays or petals is supported by four rectangular section columns placed in pairs at the sides of the slots which separate the petals. These columns are of in situ concrete and extend downward into the substructure and foundations which are built on limestone. The columns are sufficiently massive to resist horizontal shear loads, including possible seismic loading, without the need for any bracing.

Two principal annular beams span between the columns to create giant curved portals onto which the radial segmental units are placed to form the complete bowl. The principal beams, which are built from in situ concrete, are not apparent from the outside.

Their depth fits within the volume between the segmental units' soffit and the seating units on top. In effect each of the radial segments cantilevers forwards and backwards from the front and back annular beams respectively. Those segments which are at the sides of the petal are specially modified to support the extra loads from the roof cantilever arms, which are supported from their back extremities.

The cross-section for each segmental unit has an inverted 'T' outline. Its curved bottom flange forms the finished soffit to the stand structure and was precast on site using a concrete mould. Each complete radial segment is composed of three precast units joined at the annular beams. The vertical web of the T-beam was then constructed from in situ concrete after the precast pieces were in position. The T-beams in their turn support precast concrete seating units which run round the bowl.

The stand structure is completed by two in situ concrete beams which tie the segments together at the front and back edges of the stand and give a finished profile with a sloping lip around the back edge.

The canopy roof structure

Each of the 26 petals to the upper stand has its own independent canopy roof structure springing from the rear edge of the stand. The canopy roof structure provides support for the stadium's floodlights and the two scoreboards located at each end. The zones between the adjacent canopy structures to each petal are spanned by infill roof structures which cover the open slots between petals.

The width of the roof on plan varies from about 27m at the middle of the sides to 14m at the ends. This variation of width does not match that of the upper tier beneath the roof and so its plan geometry is set out using different circular arc centres to define the front edge of the roof.

In section the roof has a circular arc shape which starts at a 45° inclination at its rear and curves to horizontal at the front edge.

The primary supporting elements to each petal's canopy are a pair of tapering curved, cantilever arms, built in high grade steel with a closed box section of variable depth but constant width. The length of each arm varies according to the width of the roof.

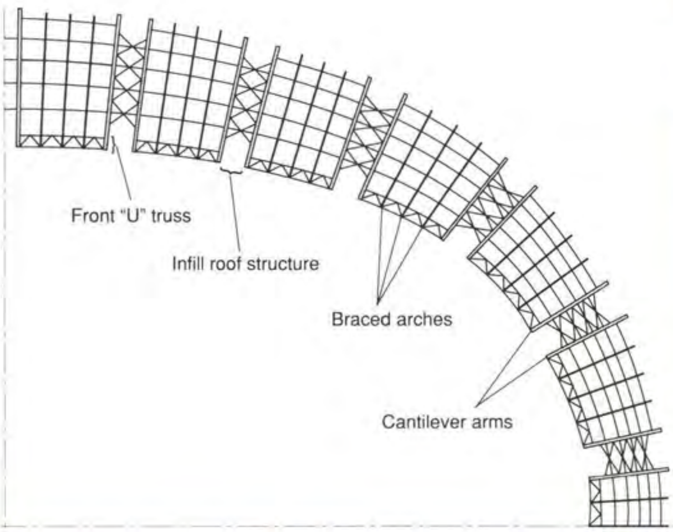
The connection between the base of the cantilever arm and the concrete stand structure is made using a set of prestressed high strength threaded bars which anchor into the back of the edge segments of the petal structure. A special steel transition block was used at the base of the cantilever arm so that the main arm could be placed more easily during construction. The transition block and the anchorage are identical for every cantilever.

The front tips of the cantilever arms are jointed together by a U-section tubular truss. The connection between the front truss and the cantilever arms allows the pairs of arms with the truss to work as a portal to resist loads parallel to the front edge of the roof. The U shape of the truss accommodates an access walkway which passes right around the front edge of the roof and also supports the floodlighting.

Spaced in-between the main arms are three braced tubular arched beams, over which the membrane roofing is stretched. These have similar curved profiles to the top surface of the cantilever arms and span from bipod supports on the back of the stand onto the front truss structure. They work as flat arches thrusting against their supports and are stabilized laterally by tubular props at their fifth points against the sides of the main cantilever arms.

The system of chord-ties which are fixed in the plane of the arch at the fifth points acts to reduce the buckling length of the arch in its own plane by resisting deformation of the arch. Because the braced arch beams would be very difficult to access for maintenance and painting, stainless steel is used for the tube sections, their chord-ties, and the lateral props.

The roof infill zones have a different structure supporting the same type of membrane material. This consists of a series of small circular arches which span between the cantilever arms on each side of the slot covered by the infill roof. These arches are stabilized both in and out of their plane by four diagonal ties which are also fixed to the sides of the cantilever arms. The triangulation created by these ties effectively forms a truss with the cantilever arms. This means that the sway deformation of the cantilever



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12

arm/front truss portal system is partially resisted by this 'soft' bracing structure (the 'softness' being mainly due to the springiness of the arches under horizontal loads at their feet).

Membrane roofing

The form found shape of the membrane has only a slight double curvature due to the long proportions of the panels between the supporting arches. However, curvatures are sufficient for the membrane to resist either downwards or upwards loads without large deflections. The concave shape between arches meant that the lateral props here had to be lowered to avoid contact with the membrane.

The membrane is fixed at the edges of the 26 panels only. The original scheme called for the fabric to be clamped to the tops of the arches so that it could invert between them under wind uplift. But Koit HiTex GmbH, the German fabric sub-contractor, felt that they would rather not penetrate the fabric in this way, as it may lead to tears in the membrane at a later date. Instead, a system of 'lazy' cables placed on top of the membrane in the valleys between arches was adopted to support the fabric under uplift.

The membrane material is a PTFE-coated glass fibre woven fabric. The membrane has a minimum strength of 80kN/m in both its warp and weft directions, although for design purposes a material factor of safety of 4 was used. The fabric has a 13% translucency.

The cutting patterns used for making up the membrane were supplied by Arups, these being created using the same software as was used to analyze the membrane. Koit used a fabric manufactured by Verseidag.

Prestressing of the membrane was achieved using a series of threaded bars which tie the membrane's edge clamp to the supporting steelwork. The gap between the membrane clamp and the anchor point of these ties is covered by an unstressed flap which is welded onto the edge of the main fabric panel. A nominal prestress of up to 5kN/m was put into the membrane for which the fabric had a 5% compensation in the weft direction and 0% in the warp direction.

Analysis

Analysis of the roof structure and membrane was made using various computer models:

(1) The largest fabric panel bay was analyzed using FABLON as was the membrane covering the infill roof. These analyses were made after the same FABLON program had been used to form find the membrane shape. Based upon the results of the wind tunnel test performed on a model of the stadium, three design wind loadcases were analyzed, representing wind blowing into the front of the roof, from behind, and across the roof. The nominal prestress load of 5kN/m in the membrane was included in the model.

(2) A non-linear analysis using FABLON was made of an individual tied arc-beam to check its buckling behaviour. By finding the collapse load of the arc, an effective length could be extrapolated which could safely be used for justification using standard methods.

(3) A linear model analysis using Arups' GSA (General Structural Analysis) was used to find the forces and deformations of the largest and smallest bay portal canopy structures. In these models the ties of the braced arcs had to be 'hand removed' until no ties were found to be in compression in the analysis results. Two sets of analysis were performed in order to check the structure's sway behaviour with and without the presence of the infill roof structure.

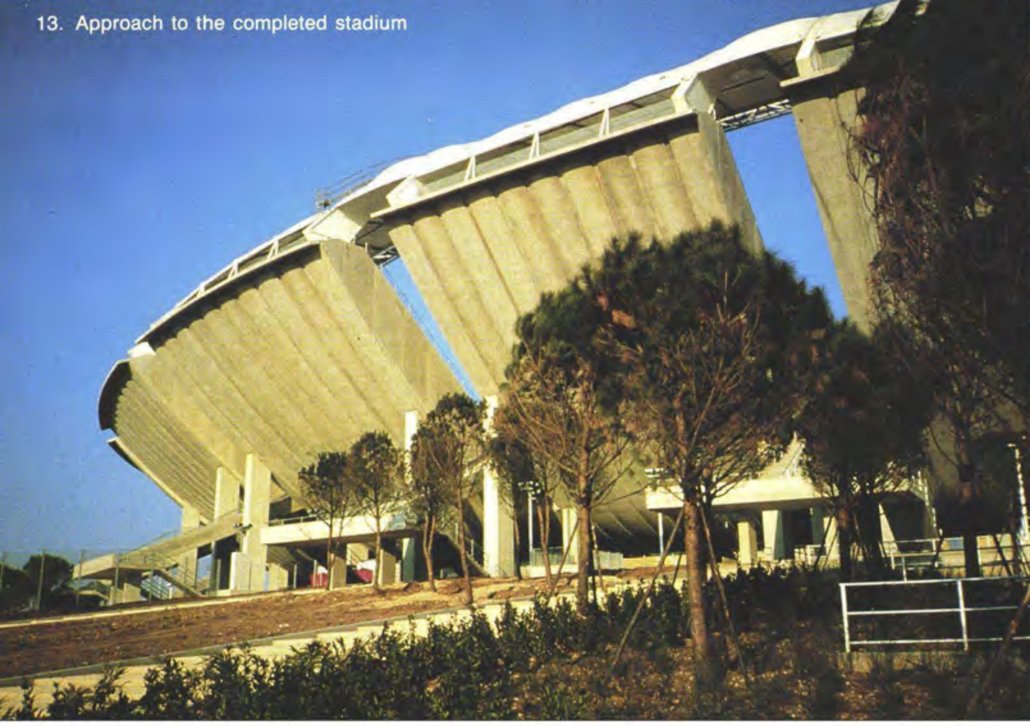
(4) A separate GSA analysis was made of the infill roof structure between the cantilever arms. The lateral stiffness thus found could then be incorporated as lateral spring supports in the analysis of the main roof structure, which also took into account the pressure of the infill.

Wind tunnel test

Because the roof was to be designed predominantly for wind loads and the stadium has an unusual form, a wind tunnel test was commissioned to find the relevant wind pressure coefficients appropriate for design. The wind tunnel test was carried out by the Aeronautical Engineering Department at Bristol University using a 1:500 scale model with pressure tapping points distributed over the roof surface and at other positions as required. The model included the scoreboards suspended from the roof at the ends of the stadium, which are subject to potentially high wind loads. The results showed that maximum net pressures on the roof could reach up to 2.8kN/m^2 assuming a wind speed based upon the 'European' wind speed map, which yielded wind pressures double that given by the standard Italian code. The same wind tunnel modelling also allowed wind environment aspects of the stadium design to be studied using hot wire anemometers to measure wind speeds at various locations around the stadium.

Floodlighting

At an early stage in the design of the stadium the edge of the roof was identified as a possible location for the floodlights required to illuminate the football pitch and the athletics track. Ove Arup & Partners analyzed a number of floodlighting arrangements to confirm that the FIFA standards on illumination level and uniformity could be met using luminaires mounted only at the roof edge. For televised sporting events it is normally the vertical illuminances in the directions facing the cameras that are the primary design criteria. The final arrangement of 264 floodlights provides minimum vertical illuminances on the football pitch of 1800 lux towards the main camera position, and 1500 lux towards the secondary positions. The height and geometry of the roof ensures that all floodlights are mounted above critical viewing angles at pitch level, so glare from the lights is not a problem for the players.



13. Approach to the completed stadium

14. Romania v. USSR, 9 June 1990

The 3500W metal halide lamps chosen for the floodlights give high efficiency and excellent colour rendering for colour television. Computerized aiming schedules were produced by the floodlight manufacturer Siemens, and allow the individual alignment of the fittings to provide a uniformity of 1:0.4 (maximum to minimum) across the football pitch.

The finished stadium

Its distinctive appearance makes the stadium a prominent landmark even from a distance. At close quarters, its visual permeability gives glimpses of the interior, and tends to invite visitors into it. Access from the surrounding parking areas is simply by walking up the radial paths to the general circulation area for spectators at the back of the lower tier, where there are toilet and refreshment facilities. The green and yellow seating lends the stadium a summery feel, further enhanced by the canopy, whose translucency becomes apparent when viewed from the inside. At night, the stadium is lit by uplighters, which illuminate the concrete soffit of the upper stands to spectacular effect.

The San Nicola Stadium was completed in time for Bari's opening World Cup '90 Group B match between Romania and the Soviet Union on 9 June, which was attended by 42 000 spectators. Later on, it hosted the third/fourth place play-off match between Italy and England on 7 July, which was played under floodlights before a vibrant crowd of some 52 000.

That occasion, watched by hundreds of millions on TV around the world, was a fitting tribute to the new Bari stadium.

Credits:

Client:
Commune di Bari

Architect:
Renzo Piano, Building Workshop, Genoa

Structural and lighting engineers:
Ove Arup and Partners International

Foundation and specialist concrete engineers:
Studio Vitone, Bari

Contracting consortium:
Bari '90

Roof steelwork contractor:
Petitpierre Sud, Bari

Fabric roof contractor:
Koit Hi-tex GmbH, Germany

Photos:
1,5,12,13: Alistair Lenczner;
7: Tristram Carfrae; 9: Bruce Danziger;
11: The architect; 14: Jack Zunz;
15: Shuji Ishida; inset © Allsport

15.

Business parks: new directions

Stephanie Mills
Brian Carter

Introduction

Following the success of Stockley Park, Arups has been involved increasingly in similar business park developments both in England and overseas. Arup Associates recently won a limited competition with London and Metropolitan plc to develop Broughton Business Park at Milton Keynes, and work progresses on an outline concept and feasibility study for a business park at Villebon-sur-Yvette, near Orly Airport, Paris, jointly undertaken with Chelsfield plc, Shimizu France SA and SOGEA as developers. However, the town authorities have still to select a preferred development team (out of three).

Earlier this year, Arup Associates was the only British entrant in a limited competition for the design of a business park at Hallbergmoos near the new Munich II Airport. Other participants included Maki Associates of Tokyo (the eventual winner), three practices from Munich and one from Dusseldorf.

The Continental approach to these developments makes an interesting comparison with that in the UK, the result of differences in the design brief and development objectives.

Crispin Boyle

Stockley Park Control Data Building

Location

The location of Stockley Park and the development proposals at Hallbergmoos and Villebon are similar in that each is situated in close proximity to a major international airport. Easy access to air transportation is an increasingly important criterion for the types of businesses that make up the composition of first division business parks. The single European market after 1992 should ease further the process of air travel and thus place more of a premium on such locations.

Photographs and drawings by Arup Associates, except where otherwise stated.

2. to 4. Site context.

2. London

3. Munich

4. Paris

Site context

A successful business park requires a certain critical mass. If one excludes the playing fields and golf course at Stockley Park, the site area given over to built development at all three of the above-mentioned business parks is comparable at around 35ha. This stems from the site area required to sustain a development between 90 000m² and 140 000m² of gross office space. It is therefore not surprising that each initiative occupies a site on the urban fringe in order to avoid the difficulties and expense of the land assembly required of urban sites. A major advantage of business park developments is that they can be instrumental in transforming derelict land into prime property.

Stockley Park represents a major achievement in the transformation of badly polluted land. Located within London's Green Belt on the site of former gravel workings and a rubbish tip, a parkland has been created as a setting for new development.

A similar strategy is proposed for the site at Villebon which is located on an excavation tip and Buropark Hallbergmoos which is to be developed on marshy agricultural land.

Access

Like all business parks, Stockley Park, Buropark Hallbergmoos and Villebon are inherently car-orientated. Each has easy access to the motorway network and ample parking. This emphasis on individual mobility is both an attraction and a constraint. In Britain a new generation of 'mid-urban' parks is emerging (eg Chiswick Park) to reduce reliance on the car, while on the Continent endeavours are made to extend or connect into public transportation systems. The only public transportation at Stockley is a local bus service, while at Hallbergmoos an extension of the S-Bahn (fast suburban trains) is proposed to link the site with the airport and the centre of Munich. In addition to this, the Arup Associates entry suggested a future underground spur off the S-Bahn to feed three stations positioned in the heart of the enterprise zone. Villebon is currently served by the RER line B4, and 5km away at Massy is the future site of the TGV terminal and RER line C. The site will thus be very well connected into the rapid metropolitan rail system as well as the European high speed rail network. British business parks could benefit from better links to public transportation.

Parking

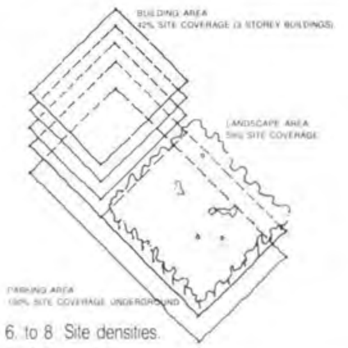
Initial development requirements at Stockley Park were for a parking ratio of 1 bay for every $33m^2$ of development, a figure which is comparable to ratios at Hallbergmoos and Villebon (1:$30m^2$). To date, all parking at Stockley has been accommodated in the open air at grade in landscaped courts. At Hallbergmoos the client's brief demanded that parking requirements had to be met in underground structures which ultimately would cover the entire site area of each development parcel on a single level. Unlike Britain, covered parking is taken as standard in Munich, so ventilating such structures and landscaping over large concrete decks is more commonplace, and the cost is taken into consideration. At Hallbergmoos this process was facilitated by the need to excavate the area to remove peat and to raise the ground level to reduce the impact of a high water table. At Stockley the parking ratio, originally limited by the local authority, was found to be inadequate and has recently been increased to 1:$23m^2$, which for the first time makes structured parking necessary and opens up new site planning constraints.

Densities

Buropark Hallbergmoos has a plot area ratio of 1:1, double that of Phase 1 at Stockley Park (1:0.5) and Villebon (1:0.6). The higher density and greater site coverage (42%) produce a more urban character and it is the proposed three-storey buildings that are used to create a coherent framework and to give definition to public spaces. Underground parking allows the remaining 58% of the site to be given over to landscaping. This approach contrasts with the lower densities at Stockley Park and Villebon where landscape elements, rather than buildings, are used to determine the character of the site and to structure public space. This is not to say that the form of the buildings (ie low rise, pitched roof silhouette) at Stockley do not make an important contribution to the overall character of the development. In Phase 1, buildings of mostly two storeys have a site coverage of 25% with a further 50% given over to surface parking and the remaining 25% to landscape. The proportions at Villebon are similar. However, Phases 2 and 3 at Stockley have higher plot area ratios than the first (an average of 1:0.8 and 1:0.6 respectively), which together with the greatly increased parking ratios, is changing the character of the development to one that is much more urban.

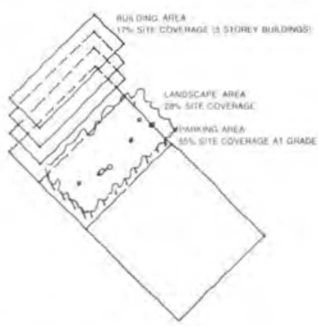
5.

Peter Cook

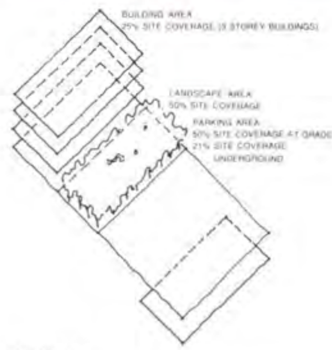


6. to 8. Site densities.

6. Stockley Park



7. Hallbergmoos

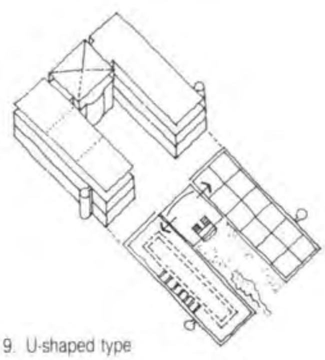


8. Villebon

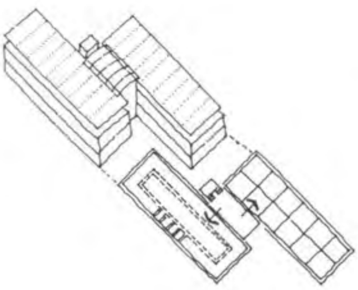
Building types

The brief for Buropark Hallbergmoos was for a combination of single tenant (40%) and multi-tenant buildings (60%) while at Stockley Park only 10% of the total floor area is occupied by multi-tenant groupings. Arup Associates have completed 12 buildings to date at Stockley, variations on a pavilion type of building developed to meet tenant requirements. The square shape derived from the need to minimize the proportion of the external envelope which constitutes 37% of the total building cost. These buildings have been developed as shell-and-core only and are based on an 18m module on either side of a 6m or 9m atrium which has proven to be extremely flexible and space efficient (90% usable floor area). Initial floor plate sizes of $3250m^2$ were found to be at the uppermost limit for easily lettable space and a reduction in area to $2500m^2$ has resulted in the change from two to three storey buildings (also specified at Hallbergmoos and Villebon). These buildings are more prominent in the landscape and together with increased parking ratios they call for a change in the design rules for development.

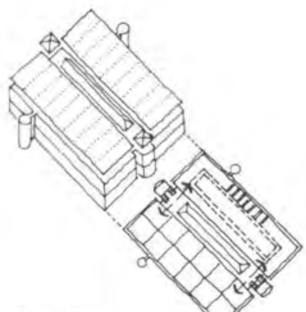
The square building type was retained for single tenant requirements in the proposal for Hallbergmoos, but the high proportion of multi-tenant space requirements led to the evolution of a linear type building tailored to accommodate flexible spaces ranging from $300m^2$ to $6000m^2$ with a lower overall efficiency of 80% specified. At Villebon these requirements have not as yet been ascertained, but in current phases at Stockley Park the proportion of multi-tenant space is likely to increase to the region of 30%. This might therefore suggest a different building type with its own identity as in the Munich example.



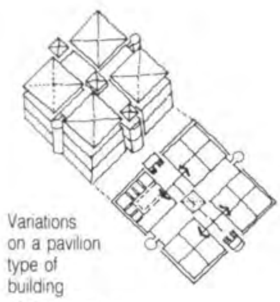
9. U-shaped type



10. Linear type



11. Doughnut type



Variations on a pavilion type of building

12.Square type

Mix of uses

The genesis of business parks stems from the changing nature of industry (ie the transition from manufacturing to services) and historical links between universities and industry in the United States after the Second World War. The resultant research and development parks concentrated high technology companies in campus-type settings and facilitated an exchange of ideas for mutual benefit. Earlier industrial estates and many Continental examples tended to mix high technology industry with goods storage and distribution uses. Part of the success of Stockley Park in the real estate market has been its rigorous adherence to B1 (ie 'clean' or high-technology industry and business) uses only. This enabled environmental standards to be raised and has created a new image for such developments, allowing them to command high rentals.

These communities generate other requirements. The Arena Building at Stockley Park is at present the only multi-purpose building in the development catering for communal needs. It houses the central administration and management suite, a restaurant, wine bar, conference facilities, indoor sports centre and minor retail and service outlets. The Continental equivalents encourage the integration of a much broader mix of uses both in general, and within individual buildings.

The development at Villebon is planned to include a greater range of facilities including an hotel. At Buropark Hallbergmoos, Arup Associates proposed a central linear spine to the business park to concentrate and unify the disparate retail, restaurant and service facilities listed in the brief.

This spine would be connected to the proposed underground rail system and would include residential accommodation in the form of apartments and hotel space.

A conference centre is also proposed, and the construction of an adjoining hotel was already completed.

13. Hallbergmoos
Detail of site plan

Overall framework

A strong design framework is required for developments of this scale if coherence and an overall identity are to be achieved. This is particularly so if the buildings are to be designed by a number of different architects, in which case the evolution of guidelines is essential, as is the choice of architect(s), and the establishment of a management structure to guide the process of design, development, change and maintenance. This requires a strong ongoing commitment on the part of the client and the masterplanner.

At Stockley Park the client retains the freehold of the development in order to maintain quality control and this is backed up by the dedication of the master planning team with Arup Associates as prime agents. A sense of unity has been achieved by means of a consistent landscape structure and a building vocabulary established through the design, by Arup Associates, of many of the buildings. The landscape structure is informal with green valleys containing lakes penetrating development parcels to create prime frontages. A progression of street-parking-front-entrance is set up with each building fronting onto landscape amenity. Development is concentrated in the southern part of the site while to the north, where the land form has to be sculpted by landfill transfer, a golf course and playing fields have been created. This public amenity land is shared with the adjoining residential neighbourhoods. More formal landscape elements and axial devices are used around and between buildings and to create courts to conceal car parking. A double avenue of lime trees structures the space adjacent to the building sites and links different phases of development along a common access road.

At Buropark Hallbergmoos a formal development framework was created in response to the flat marshy landscape with its linear drainage canals and the geometric order of the adjoining settlements. The higher density and decked parking also demanded great rigour. Arup Associates' response was to create coherence by means of a gridded layout with a series of north-south avenues parallel to the canals and reinforced by lines of tall poplars. All vehicular access (excluding service vehicles) to each development parcel would be off these avenues into a shared courtyard space defined by buildings. Drop off points would occur at grade within these courtyards, as would a single access point to the basement parking below, with a network of pedestrian routes penetrating the site. The curved arc generating the central space in the first development parcel is the result of one such pedestrian route linking the town with the central spine.

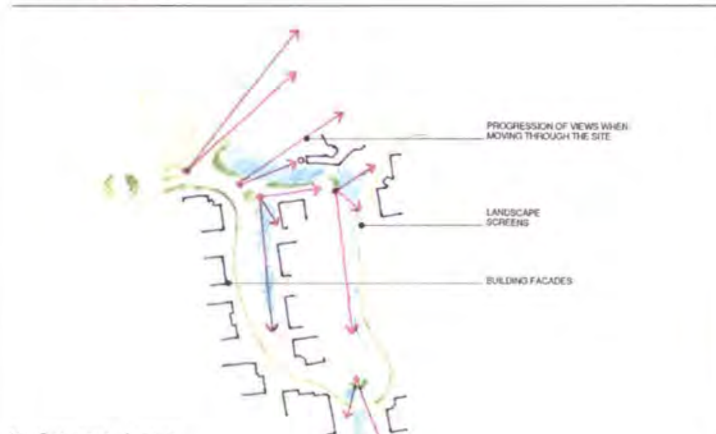
The single tenant pavilions would front onto this spine with multi-tenant buildings located to the rear. The development is essentially linear and runs parallel to the wooded belt along the Isar River to the west, and the existing settlement of Hallbergmoos to the east. It is reinforced by a zone of woodland planting along its eastern length to act as a buffer to the adjoining settlement and to conceal disparate developments along this frontage. Two urban parks will separate different phases of development.

The site layout at Villebon has many similarities with that at Hallbergmoos. A linear development is planned with parcels fronting onto two existing river corridors that traverse the length of the site. The roads would be reinforced by formal avenues of trees while at-grade parking would be visually contained within courts created by hedges. The river corridors, expanded to create larger water bodies, are conceived as 'informal' natural landscaped elements, in contrast to the orthogonal formality of the roads, buildings and parking areas.

Stockley Park

14. Public open space

16. Landscape structure



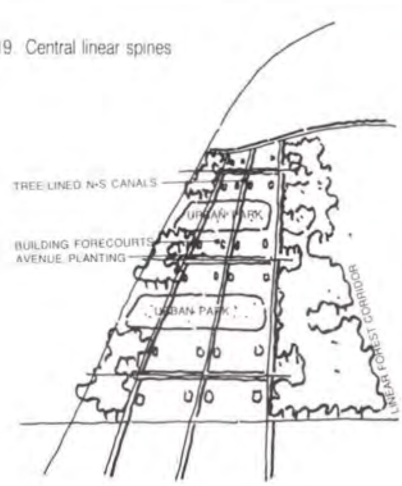
15. Sequence of views

17. Building relationships

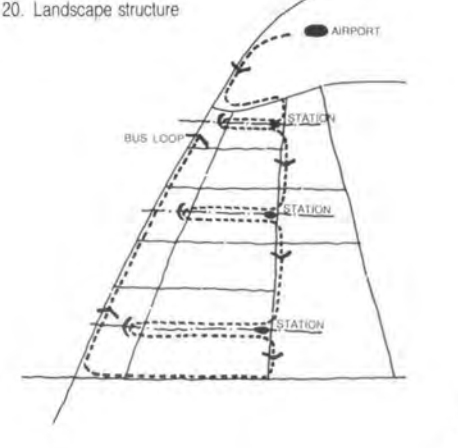
Hallbergmoos

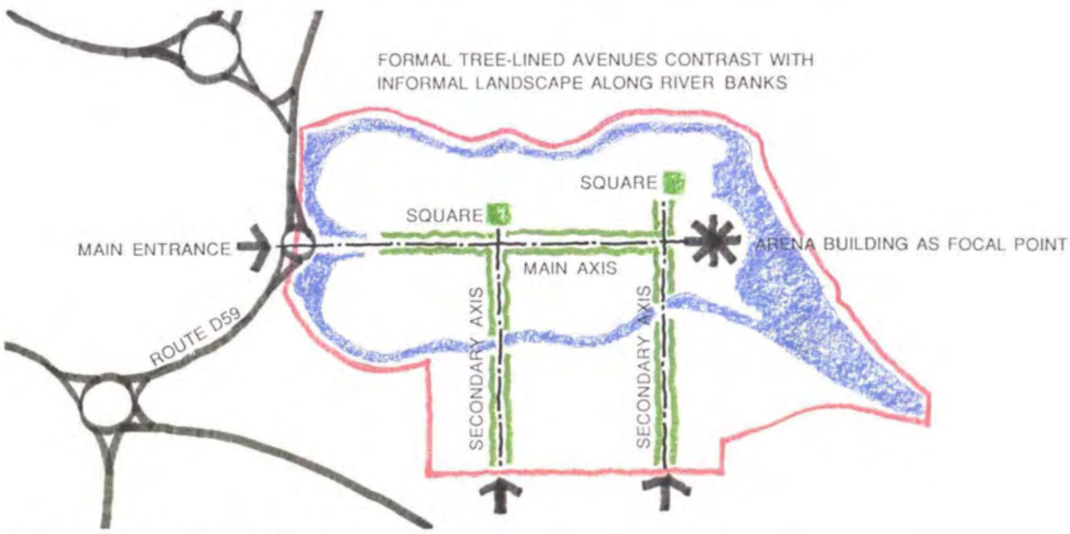
18. Street framework

19. Central linear spines



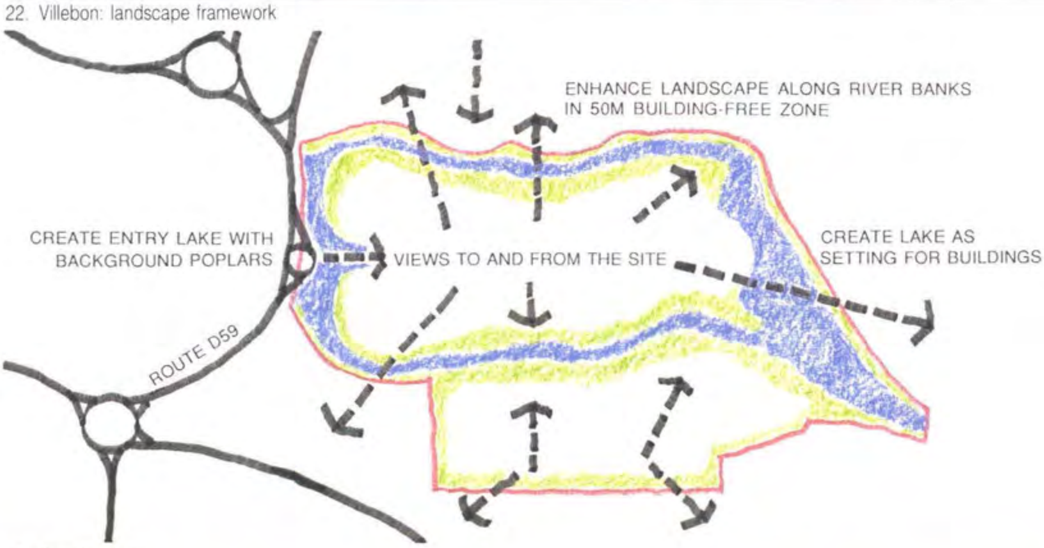
20. Landscape structure





21. Villebon: urban design framework

22. Villebon: landscape framework



23. Stockley Park

Crispin Boyle

Conclusions

According to a *Financial Times* Survey (11 May 1990), 800 new business parks are currently planned in the UK, totalling 30 million m^2 of campus-type office space, the equivalent of 30 years take up of space at current rates. These figures suggest that a reassessment is required about:

- the viability of many of these developments, particularly in the light of competition from other European equivalents in an open market post-1992;
- the impact of such developments on our cities and the quality of life that they engender.

New directions point the way to:

- a reassessment of business park locations and optimum sizes
- improved public transportation
- a much greater emphasis on energy efficiency
- a richer mix of compatible uses
- increased densities and higher parking ratios requiring a rethink about the concept of 'park' setting and the design rules for development
- a clear vision and strong design framework, particularly within a structured landscape, in which coherent development can occur
- a commitment to architectural excellence and landscape quality
- an ongoing assessment of building types
- effective management and control.

63 St. Thomas Street

Architect: Mills Design Partnership

Chris Ambrose
David Fullbrook
John Loader

Arups' new office in Bristol was originally constructed in 1952 as a two-storey pharmaceutical warehouse occupying an irregular corner site of approximately 45m by 35m. The internal structure was a concrete-encased steel frame on a regular grid, approximately 5.5m square, supporting a concrete hollow pot slab at first floor and roof levels. The external walls were of solid load bearing masonry construction. The headroom at first floor level was not generous (2.35m to underside of beams), which made the deep-plan internal space oppressive.

The architect, Mills Design Partnership, had obtained planning permission on behalf of the previous owner for Change of Use to provide 2320m^2 of offices around an open courtyard on the upper two levels, with car parking at ground level.

Ove Arup Partnership purchased the building in July 1988 and over the next three months this basic scheme evolved into a building which met the needs of a large multidisciplinary design office. The central courtyard concept was changed to a glazed atrium, to provide visual and physical links between all parts of the offices on the upper two levels. The roof glazing gave a good level of light, in particular to the parts of the office next to the windowless party wall. All design and support groups within the office operate in a single space, with a spiral staircase in the atrium linking different engineering disciplines on each level.

The major remodelling of the building involved the removal of the existing flat roof, and its replacement with a metal deck and in situ concrete floor to act compositely with the existing steel beams to form an additional floor with 'institutional' loading. A new triple bay, tied portal roof structure, exposed internally, was built, with the central bay glazed to form the atrium.

The alteration work involved areas of local strengthening of the structure, and checks that changes in column loads did not overstress the large concrete pad foundations. The irregular plan shape posed problems of detail where new steelwork was to be exposed internally, in particular along one side of the office where the span of each truss is different, and where the roof ridge rises as the truss spans increase, to maintain a constant roof pitch.

Provision of all design office facilities on the first and second floor levels enabled the totally enclosed ground floor space to be replanned to accommodate the enlarged entrance area, a large fully serviced lecture theatre to seat 150, a lounge, printing facilities, archives, mechanical and electrical plant and parking for 21 cars, with space for motorcyles and bicycles.

The triple height entrance contains a spectacular suspended steel staircase which returns back on itself to give access to the reception area across a steel bridge on the first floor.

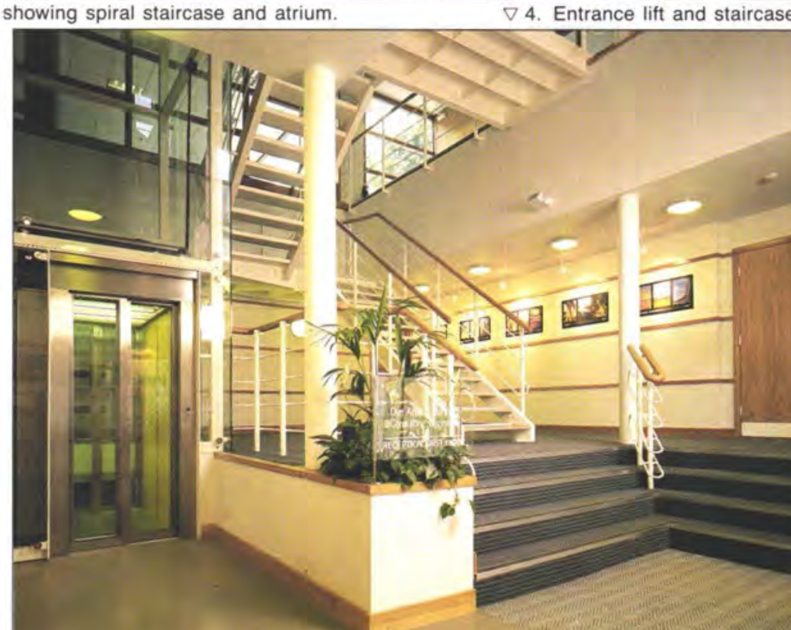
Throughout the design, the materials and components reflect the designers' interest in the use of lightweight, economical, well-detailed and maintenance-free materials. The atrium has a ceramic tiled floor, and large brick planters containing Californian Palms. The time of day and seasons are brought into the office by the play of sunlight and shadows and the introduction of artificial lighting in the winter.

American Oak was used for the exposed joinery of the handrailing, and glazed screens give a feeling of lightness and quality, as well as low maintenance costs.

Externally, the original brickwork and reconstructed stone surrounds were cleaned, the walls raised with contrasting banded brickwork, and capped with precast concrete decorative cills to support the additional floor of continuous glazing under a slate roof. The new second floor structure is expressed externally with yellow clad columns, set freestanding from the continuous ribbon glazing; the remaining windows in the original structure have been replaced with contrasting powder-coated, double-glazed windows.

1. △ Before conversion 2.▽ and after.

△ 3. Interior showing spiral staircase and atrium.



▽ 4. Entrance lift and staircase.

SERVICES ASPECTS

Environmental considerations

The inward looking building form, with only three walls having windows, low ceiling heights and the introduction of the atrium suggested that a comfort cooling system would be required. Computer needs confirmed this.

The system needed to be as simple as possible, economic to install and run, and to avoid most of the problems currently associated with controlled environments. After considering a number of possible options a displacement ventilation and cooling system was deemed to be the most appropriate. (See Displacement System Panel).

Air-handling plant is located at ground floor level in the car parking area, with primary air ducts routed horizontally, making use of the generous floor to ceiling height at this level. Secondary air ducts connecting to supply-and-extract air terminals are brightly coloured and routed vertically, overcoming the problem of the existing low ceiling at the first floor level and allowing the new roof form and structure to be expressed.

All the building fabric now conforms to the current Building Regulations, which required upgrading of the thermal performance of existing masonry walls and the first floor slab. Double glazing has been used throughout; the atrium glazing is of the low emissivity/solar control type, retaining heat in winter and reducing solar heat gain in summer. Fabric heat losses are offset by a purpose-designed perimeter convector heater fed by compensated heating circuits and a pipe coil surrounding the atrium. The existing boiler and circulation pumps have been refurbished and re-configured into a multi-zone primary/secondary heating arrangement.

Energy management

A traditional analogue control system was originally intended for the mechanical services. Further research, however, prompted the use of a Trend energy management system (EMS), held on an Apricot XEN-i within one of the Building Engineering teams. In its current form, this system is fairly rudimentary but provides direct digital control (DDC) of the mechanical services, enabling tailoring of control strategies according to operational experience, particularly for the displacement system.

Lighting

Lighting of the first floor is by recessed luminaires with semi-specular low brightness louvres and high efficiency compact fluorescent lamps. A design illuminance of 750 lux and a high degree of uniformity is achieved in the open plan office areas. Low voltage dichroic lamps provide accent lighting in the core areas, main conference room, reception area and main entrance.

Lighting of the second floor is designed to complement the pitched roof form and exposed structure and services. After considering a number of options, including uplighting, the chosen system combines brightly coloured tubular 'pipeline' fluorescent luminaires with task lighting of individual workstations. This arrangement provides an ambient lighting level of 400 lux with the task lighting raising this locally to 750 lux. Lighting track incorporated in the pipeline system also allows for uplighters to emphasize the roof form.

During the daytime the atrium floods the interior with natural light, increases outside awareness and relieves an otherwise deep plan building form. In the evening, the mood changes but the outside feel is maintained by the use of linear metal halide floodlights and spherical luminaires of the external type with MBF lamps.

A lighting control system provides automatic switching of circuits on a workstation-by-workstation basis. This is configured to provide illumination for daytime lighting, cleaning and security modes, thus minimizing electricity consumption and maximizing lamp life. A programmable microprocessor controller uses mains signalling to switch groups of luminaires. This can be manually overridden by local switches for a pre-set period.

Displacement system

The office uses a system of displacement ventilation and comfort cooling, comparatively recent and undocumented in this country but used more widely in Scandinavia. Its principle is, however, age-old: as cold air falls, warm air is displaced and rises because it has a lower density and is therefore more buoyant.

Air is supplied to the office at very low velocities by displacement terminals and at a temperature slightly below the ambient in the space, and then fills it from floor level upwards. Heat sources within the office cause convective air flows which are displaced upwards whilst attracting the cooler supply air in at floor level at an equal rate. By extracting the heated air at high level a cycle of upward air flow with virtually no mixing in the occupied space is established (Fig. A).

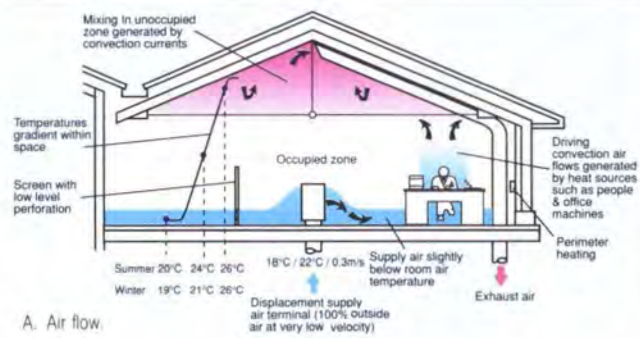
The system was modelled with the assistance of Arup Industrial Engineering using computational fluid dynamics (CFD) techniques, which determined some of the limitations of the system, clarified internal planning restrictions on office furniture close to the terminals, and prompted the introduction of a perforated section at the base of the office screens to improve air distribution from the displacement terminals. In practice, more air is required than originally designed for at the second floor level, due to the atrium effect and limited ability of the sealed glass balustrade to contain the second floor environment. This has been addressed by some re-balancing of the air and water systems.

The system uses 100% outside air without recirculation, which together with the method of air distribution, results in a much higher ventilation efficiency than more conventional mixing systems. It also recognizes the presence of 'olfs'. (This measure of atmospheric impurity, from the Laboratory of Heating and Ventilation, Technical University of Denmark, is defined as 'being the air pollution from one standard person, i.e. an adult sitting in comfort with a standard hygiene of 0.7 baths/day'!). With this system impurities rise to high level and are not re-circulated or remixed in the space, thereby minimizing any irritation to eyes, nose and throat. Supply and extract air volume flow rates are varied from 50% duty in winter to 100% duty in summer by means of two-speed fans.

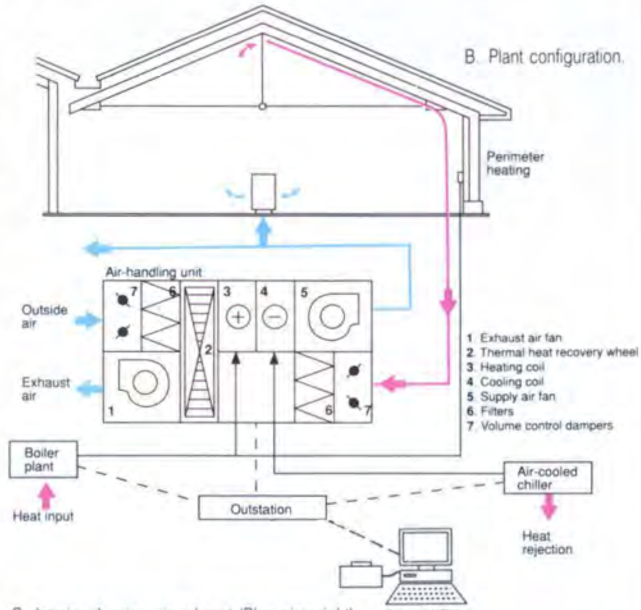
The displacement system allows the use of a higher supply air temperature when compared with traditional mixing systems, enables greater use of 'free-cooling' by outside air, and minimizes the need for refrigeration plant. The supply air temperature is reset from 18°C to 22°C from summer to winter.

Thermal wheels heat the supply air, recovering some 80% of the heat in the extract air stream (Fig. B). Top-up is by heating coils in the air-handling units supplied from an existing modular gas-fired boiler. During mid-seasons little boiler power is required. Cooling of the supply air is achieved by chilled water coils in the air-handling units, supplied from an air-cooled chiller. The higher supply air temperature permitted more economical sizing of the cooler coils and chiller.

It was recognized that low humidities could arise under certain winter conditions with this system. However, as it was not possible to ascertain the contribution of atrium planters at design stage, building performance was monitored in use.



A. Air flow.



B. Plant configuration.

C. Interior showing air exhaust (Blue pipe right).

Power, communications and data
Low voltage incoming power is taken from a SWEB substation located within the building and is distributed from the main switchboard to the office areas. Power is distributed at the first floor level via a dado trunking integrated with the perimeter heating unit and around internal columns. The greater headroom available at the second floor level allowed the introduction of a raised floor with power being distributed via an *Electrak* underfloor distribution system to floor boxes having power, telephone and data outlets.

Mercury and BT telephone lines are brought into the building to a new digital PABX and the system is programmed to choose the cheapest available route.

Computer equipment is fed by clean supplies and data wiring has been installed for an Ethernet local area network (LAN). Sufficient capacity has been allowed in the system so that any workstation can be connected in the future. Currently, Perq/CADRAW machines, an Integraph workstation and Compaq with Autocad are connected to an HP7585B plotter through the Ethernet system, and requirements will dictate further expansion.

5. The auditorium

6. The atrium

5△ 6▽

Fire protection
The fire alarm and detection system consists of manual break glass units and automatic smoke/heat detectors linked to a panel in the main entrance. A fire hose reel system and portable fire extinguishers have been provided for first aid fire fighting use.

Security system
Access is controlled from the main entrance and car park. Entry is by means of electronic tags issued to all staff or by remote release from the reception desk. CCTV monitoring and a two-way intercom system are also provided at the entrances. An intruder system monitors all external doors and is linked to a remote security monitoring centre via an auto-dialler.

Audio-visual facilities
The auditorium at ground floor level was developed in conjunction with Arup Acoustics for both client presentations and for use by the Partnership as a whole. Included are:

- Seating capacity for up to 150
- 35mm slide projection and dissolve
- Video presentation of VHS and U-Matic formats and provision for computer generated images
- Sound reinforcement system
- Audio reproduction from any source
- Recording of proceedings
- Audio induction loop for the hard of hearing and for use with simultaneous translation equipment
- Tie-line infrastructure for special events
- An open learning centre containing computer equipment and audio booths

Houselighting facilities suit simultaneous projection and note-taking. Dimming and source control allows the creation of the right atmosphere for different events.

Procurement and commissioning
In order to speed up the design and construction period a management contractor was appointed and a decision made to procure major items of equipment and specialist systems direct from the suppliers ourselves. The traditional trade contractors were then asked only to provide and install pipework, ductwork, cables, etc., with all the plant items being issued free. This proved successful at reducing both the time scale for completion and overall capital cost of the installation.

Credits:
Client:
Ove Arup Partnership
Architect:
Mills Design Partnership
Consulting engineers — structure, building engineering services:
Ove Arup and Partners
Quantity surveyors:
W.P.E. Ltd.
Management contractor:
Pearce Construction (South West) Ltd.
Mechanical contractor:
Drake and Scull Engineering Ltd.
Electrical contractor:
David Fear Ltd.
Commissioning:
Arup Research and Development (Commissioning Group)

Photos:
1, 4, 5, 6, C: Chris Bland
2, 3: Brian J. Middlehurst

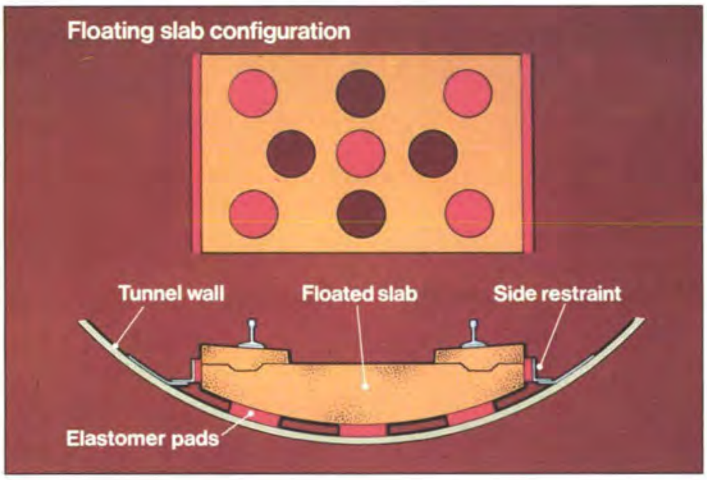
ARUP ACOUSTICS IN HONG KONG

Introduction

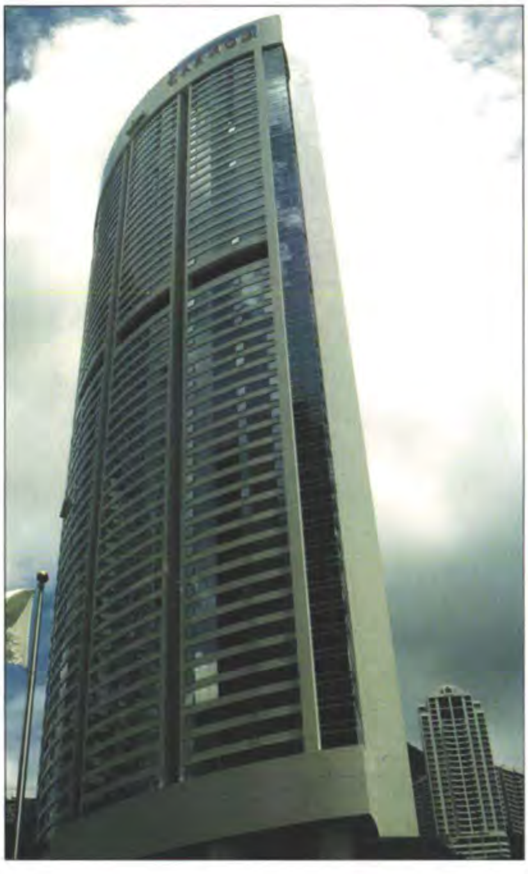
Acoustic consultancy for Sir Norman Foster's Hongkong Bank Headquarters building took Arup Acoustics to Hong Kong in August 1980. The project required studies of railway track isolation, construction noise and vibration controls (including controls on blasting in the seawater tunnel and for rock anchors), atrium acoustics, boardroom voice enhancement, public address, floor dynamics and sound insulation.

Such a commitment attracted enquiries for other work — and work of sufficient technical interest to justify enthusiasm for its development. Early acoustic consultancy projects covered a wide range of interests. Commercial development projects were commonplace, eg with the Swire developments at Taikoo Shing Phase II and Pacific Place 2, where the practice dealt mainly with sound insulation, impact noise control, building services noise and vibration and electroacoustics, and guidance on construction noise controls to EPD (Environmental Protection Department) requirements. Acoustic advice was required for two Ove Arup & Partners' projects in China, the Hilton Hotel in Shanghai and noise protection for the control room area at the Shajiao Power Station. In addition to a growing range of smaller and varied commissions, Arup Acoustics was also appointed to carry out a full acoustic consultancy for the Hong Kong Convention and Exhibition Centre.

Work continues to develop in environmental studies (particularly construction noise controls); Government projects; overseas in Macau, Taiwan and Indonesia; and for major building projects, which include many hotels. Last year the Jockey Club appointed Arup Acoustics to advise on the new University of Science and Technology.



1. Hong Kong Bank: detail of track isolation



2. Pacific Place

Hong Kong Convention and Exhibition Centre

It is perhaps surprising that a trading centre as important as Hong Kong did not, until recently, have a dedicated Exhibition Centre.

However, in 1984 the Hong Kong government signed an agreement with a developer to create the Hong Kong Convention and Exhibition Centre. Arup Acoustics were appointed as acoustic consultants. In early 1985, a start was made on a magnificent site on the north edge of Hong Kong Island, overlooking the harbour. One building contains exhibition and conference facilities, two world class hotels totalling nearly 1500 rooms, 1170m^2 of office space and a residential tower. In Hong Kong this means building vertically.

The convention facilities include a large conference hall (2600 delegates), two theatres, and two floors of meeting rooms of differing sizes. Operable walls (large, sliding, sound-insulating panels) enable the conference hall and meeting rooms to be subdivided.

Building vertically presented unusual challenges in the acoustic design, in particular, protection of the conference spaces from the substantial impact noise created in the exhibition halls as, for a number of practical reasons, the two theatres and the main conference hall had to be located directly beneath them. Cargo lifts allowed 40ft container lorries onto the exhibition hall floor. The manoeuvring of such large vehicles, unloading, hammering and fixing associated with exhibitions would bring substantial impulsive forces into the structure.

The theatres were constructed as totally isolated box-in-box structures on isolation pads.

The conference hall, being large and normally served by sound reinforcement, was slightly less critical than the theatres where lower background noise limits were appropriate for natural speech.

Therefore, a double slab was installed above, the top slab being isolated. The conference hall walls were isolated from the exhibition hall floor and a floated heavy ceiling used.

To be effective, the natural frequency and damping of this system had to be tightly controlled, the natural frequency being well separated from that of the supporting structure and the floating ceiling beneath. The ratio of 'dead plus live' load to 'dead' load was highly variable. Although a

3. Hong Kong Convention and Exhibition Centre

4. Conference hall showing isolated ceiling and operable walls

low isolation frequency was possible with limited loading, it was necessary to increase the stiffness of the isolation system as the load increased, by using a composite isolation pad construction.

50mm deep isolation pads were used to support the floor during low load conditions. As these pads deflected, a second set of 25mm deep pads, the top surface of which were 3.7mm lower than the first set, and which were much stiffer than the other pads, were brought into play.

The dynamic design of the floating ceiling beneath the floating floor was less complex. The sound insulation was provided by three layers of gypsum board and architectural cladding panels on a steel frame.

The assembly was supported on conventional spring hangers from the fixed slab beneath the floating floor.

As might be expected, the installation of the ceiling was a very complex task in practice. The void above the floating ceiling was densely packed with air-conditioning ducting and other building and theatrical services, most of which had to penetrate the ceiling as did the supports for the operable walls. The detailing of these potential sound insulation weaknesses and vibration flanking paths was the most critical phase of the design.

On completion, tests to assess the effectiveness of the isolation were conducted. A 100mm diameter steel ball falling over a range of distances onto different materials was used as an impact source. The most severe impacts were audible within the ceiling void above the conference hall but not within the hall itself, showing that the objective was met.

The auditorium acoustics, sound reinforcement system, sound insulation and services noise and vibration controls have also achieved good standards in challenging circumstances.

5. Theatre 1 at the Convention Centre

New University

The Hong Kong University of Science and Technology located in the New Territories and largely funded by the Jockey Club involves high standards of research and development necessary to allow Hong Kong to compete with the other Pacific 'dragons'. The first phase must be ready for the start of the 1991 academic year.

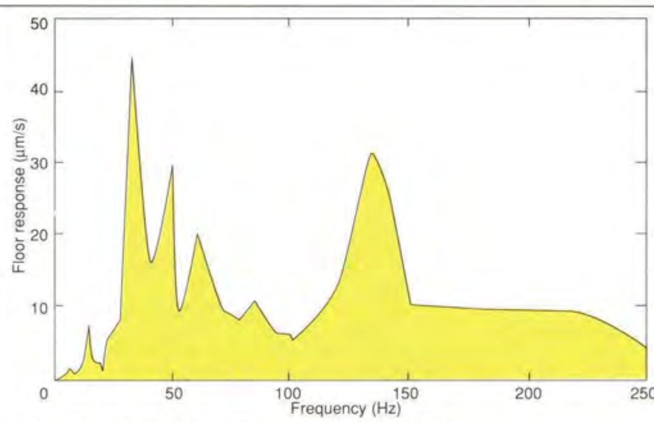
Flexibility has been an essential element of the planning of the academic buildings, often competing with acoustic requirements.

The lecture theatres and other fixed teaching facilities were relatively conventional designs. However, there was a requirement to provide many smaller rooms with a good standard of sound insulation which could also be simply and quickly rearranged.

The use of proprietary relocatable acoustic partitions was outside the budgetry constraints and a flexible system had to be developed using conventional dry walls with a special high density ceiling to control noise flanking via the ceiling voids.

Vibration from footfalls, local impacts or services, was a key issue in view of the intended use of highly sensitive laboratory instruments. To a certain extent preference for stiff structures ran counter to the flexibility requirements of as much column-free space as possible. Extensive and detailed dynamic analysis showed that constraints would have to be imposed on the location of very high precision equipment, and each area was studied to enable the users of the building to plan for this.

6. Model of the new Hong Kong University of Science and Technology.



7. Vertical response of structural laboratory building floor

From discussions with the academic staff it was agreed that some planning restraint would not adversely affect the planned usage of the buildings. Widespread stiffening of the floor slabs was thus avoided. Studies by Arup Acoustics also enabled laboratory bench design to limit response to vibration.

Photos:
Arup Acoustics/Ove Arup & Partners

The design and construction of M40

Dennis Bradley

1. CRCR paving train: Banbury contract.

Introduction

As a rule the design and construction of a motorway is a long and drawn-out process and the London – Oxford – Birmingham Motorway M40 is no exception. After a planning period stretching back to the immediate post-war years, the London to Oxford section of M40 to Waterstock was finally opened to traffic in 1974. Meanwhile the feasibility study into the need for a new route between Oxford and Birmingham had commenced in 1968 and was completed in October 1969. In May 1970 the government White Paper *Roads for the Future* confirmed the need for a new route between Oxford and Birmingham and it was included in the Trunk Road Preparation Pool in 1972. In the same year the Draft Line and Side Road Orders were published for the section of M40 northwards from Warwick and M42 around the south side of Birmingham. In the second half of 1973 a seven-month public inquiry was held and the Secretary of State announced his decision on the lines for M40 northwards from Warwick and M42 in August 1976.

In November 1981 the Draft Line and Side Road Orders for the Waterstock to Warwick Section of M40 were published and this was followed by a nine-month public inquiry into the Draft Orders commencing in September 1982. The Secretary of State gave his decision on the line of the Wendlebury to Warwick Section M40 in December 1984. The line for the remaining Waterstock to Wendlebury section across Otmoor was the subject of considerable contention and it wasn't until March 1989 that all the Statutory and Compulsory Order Procedures were totally completed for the whole route, over 20 years after the commencement of the feasibility study into the need for a new route between Oxford and Birmingham.

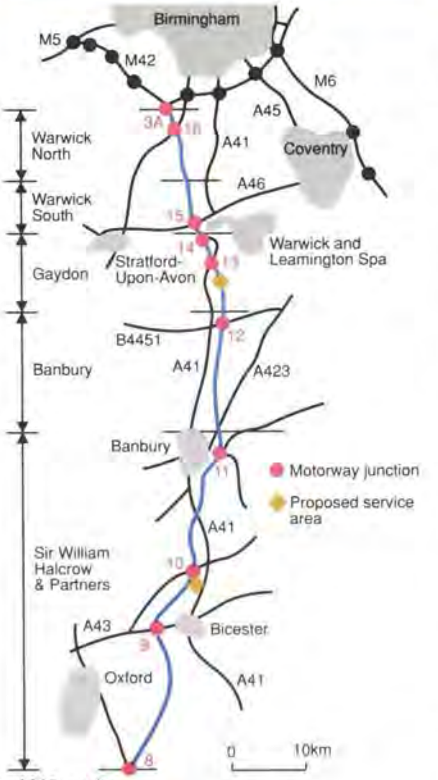
Arups took over the responsibility for the detailed design of the Banbury to Birmingham Section of M40 in January 1982 from the Warwickshire County Council Sub-Unit of the Midland Road Construction Unit when the Conservative government decided to privatize the Road Construction Units. At about the same time Sir William Halcrow & Partners took over the design of the Waterstock to Banbury section. Arups' section of the M40 was split into four contracts and for these the Coventry Highways Office has been responsible to the West Midlands Regional Office of the Department of Transport throughout the design and supervision of construction stages.

Route

The Arup part of M40 starts just south of the Banbury – Coventry Road (A423), at the northern limit of the Halcrow section, and runs north west for 45km to meet the south east corner of the existing Birmingham Orbital Motorway (M42) at Umberslade Park.

The motorway runs generally parallel and east of the existing Banbury – Warwick Road (A41), through the Hanwell valley between the Burton Dassett Hills Country Park and the large military establishment at the Central Ammunition Depot, Kineton, eventually crossing the River Avon south of Warwick.

An interchange is provided on the B4451 about 1km north east of the village of Gaydon. The Leamington Spa and Warwick area is served by the major Longbridge interchange with the A41, A46 and A429 roads and the directional interchanges at Barford and Bishop's Tachbrook.



2. M40 route

Between Warwick and Birmingham the motorway generally runs to the west of the Warwick to Birmingham road (A41) and north of the Warwick to Henley-in-Arden road (B4095). The motorway, after crossing the Hatton branch railway line, runs alongside the Didcot to Chester railway line for 1.5km before crossing the Birmingham – Stratford canal near Finwood and passing under the A34 south of Hockley Heath to join M42 at Umberslade Park. A west directional interchange is provided at the A34, south of Hockley Heath.

Geology

The area between Banbury and Birmingham crossed by the motorway can be divided into two geological classifications. North of Banbury the route is over Middle Lias but very quickly runs into Lower Lias of the Jurassic period which continues through to the Gaydon Road Interchange. From here northwards the route runs down an escarpment where Blue Lias, White Lias, the Rheatic and Tea Green marls outcrop, and then continues to the River Avon on Keuper marl of the Triassic period.

From the Avon northwards the route runs across the Keuper marl series, including Arden sandstones, through to Umberslade Park. Tracts of alluvium and river terrace deposits occur at various locations along the route, with the largest deposits occurring in the Avon valley. Similarly, glacial material from the western and eastern drift is found at various locations along the route.

Archaeology

Three archaeological sites on the route of M40 were examined by the Warwickshire Museum before construction began. They were located adjacent to Little Dassett Road, near Park Farm at Greys Mallory and immediately north of the Birmingham – Stratford Canal near Lapworth. Of the three sites, the most extensive series of excavations took place on both sides of the Little Dassett Road, at the foot of the Burton Dassett Hills, where the buried remains of a thriving 14th century market town, known as Chipping Dassett, were examined and recorded. Large quantities of pottery and other artefacts were also discovered.

Excavations at the other two sites confirmed the existence of an Iron Age settlement at Park Farm and a Roman settlement with tile kilns at Lapworth.

During the construction of the Gaydon Section the Warwickshire Museum was also given the opportunity to examine and record the evidence of the Roman road, Fosseway, which was exposed by the excavation for the pavement of the realigned road.

Design

The design of M40 started in the early 1970s with the mapping of the proposed route and the updating of the appropriate 1/2500th Ordnance Survey sheets. This was followed by the preparation of digital ground models for the route of the motorway and the provision of 1:1250, 1:1000 & 1:500 scale plans.

During the period October 1970 to June 1984 seven ground investigation contracts were carried out by four different contractors with additional information for the M40/M42 Interchange being obtained in the ground investigation contracts for the Birmingham Orbital Motorway (M42).

The detailed design of the road and bridgeworks commenced as soon as the Minister confirmed the line of the motorway, but the main design effort was concentrated into the respective two-year periods before each of the contracts went out to tender, in the latter half of the '80s.

The motorway has dual three-lane carriageways with hard shoulders throughout and an overall width between back of verges of 35.6m. Of its 69 structures, 47 will be seen and passed under by motorway drivers. A consistency of treatment and similarity of appearance of the two-span farm accommodation bridges and the four-span side road bridges distinguishes the Arup section of M40. Most of the overbridges have cast in situ concrete decks with supporting columns, the tops of which are built into the bridge decks. These two features have produced slender, aesthetically pleasing structures and it was very gratifying to receive particular commendation from the Royal Fine Arts Commission in their approval.

3. Lime stabilization in progress: Warwick North contract.

4. Earthworks in progress on Warwick South contract.

Construction contracts

The construction was divided into four contracts (Banbury IV, Gaydon, Warwick South and Warwick North). The first, Warwick South, was let by the Department of Transport on 19 June 1987 and work commenced on site on 27 July 1987. Warwick North started four months later in November 1987, to be followed on 8 August 1988 by the largest and longest of the four contracts, Banbury IV. The last, Gaydon, commenced on 9 January 1989.

Warwick South and Warwick North are now complete and were opened to traffic by the Rt. Hon. Robert Atkins, MP, Minister for Roads & Traffic, on 19 December 1989. The Gaydon and Banbury IV contracts will be opened to traffic early in 1991.

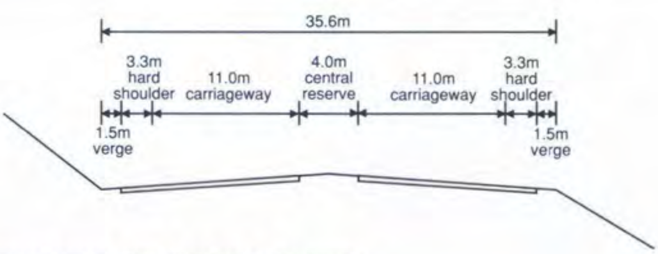
The four contracts have many common features and yet each has its own individuality imposed by the demands of the terrain within which it lies. Site clearance, fencing, pre-earthworks drainage, carriageway drainage, safety fencing and road markings on all follow a similar pattern. It is in the earthworks and pavement works where the individual differences between them occur. The Banbury IV earthworks went very smoothly. The weather was mild and dry; hence the Lower Lias was consistently acceptable for use in the works and the contractor was able to work throughout the winter of 1988/89. On the middle two contracts the earthworks also went well, despite the occasional interruption, but on Warwick North they did not work out as anticipated. More unacceptable material was found than expected and this situation had a disruptive effect on the progress of the contract.

Tenderers for motorway contracts are normally allowed to quote for both flexible (asphalt) or rigid (concrete) pavement construction, the cheaper being selected for the contract. The successful tenders for Warwick South and Warwick North (from R M Douglas and Balfour Beatty respectively) were based on the use of fully flexible pavement construction. However, the contractors for Banbury IV and Gaydon were given no choice by the DTp; they had to construct a pavement which included the use of CRCR (continuously reinforced concrete roadbase). We had, therefore, the tried and tested flexible pavement on two contracts and 'black' wearing and base courses over the new and untried CRCR on the two southern contracts. On Banbury the CRCR was completed in December 1989. The contractor, Balfour Beatty, laid 105 300m^3 of C40 concrete in 25 weeks, at an average output of 4210m^3

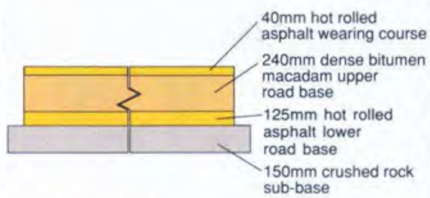
5. Concreting Henley Road Bridge deck: Warwick South contract.

6. Contract details

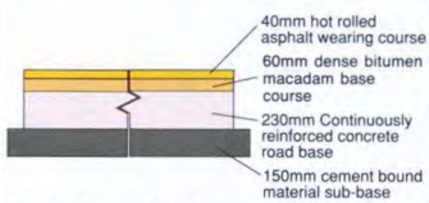
Contract	Construction period					Length (km)	Contractor	Tender total (£)
	1987	1988	1989	1990	1991			
Warwick North						10.4	Balfour Beatty	26 583 531
Warwick South						7.9	Douglas	22 427 267
Gaydon						11.4	Douglas	33 985 307
Banbury						15.8	Balfour Beatty	51 712 704
						45.5km		£134 708 809



7. Typical cross-section: Dual three lane motorway



a) Warwick North and South: Flexible pavement details



b) Gaydon and Banbury: Rigid composite pavement details

8.

9. Two-span farm accommodation bridge.

10. Four-span side road bridge.

per week. It was a very slick and successful operation. At Easter 1990 the CRCR was about 50% covered with its 60mm dense bituminous macadam base course and 40mm hot rolled asphalt wearing course. The final riding quality of this section of motorway should be of a very high standard. Pavement construction of the Gaydon contract, including the CRCR, started in June 1990 and will be completed later this year. It will be interesting to compare the techniques of the two respective contractors, Balfour Beatty and R M Douglas. The motorway will be completed with the construction of the safety fencing, signing, markings and communications.

Special features

To the highway engineer, the Banbury to Birmingham section of M40 includes a number of interesting features.

(1) Lime stabilization has been used, on three contracts, to form a multi-element capping layer to the earthworks formation.

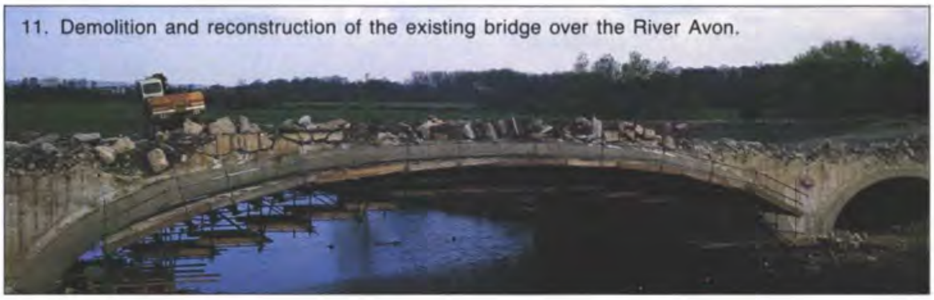
(2) 1.5km of single track railway line has been constructed for British Rail (on the Banbury IV contract).

(3) The bridges on the southern 20km of motorway have been designed to withstand the effects of subsidence due to possible mining at a much later date.

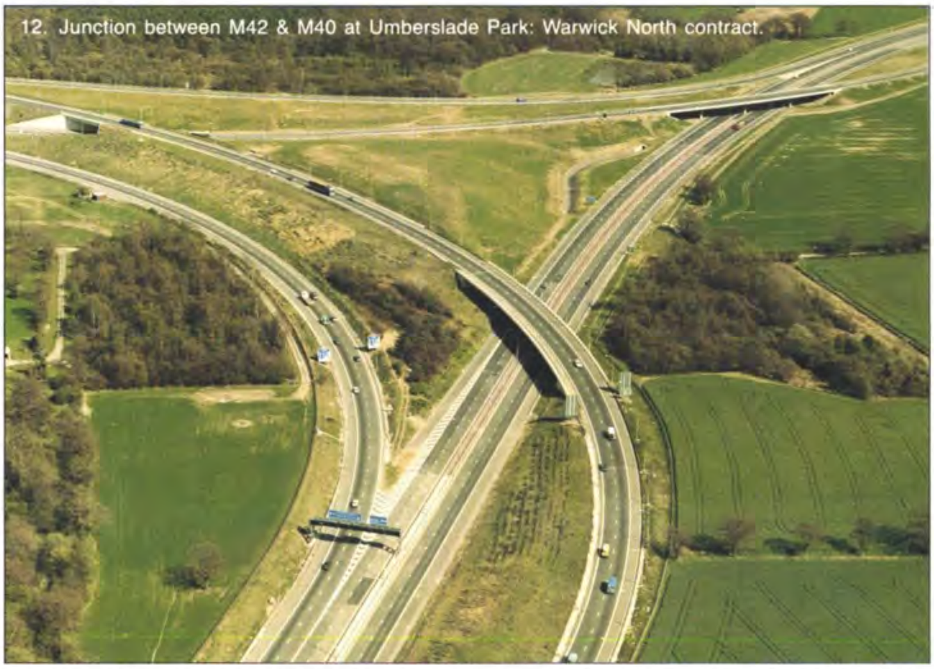
(4) The existing elegant three-span masonry arch bridge over the River Avon has been widened to carry the southbound carriageway of the new motorway. An equally elegant new bridge has been constructed to carry the northbound carriageway.

(5) The three-legged directional interchange at Umberslade Park between the M40 and the M42 west and north has been completed and opened to traffic. The M42 sections were finished in 1985 as part of the Umberslade contract. The M40 connection was opened in December 1989 with the M42 section from Warwick. Arups are now engaged on the design of immediate measures to increase the traffic capacity through the links of this interchange in line with the higher than expected traffic flows both being experienced already and forecast for the future in national statistics.

Every effort has been made in the alignment design of the motorway to sit the route into the topography so that it will cause the minimum visual intrusion to and severance of its surroundings. To this end, extensive visual and acoustic earthmounding has been included in the design. The Department of Transport has also already commenced an extensive programme of tree and shrub planting. In all, about 360 000 plants will be used on the embankment and cutting slopes of the motorway, and the side roads which cross it.



11. Demolition and reconstruction of the existing bridge over the River Avon.



12. Junction between M42 & M40 at Umberslade Park: Warwick North contract.

Severed areas of land in the Department's ownership abutting the motorway have been landscaped and these too will be planted. However, the M40 will still provide the motorist with many pleasant views of rural Oxfordshire and Warwickshire. In the Hanwell valley the villages of Hanwell, Shotteswell, Warmington, Farnborough, Mollington and Great Broughton hug the skyline on either side of the motorway. From just north of the Gaydon Road the motorway drops down into the Avon flood plain with open vistas of the gentle landscape of Warwickshire. Once across the flood plain it starts its climb to Umberslade Park and the landscape changes from the open valleys of Oxfordshire and South Warwickshire to more undulating countryside with smaller fields and areas of woodland. The Tapster valley immediately east of the A34 leads into the parkland of Umberslade with its distinctive tall dark trees.

20 years ago the Government recognized the need for a new motorway between Oxford and Birmingham in its White Paper *Roads for the Future*. Since then many people have been involved in the design and construction of the Arup section of M40 and we hope the road will bring prosperity to the area it serves and be an attractive and safe route for those who travel along it.

Credits:

Client:
Department of Transport

Design and construction supervision:
Ove Arup & Partners

Contractors:
Balfour Beatty Construction Ltd.
R M Douglas Construction Ltd.

Photos:
1,3,9,10,12: Photographic Engineering Services
5: R M Douglas
4: Dennis Bradley
11: Paul Smith

Lintrathen water treatment works

Alasdair Macleod

Historical background

Over a century ago, Dundee needed a better water supply for its growing population, swollen to 140 000 by the expanding Scottish textile industry. 30km north of the city, in the foothills of the Grampian Mountains, the River Melgam was dammed to raise the level of Lintrathen Loch and create a reservoir. The construction of this and the necessary plant in 1873 by the Dundee Water Commissioners was a bold step, releasing the city from reliance on small and inadequate water resources. The reservoir's enlargement in 1911 took care of increasing needs for many years, until in 1969 the River Backwater north of Lintrathen was impounded by a 43m high dam, the first major earth dam of its type in the UK, to create a 3.2km long second reservoir with twice the capacity. Together, Lintrathen and Backwater can provide 100 000m^3 of water daily for two-thirds of Tayside's 394 000 population.

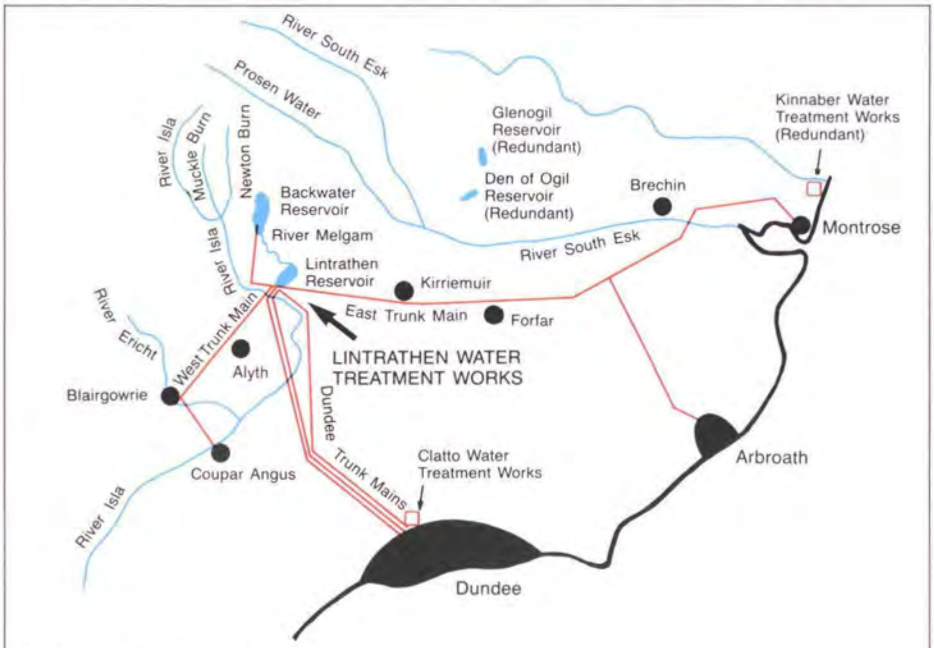
1.

Since 1972, when the £2.2M Clatto water treatment works was commissioned on the outskirts of Dundee, high quality water has been distributed into the city area by trunk mains. Another trunk main to the west supplies the Blairgowrie-Alyth-Coupar Angus area, and a further one to the east serves Kirriemuir, Forfar, Arbroath and Montrose. The inauguration of the new Lintrathen works enables this remainder of the area supplied by Backwater/Lintrathen to have the same high quality of water as the city, and is the culmination of Tayside Regional Council's strategy of taking advantage of the foresight of the former Dundee City Fathers in developing these reservoirs as a regional water source.

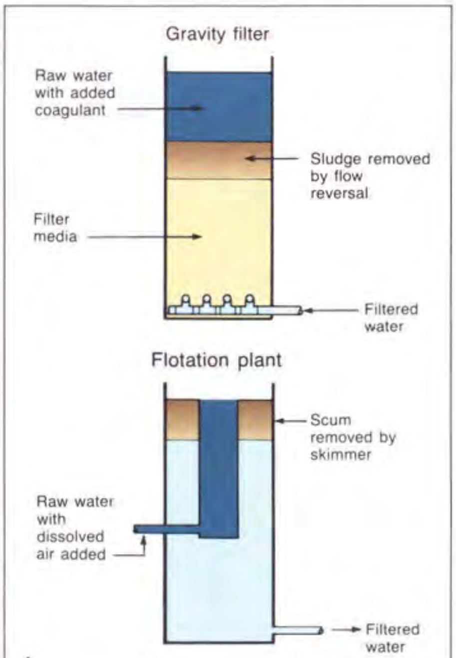
The new plant

The location of Lintrathen was selected because here water can be drawn from both reservoirs and sent by gravity, after treatment, as far as Montrose. The first phase is designed to meet an initial demand of up to 42 000m^3 per day, but the plant can be extended in the future to meet increases in demand up to 70 000m^3 daily.

A pilot unit was set up in 1974 by Tayside Region to compare the economics and effectiveness of dissolved air flotation with Clatto's direct filtration system (see Fig. 4). It was found that the advantage offered by flotation would be offset by increased electrical costs for recirculating water and for additional chemicals. It was later confirmed that dissolved air flotation would be higher in both capital and running costs.



2. Tayside water network



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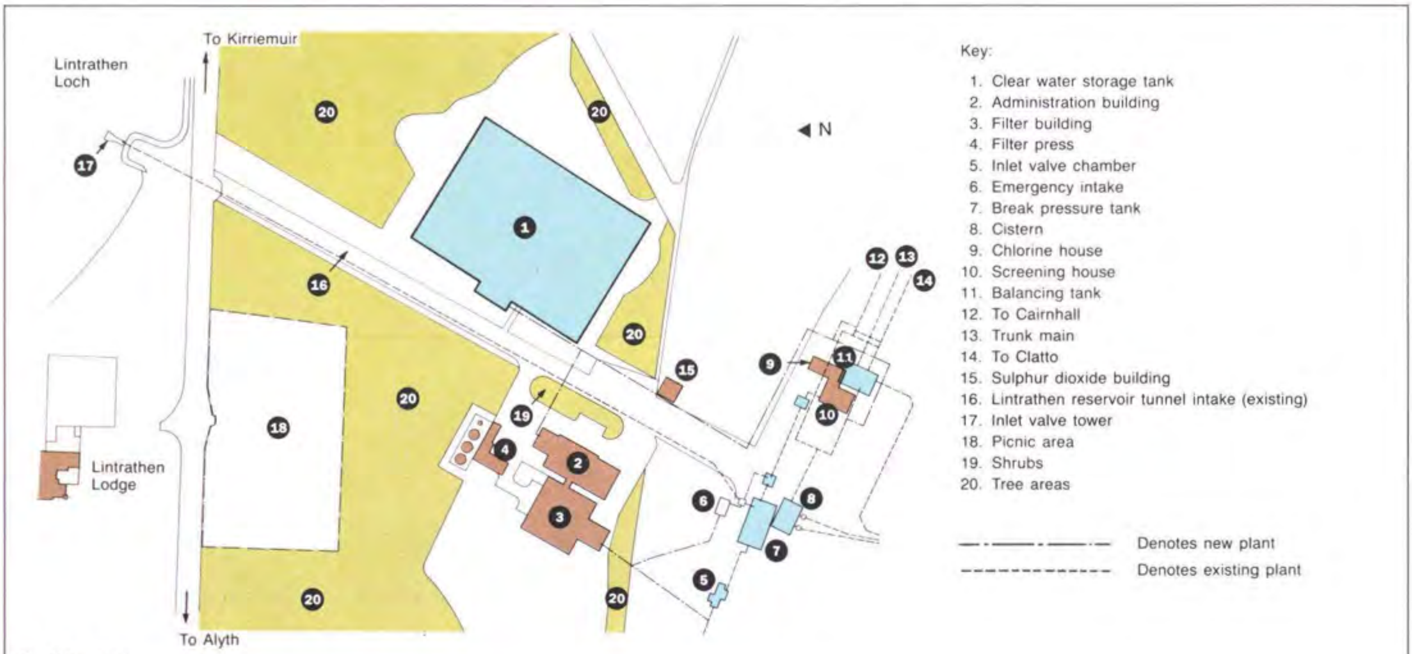
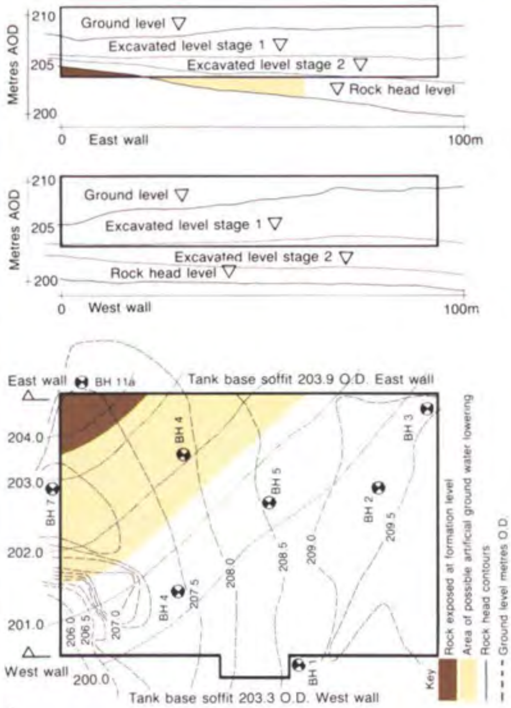


3. Site plan



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Cost constraints prevented the Regional Council from progressing with the plant until 1984 when a design, construct and commission package was chosen. Six firms, out of 25 interested specialists, were invited to make preliminary submissions from which three were asked to tender in two stages — a technical submission, to ensure the Council's requirements were being met, followed by a submission of priced tenders based on an amended form of the ICE Conditions of Contract. In June 1986 the Regional Council awarded the contract to Biwater Treatment Ltd. The team formulated by Biwater at the outset of the tender process included Ove Arup & Partners Scotland as building and civil engineers, with Charles Gray Builders of Dundee responsible for the construction of the Arup-designed elements. The architectural design of the administration and filter buildings was subcontracted by Arups to Wilson & Womersley of Perth.

Great sensitivity has been exercised in trying to ensure that the plant blends with its surroundings. The wooded area opposite Lintrathen Lodge serves as a backdrop and, although it is on the edge of a ridge overlooking the Valley of Strathmore, the plant does not intrude into the landscape.

The driveway from the road which encircles the Loch is through this wood, where mounded landscaping screens the buried 40 000m^3 treated water storage tank, 94m long, 66m wide, and 7m deep. This has been constructed on stiff clay overlying rock, and needed a two-phase excavation (see Fig. 9), including installation of relief wells on completion of the first phase to relieve uplift pressures from a trapped aquifer. The tank has been built with no movement joints, and a pinned connection to the wall head permitted the walls to be designed economically as propped cantilevers.

5. North elevation of Administration Block, showing main entrance and chlorine drum store.

6. Outlet and overflow pipelines from water storage tank.

7. Water storage tank underfloor drainage and screed.

8. Central gallery of filter beds.

9. Plan and sections of water storage tank two-phase excavation.

10. Filter press sludge treatment and ancillary buildings.

11. Water storage tank columns and roof under construction.

12. The completed tank roof and earthworks from the south.

13. Sludge thickening and holding tanks.

14. Filter beds showing inlet and turbine room.

Photos:
5, 8, 10, 12-14: Harry Sowden
6, 7, 11: Raymond H. Cox

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The filtration block and ancillary buildings are at the end of the driveway. The buildings reflect the colour and texture of the local stone and the dark green cladding is designed to blend with the surrounding trees.

Water arrives at the existing treatment works through a 1.22m diameter main from the Backwater Dam, a few kilometres north in the glens. The difference in level is some 80m, and this potential energy has been harnessed by a water turbine to generate more than enough electricity to operate the new treatment works. The main was tapped just upstream of the existing works and, through a system of valves and pipes, conducted northwards to the filtration block. The turbine and generator for power creation are located at high level at the inlet to the block.

As water enters the filtration block, from which light is excluded to curb the growth of algae, coagulants are added to bind particles, making filtration easier. The process centres on six filter beds each 7.5m × 10m × 5m deep, on either side of a central control gallery. The filtration material is 800mm of anthracite and sand supported by 175mm of coarse sand and gravel. Normally, the filters are cleaned daily by scouring them with air and reversing the water flow. Impurities in the water are abstracted in the form of sludge, which is dewatered through a series of reinforced concrete chemical dosing settlement tanks, and finally plate pressing. The resulting cake is deposited in a nearby quarry. Lime, to correct acidity, and chlorine, to disinfect, are added to the filtered water in a holding tank located under the administration block, before it passes to the treated water storage tank. As it leaves this reservoir, bound for the consumer, sulphur dioxide is added to neutralize excess chlorine.

Within the administration and chemical block, the automated process plant has been designed to be manned eight hours a day. A programmable logic controller, situated in the control room overlooking the pump hall, is the key. Failure of essential equipment or change in water quality triggers an alarm call.

The administration block is of two-storey steel-framed construction with blockwork walling and profiled metal deck roofing. The structure carries a monorail crane capable of extension beyond the building, and a gantry crane over the pump hall and control room. In addition to the chemical dosing, administration and staff facilities, provision has been made for a boardroom finished to a very high standard to replace the existing facility at Lintrathen Lodge.

Conclusion

In this project, we confronted the need to prepare a competitive design for a design and build contract, of which there was little experience in 1984-86. It also called for the use of a formal quality assurance scheme, which was relatively uncommon for this type of project.

The official opening ceremony for the plant was performed on 5 October 1989 by HRH The Prince of Wales. The Tayside communities now enjoy high quality water, drawn from reservoirs protected from pollution, processed by a plant whose design demonstrates that a modern regional treatment works can be engineered to fit into the natural environment. Indeed, Lintrathen Loch is recognized by the Nature Conservancy Council as a Site of Special Scientific Interest, and is also designated by the Scottish Wildlife Trust as an important European bird sanctuary.

Even now, the catchment area of the Backwater/Lintrathen reservoirs has not been fully developed. The headwaters of the Muckle and Newton Burns could be diverted east into the Backwater reservoir to provide a further 27 000m^3 of water daily, and the River Isla may also be developed.

Meanwhile, the new Lintrathen works are designed to be flexible enough to meet the needs of Tayside for a high quality water supply into the 21st century.

Credits:

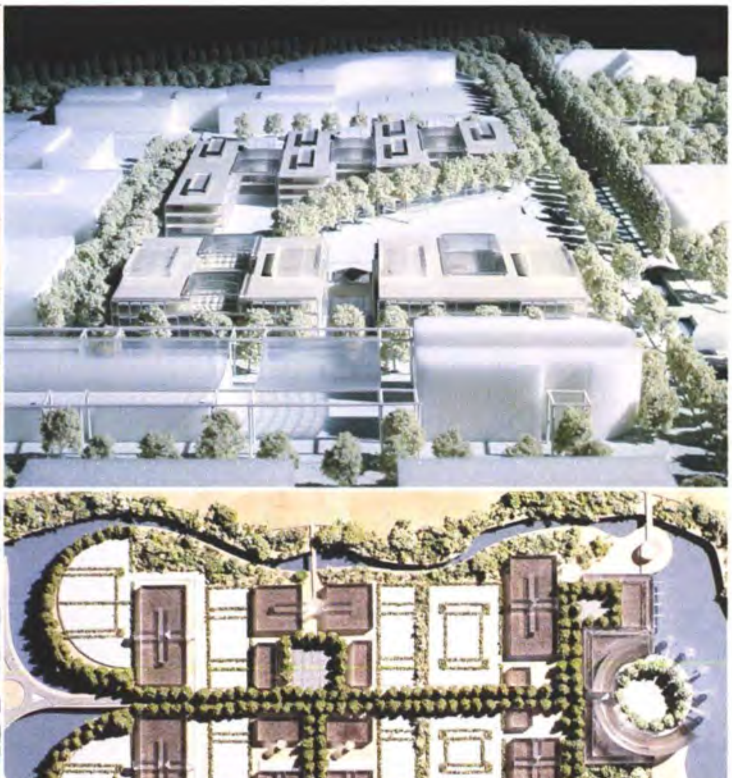
Client:
Tayside Regional Council

Building and civil engineering designer:
Ove Arup & Partners Scotland

Main contractor:
Biwater Treatment Ltd.

Subcontractor (building and civil engineering):
Charles Gray (Builders) Ltd.

Consultant architect (administration and filter buildings):
Hugh Wilson & Lewis Womersley

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