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Hong Kong University of Science & Technology. (Photo: Colin Wade)

Back cover:
Palacio de Villahermosa, Madrid. (Photo: Entrecanales y Tavora SA)

The Hong Kong University of Science & Technology
Robin Forster

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This new university provides facilities for 7000 students in its first two phases — all conceived, designed and built between 1986 and 1991. Ove Arup & Partners Hong Kong were responsible for the design of the site formation, surface water drainage, and foundations; infrastructure including roads, storm and foul water disposal, irrigation, and the seawater intake system; and all structural engineering for academic buildings and housing.

Communications at Bracken House
Patrick Bolger

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Following Ove Arup & Partners' design of new structure and services for the British Construction Industry Award-winning refurbishment of Bracken House in the City of London, Arup Communications undertook the conceptual and detailed planning of the communications systems for the building's occupants, Industrial Bank of Japan and IBJ International.

Harrogate drainage area study
Graham Fardell

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Ove Arup & Partners' Leeds office carried out a comprehensive examination and report on the sewerage system, some of it over 100 years old, in two catchment areas of Harrogate, the Victorian spa town in North Yorkshire.

The Rural Village Water Supply Programme, Botswana
Keith Small

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Arup Botswana Ltd. are examining the existing provisions and designing new village water systems for a number of rural settlements in Botswana, as part of the Botswana Government programme to combat the effects of the country's chronic water shortage.

Palacio de Villahermosa Museo Thyssen-Bornemisza
Philip Jordan
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John Pullen

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A new gallery to house and display the vast art collection amassed by two generations of the Thyssen-Bornemisza family has been created in an 18th century former mansion in the centre of Madrid. Ove Arup & Partners International Ltd. were structural and services consultants for the conversion from the building's most recent use as bank premises.

The Hong Kong University of Science & Technology

Architects: Simon Kwan & Associates Percy Thomas Partnership

Robin Forster

1. Main entrance to University.

Introduction

To design, build, and open in phases a campus university for 7000 students in less than four years is a 'once-in-a-lifetime opportunity' for any design team. With the new Hong Kong University of Science & Technology now approaching the completion of its second phase, all the difficulties are inevitably fading. Nevertheless, the memories of those days in the late '80s when the task seemed almost impossible will, for some, stay forever.

The design team were there on a warm and sunny 10 October 1991 to witness the Governor, Sir David Wilson, open Phase I. This provides teaching facilities for a student intake of 2500 with the majority resident on campus. Phase II will increase this intake to 7000, while the masterplan for the whole University provides for future expansion to 10 000 students.

History

In September 1985 the Government's Executive Council agreed that the provision of tertiary education should be given a high priority. The Hong Kong University and the Chinese University of Hong Kong had been founded respectively in 1911 and 1963, and in May 1986 the Government announced its intention to establish a third university, with a grouping of professional schools emphasizing science, technology, management and business studies.

In September 1986 a planning committee was appointed to provide advice to the Government on matters relating to setting up the University, with a brief to provide degree places for 7000 full-time (and equivalent part-time) students with room for expansion to 10 000, and a first student intake no later than 1994.

The committee's major recommendations included accepting a 41ha site at Tai Po Tsai Sai Kung (formerly the Kohima Barrack site — Arup job 10938 of the early '80s), staging an architectural competition and, in true Hong Kong style, a target date for first student entry in September 1991. This effectively reduced any previous conceived programme by almost three years.

In June 1987 an offer to donate a major share of the building cost from the Royal Hong Kong Jockey Club was accepted, with the Club taking full and sole responsibility for the campus construction. A campus project subcommittee and a planning committee with representatives from the Club were established. Now with the committees, project managers and funding bodies in place, the design team could get down to work.

A two-stage architectural competition was held from April to November 1987. For its second stage the design brief was amended as follows: 'The aim of the campus design is to create a total, comprehensive environment by the integration of buildings and landscape. It may be seen as a living organism which adapts to rapid changes in technology, provides a visual impression of experiment and enquiry, and is both functional and aesthetically pleasing.'

2. Location of University.

The design team

The lead consultant was a joint venture between Simon Kwan & Associates and Percy Thomas Partnership. Simon Kwan, a well-established and prominent Hong Kong architect, was responsible for the overall site planning, building massing and elevation treatment, whilst Percy Thomas, with their considerable experience in the design of educational establishments, planned the internal academic spaces. Thus the Percy Thomas 'modular' style was superimposed on the 'non-linear' Simon Kwan approach to massing and form: although at times an explosive combination, the considerable efforts of these architects is revealed in the 'living organism' now created at Tai Po Tsai. It would be fair to say that the needs of the brief were satisfied.

Ove Arup & Partners Hong Kong designed the civil and structural engineering work, while John Roger Preston (JRP) dealt with building services. Quantity surveying was handled by Davis Langdon & Seah, with the architectural practice EBC looking after landscaping. The acoustical design was tendered separately and awarded to Arup Acoustics.

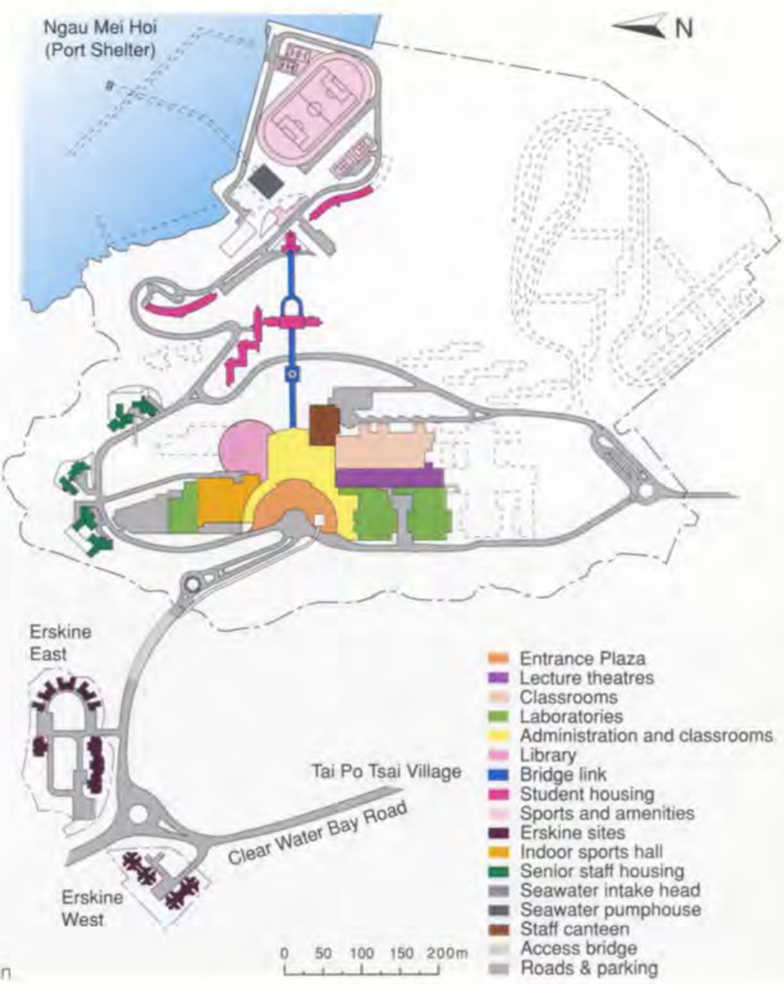
The site

The site is magnificent. Lying on the east side of the Sai Kung Peninsula, it provides spectacular views across Port Shelter to Kau Sai Chau and Tin Chung Chau islands with High Island Reservoir and Sai Kung East Country Park as a backcloth. The site has a cross-section level difference of 125m in 500m, on which Arups' previous work had involved the formation of building platforms, roads and basic utilities for the Kohima Barracks. The University needed certain platforms enlarged for the academic buildings and new service roads. The steep slopes and varying ground conditions offered difficulties for formation work; the site is underlain by lavas and tuffs of the Repulse Bay Formation with weathered rock to depths exceeding 10m. Foundation conditions range from good competent rock to highly fractured rock to stiff clays. Due to the severity of certain slopes adjacent to the seafront, a number of platforms had been classified as non-building areas by the Government's Geotechnical Control Office.

On the northwest of the site two satellite parcels of land previously occupied by the British Army were made available. Called the Erskine sites, they were scheduled for use by junior and senior staff.

Design concept

The main university activities are divided between the Academic Building, located on the site's upper plateau, and amenities on existing platforms and on the reclamation area at sea level.



3. Site plan.

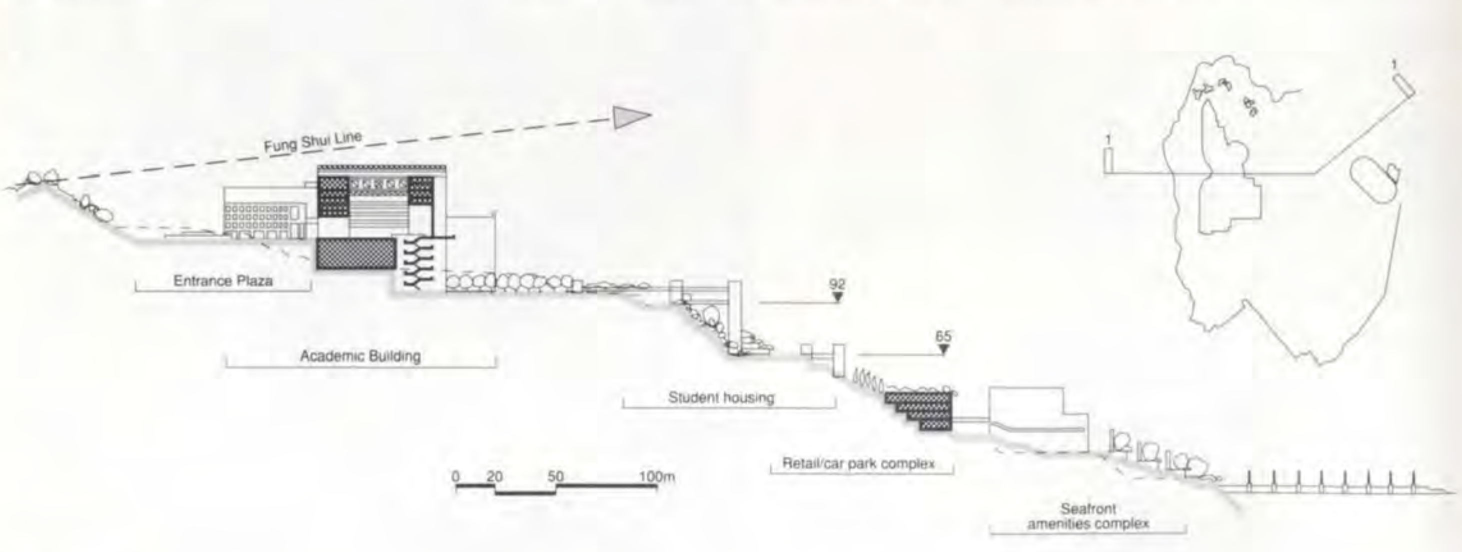
The gross floor area for Phases I & II is 175 000m^2, including accommodation for 2100 students and a mix of medium rise housing for junior and senior staff.

An 'axial' plan was adopted — dictated both by the vast volume of student movement, and by the principal arrival point for vehicles and pedestrians being situated at the north off Clear Water Bay. The origin of the axis is a semi-circular entrance where students head east to housing and sports amenities, and north/south for all departments' laboratories and classrooms.

Effectively the academic facilities are housed under one roof. The 'one roof solution' is a key feature of the design and provides a compact, efficient organization of academic departments and support. It allows departments to expand or contract within the Academic Building. Education is always changing with attention moving from one speciality to another. Emphasis was placed on locating the Research Centre and its related components next to the schools of study to bring together the research elements with the undergraduate departments.

For future changes a flexible approach was adopted to structure and services planning. A uniform planning and services grid with easily adaptable services installations will allow movement between departments.

Linking all research laboratories and schools is a central services spine running north/south below ground floor level.



4. Site section.

▲5
Sports ground
with main campus
in background.

◀6
Façade wall
at semi-circular
main entrance.

7▶
Postgraduate
student housing
Phases I and II.

▲8. Behind the main entrance.

Arups' role

The firm's duties on this project were considerable, and more far-reaching than on traditional projects: the site formation contract alone involved bulk excavation for 350 000m^3 and 120 000m^3 of filling. This article concentrates on some of the more interesting and challenging aspects, particularly in civil engineering.

In summary the scope of services was:

Geotechnical engineering
Site formation and surface water drainage
Foundation design

Civil engineering
Roadwork
Principle storm and foul water disposal
Irrigation
Seawater intake system
Street fire hydrant system

Structural engineering
All aspects of academic and housing structures.

In order to achieve the objective of student intake in September 1991 (following the endorsement of the masterplan in early 1988) the construction work was tendered in packages as shown in the table.

Initially Arups provided a site liaison team as supervision of construction work was carried out by the Jockey Club. This role eventually expanded to providing site engineers on secondment to the Club.

Tender packages

Contract ▼	Description ▼	Site start ▼
A1	Site formation	September 1988
A2	Site offices	October 1988
A3	Civil works	March 1989
A4	Sewage tunnel	April 1989
B1	Academic building Phase I	August 1989
B2	Housing Phase I	September 1989
C1	Academic building Phase II	September 1990
C2	Housing Phase II	October 1990

Sewage disposal

In certain respects the east of the Sai Kung Peninsula is not the best of locations to build. On the west side, where massive development is taking place in Junk Bay, a sewage treatment works has been constructed. On the east side no sewage treatment facility exists and lease conditions require developments to provide individual treatment works before disposal into Port Shelter. Invariably

Seawater cooling system

In Hong Kong, wherever feasible, seawater is used as a cooling medium for air-conditioning systems, as for example in the Hongkong Bank. Arups' previous experience with the Bank and Shajiao B Power Station provided suitable technical expertise to investigate several alternative schemes.

A. Seawater intake culvert plan.

The opportunity existed to use seawater from a depth where advantage could be taken of lower sea temperatures during summer. A careful study of annual and peak demands of cooling loads for all phases was carried out by JRP to arrive at a design temperature for the cooling system of 25°C. During summer, seawater surface temperatures can exceed 28°C; cooling water at these temperatures would not provide the total energy requirement, and additional energy would be needed. The economic equations become complex when the relative costs of civil works are weighed against the additional energy costs of maintaining a 25°C design temperature.

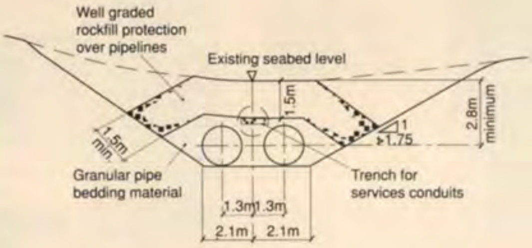
The study concluded that an extended intake system should be constructed to extract seawater at the lowest possible temperature during the summer, the simple theory behind this being that seawater is free while power costs will always increase.

Design work commenced in early 1988, and it was vital that a summer hydrographic survey of the area be carried out. Available information on seabed levels and temperatures suggested a possible location for the head of the seawater intake, some 250m offshore in water of about 7m. Seawater temperatures were measured, and seabed levels, current directions, and ground conditions surveyed. A seismic survey of the geological features, back-checked with boreholes, was also included.

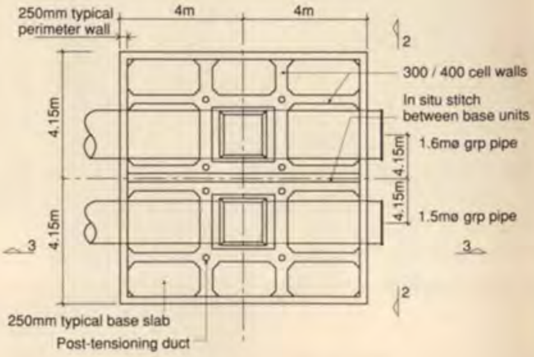
The seabed has a gentle gradient to approximately 8m and dips sharply away to depths over 25m. It was fortunate that no marine deposits were found in the area, and there were sufficient sands and gravels overlaying the volcanic rock to provide a competent foundation for the intake structure and pipework.

While not a compulsory requirement of the brief, there was a request that some consideration was given to improving the existing coastline with an emphasis on sailing and water sports. The site formation work would result in a surplus of material and to offset this the construction of a breakwater and beach was investigated.

B. Condenser cooling pipework in box culvert leading to seawater pumphouse.



C. Seawater intake culvert: Section 1-1.



D. Plan of intake head for seawater intake systems.

these works are poorly maintained, and untreated sewage ends up in the sea. In recent years the Environmental Protection Department (EPD) has been granted greater powers and as a consequence Port Shelter is now classified as a water control zone. Sewage treatment on site was considered to be the only viable solution and with a final student and staff population of over 12 000 to deal with, a separate study commission was given to Arups and Watson Hawkesly to report on the issues of sewage disposal. Watson Hawkesly studied and prepared designs for the treatment works while Arups examined other options including pumping to the Junk Bay treatment works; other pumping routes along the coast were also considered.

The pumping scheme was concluded to be the most effective in terms of capital cost and maintenance, but required large pump stations to be constructed around the campus — obviously a disadvantage in the midst of a small site, with the problems of odour and septicity, power and equipment failures, and the need for architectural treatment to the associated pumprooms.

A third alternative emerged. With the site basic planning complete, it was possible to drive a tunnel from the lower area of the site through to Junk Bay under the peninsula. A less than 1% grade was possible with a sewer pipe fed by gravity into the government sewer in Junk Bay.

Based on pumping for the completed campus, the costs for pumping including 20 years' running costs were assessed to be almost equal to the tunnel scheme. However, taking pumping costs for Phase II only, the tunnel solution was considerably more expensive.

At this stage the pumping scheme had been included in the civil engineering works tender.

The pumping design was quantifiable while the tunnel had risks — potential delay to the University opening.

Interest in the tunnel scheme was expressed by the Environmental Protection Department who saw this as a future conduit to provide sewage disposal for some isolated areas of Sai Kung, so with a financial contribution from the EPD the tunnel solution was adopted. There were, however, certain provisions in that the design should provide disposal routes to the tunnel from the village of Tai Po Tsai and the new English Schools Foundation (ESF) junior school to be built alongside the University site. These routes were provided within the capacity of the campus system.

Providing disposal for the satellite Erskine Sites, Tai Po Tsai village, the ESF school and the staff quarters for TV studios effectively cleaned up the whole area.

The tunnel drive was complete, the 400mm diameter gravity sewer installed, and the system connected ahead of the opening of Phase I.

▲9. Erskine East senior staff housing.

With all these parameters, five options for the offshore intake works were studied:

(1) a long intake culvert with intake head and pumphouse on shore
(2) a long intake (as 1) but with a breakwater/causeway to provide access to the intake head for chlorination pipes and electrical cables; pumphouse on shore
(3) the construction of the pumphouse at the intake and within the causeway, with all connecting pipework (that would now be high pressure fresh water) constructed within the causeway
(4) similar to (3) but with the high pressure pipework constructed in the seabed
(5) a pumphouse constructed at the intake head but connected with a jetty that could be used for mooring.

This study concluded that option (1) (the original proposal) was the most practicable. However, in the future there could be a demand for water of lower temperatures if power costs escalated more than predicted in the study. A facility was to be built in to the intake head for future extension of the pipework. With the Building Services Unit (principal plantroom) located on the upper platforms at level +96mPD the routing for the condenser cooling water from sea level was tortuous. The original design provided a box culvert for the main route from the pumproom to the BSU, but for cost reasons this was dropped in favour of carrying the services within link bridges and under student housing buildings.

The resulting hydraulic gradient positioned the intakes at -8mPD and the pumphouse intake chambers at -7mPD. With the pumphouse positioned behind the existing seawall, an excavation to -9mPD was needed.

Various schemes were looked at, including the construction of the pumphouse offshore and floating into position. In the end, however, the structure was built in situ in a part open cut and cofferdam.

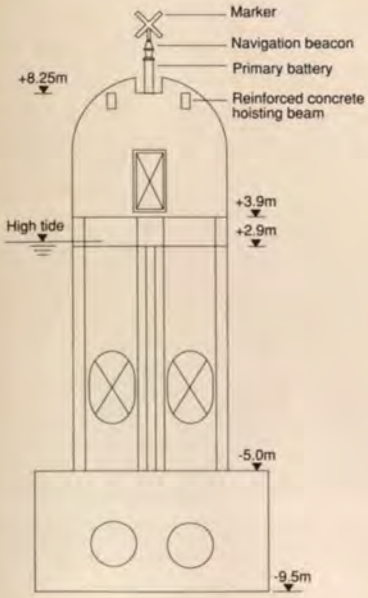
The design of the intake culverts and head could now start. Pipes buried in the seabed invariably give the designer problems. Since corrosion, not jointing, was the main concern as operation pressures were low, glass reinforced plastic was proposed. The intakes were designed to be 1.5m in diameter, laid in an open trench with simple collar joints and access manholes for future cleaning (Figs. A, C). A video was made to check that joints were adequate and the interior of the pipes clean.

The intake head (Figs. D-F) was to be constructed in 7m of water. Arups' tender drawings indicated a precast concrete cellular base slab, complete with intake pipework that could be lowered into the open cut in the seabed. For the intake head a precast box that could be lowered onto this base slab was shown, the head 'tied' to the base by post-tensioned cables passing through a U-shaped duct in the base. The access platform on the head above seawater was to be constructed in in situ concrete.

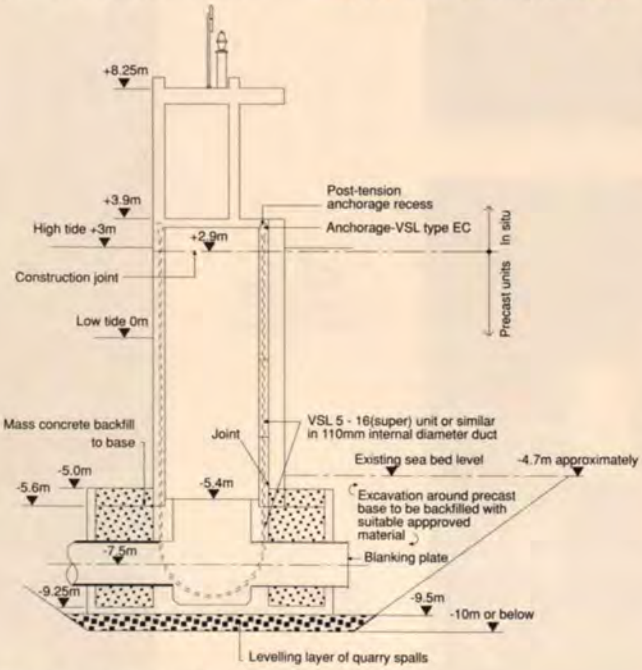
With this type of construction it was expected that the tenderers would return with alternatives, but this was not the case and the head was constructed as designed. Working very closely with the civil contractor, the construction proceeded well with only minor modifications.

Although Port Shelter is clean of flotsam and jetsam when compared to Hong Kong harbour, lapsap (Chinese for rubbish) screens were installed in front of the intakes.

Generally these screens are made in stainless steel but glass reinforced plastic screens were used.



E. Intake head: Section 2-2.



F. Intake head: Section 3-3.

Structures

Included in Phases I and II are 32 separate buildings for staff and students, nine buildings for academic use, and a 50m swimming pool and running track linked to the Academic Building by two pedestrian footbridges. All the structures follow a certain architectural theme derived from the elevation treatment of the Academic Building.

Not unlike any other developments in Hong Kong, the principal structural medium was reinforced concrete. It is almost traditional now that for medium-class residential development all external walls are constructed in reinforced concrete, providing both gravity and lateral load-carrying capacity.

Residential buildings

For the junior staff who occupy the Erskine West site the blocks are founded on hand-dug soil caissons approximately 20m in depth. The geology of both the Erskine sites consists of about 7m of colluvium of medium/dense claying silt to silty sand overlain by 2m of fill in local areas.

The superstructure to these blocks was simple, with slabs spanning between external reinforced concrete walls.

In the Erskine East site, rock head was found almost at the surface under the two-storey senior staff houses. Rock was not always present and the site investigation suggested founding levels 4-5m deep. In some locations this level was higher and wide strip footings were used; for buildings on poorer soil, cellular rafts were used.

Although of a higher standard in terms of size and finish, the Erskine East buildings were again simple slab to external wall structures.

A new road and bridge linked the Erskine sites to the main campus.

The main campus site provided varying foundation problems. Senior staff housing blocks are located on the top of steep-sided slopes on the northeast. These blocks have 12 floors and were designed to take full advantage of the views across Port Shelter. Car parking and play areas are provided at ground and semi-basement level. Wherever possible, shear walls were taken down to pile cap level, uninterrupted by openings. However this was not always possible and some minor transfer structures were needed. The superstructure of these blocks was a combination of beam and slabs spanning on to walls and columns. Rock head varied in depth to such an extent that these buildings were supported on both pad and caisson to rock foundations. There was concern as to the continuing stability of the adjacent slopes as rock profiles to sea level could only be estimated from current site boreholes, and considerable interactive analysis between slope and foundation was carried out in order to arrive at acceptable founding levels for the caissons. This was generally the case for all structures on this site.

Academic Building

Structural design for the Academic Building to a large extent was dictated by the flexible approach to planning and future use. The Academic Building was designed as a total unit that would allow Phase III to be constructed with minimum disruption. This also applied to Phase II — to be built while Phase I was in operation.

During the Kohima Barracks site work, a ridge was constructed between the village of Tai Po Tsai and the site. This Fung Shui Ridge was formed so that the residents of the village and its surroundings would not be able to see any of the Barracks. Ostensibly their view out to sea was not interrupted, and this placed a height limit on the Academic Building. Therefore, the parameters were one roof, flexibility, large floor areas and a height limit. The planning broke down this building into discrete blocks: library, administration, sports hall/car park, atrium, schools and laboratories. Various structural configurations were investigated and to suit planning and loadings the following structural grids were used:

Library	9 x 9m
Schools	12 x 12m
Laboratories	15 x 7.5m
Research spine	18 x 6m.

Wherever possible, most use was made of prefabricated formwork. Hong Kong is the 10th largest consumer of hardwood, with a significant percentage used in construction works. Glass reinforced moulds were proposed for the rib and waffle floor slabs while steel was used for the columns. While it is common to see this type of construction in the UK it is unusual in Hong Kong. Strong opposition from the contractors tendering for Phase I was expected, but it was extremely pleasing to see it taken on enthusiastically by Hip Hing Construction (the Phase I contractor). The system performed well and considerable interest was shown by Hip Hing for its use on other projects.

The Academic Building is heavily serviced both horizontally and vertically. To offer as much flexibility as possible, service core walls were ignored in the stability design and it was agreed from the outset that stability would be dependent on frame action. While providing flexibility with services design this presented problems, in particular with the positioning of expansion joints. While the schools were

◀ 10.
Northern access road bridge.

◀ 11.
Erskine East senior staff housing blocks.

12. ▶
Atrium behind the main entrance.

rectilinear, the library and administration areas had large spans at some floor levels that would interrupt the regular load-carrying vertical elements. In some places the only solution was to introduce angled columns and props that were then expressed on the elevations.

The design was a hard slog at times against an extremely tight programme and budget.

The main laboratories were constructed in Phase II. The original brief called for a structures laboratory to carry out static experiments, but later it was expanded to include dynamic testing using a 10 tonne-rated shaker, operating at low frequencies. It is normal for this type of structures laboratory to be constructed as far away as possible from the main university, but due to lack of space it was built under one of the laboratory wings at ground floor level. With the likely induced vibrations, isolation between the structure of the reaction floor and the building above was vital. A deep foundation to the former was essential to transmit and dissipate vibration energy into the substrata.

In order to mobilize a significant soil mass the laboratory floor was constructed on large diameter caissons constructed through rock to a depth of approximately 8m. The caissons were sleeved through the rock to provide an air gap and the base of the laboratory slab was constructed to span between caissons with a large air gap between it and the surrounding ground. Effectively the structure would be completely isolated from the main laboratory structure. This high-tuned foundation and reaction floor were analyzed using a two-dimensional finite element computer model to represent the reaction floor and laboratory wing. As far as is known this was the first time such a structure has been built in this kind of location.

▼ 13.
Fung Shui Ridge,
constructed in the days of
the Kohima Barracks contract.

▲ 14.
Library interior.

▲ 15. South seafront student housing.

▲ 16. Link bridge to senior staff blocks A & B.

▼ 17. Vice-Chancellor's Lodge.

Conclusion

Many interesting engineering problems were overcome on this project: the routing of the principal services spine at foundation level and its interaction with foundations, the irrigation water supply, and the acoustic treatments are just a few.

As Phase II nears completion it appears that the University is maturing quickly and is ready to respond to new needs and priorities. It has always had a high profile in Hong Kong: apart from the opening officiated by the Governor, the foundation stone was laid by Prince Charles. The speed at which 194 000m^2 of buildings were designed and constructed is a tribute to all engineers involved with this project: the resulting campus is a credit to their hard work and perseverance.

These sentiments were repeated by The Governor Sir David Wilson and Vice-Chancellor Chia-Wei Woo at the occasion of the opening. Although not directly named it is gratifying that consultants and contractors were acknowledged.

▲
18.
Sports ground with seawater intake head in background.

◀19.
Main sports hall.

20.▶
Central seafront student housing.

21.
Academic Building Phase II, sports hall, and car park.
▼

Credits

Client:
The Royal Hong Kong Jockey Club
Architects:
Simon Kwan & Associates
Percy Thomas Partnership
Structural, civil, and geotechnical engineers:
Ove Arup & Partners
Peter Ayres, George Chan, Roger Alley, John Tang, Michael Kwok, Amy Chan, Derek So, Patrick Chan, David Lai, Grace Lee, Martino Mak, Francis Lam, Power Chan, Roger Marechal, YK Lee, Donald Tsang, David Storer, Leo Tang, YN Lin, Michael Ng, Albert Ho, Sammy Cheung, Stanley Yuen, Graham Yip
Services consultant:
John Roger Preston
Quantity surveyor:
Davis Langdon & Seah
Landscape architect:
EBC
Acoustic consultant:
Arup Acoustics
Main contractors:
Gammon Construction Ltd.
Hip Hing Construction Co. Ltd.
Sung Foo Kee Ltd.
Hsin Chong Construction Co. Ltd.
Sanfield Building Contractors Ltd.
Photos:
Colin Wade, except where otherwise credited
Illustrations:
OAP Hong Kong/Martin Hall

Communications at Bracken House

Patrick Bolger

Introduction

In 1992 one of the world's largest banks, The Industrial Bank of Japan (IBJ), and their subsidiary IBJ International (IBJI), moved the headquarters of their UK operation from Bucklersbury House, Queen Victoria St. to new offices in Bracken House, the old Financial Times building opposite St. Paul's Cathedral in the City of London. Bracken House was recently refurbished by a design team including Ove Arup & Partners[1].

During the early stages of the project, Arup Communications advised the design team on the impact of the information and communications technology on the building structure and services, and were subsequently engaged by IBJ to review, update and move all communication systems to the new building.

First, the strategic objectives for the systems were set out in a Preliminary Design report, which defined the following key policies:

- Emerging digital technologies would be adopted to replace existing analogue technologies. Financial markets are in a constant state of change and banks and other institutions need computing and communications systems to respond to these changes quickly; digital systems facilitate these changes more easily than analogue systems.
- Each system would provide comprehensive systems management procedures. This would allow changes to be effected quickly from a central terminal and minimize recabling or hardware changes.
- New systems would, wherever possible, make use of existing hardware and in-house expertise. IBJ wanted to protect their considerable investment in communications and computing systems in terms of both hardware and in-house expertise.
- New systems would comply with recognized international standards. This would help ensure IBJ independence from any single supplier, guarantee basic performance levels, and safeguard against premature obsolescence.
- The preliminary design also considered the impact of the communications requirement on the building services. Detailed room layouts and specifications were produced for each of the main communications rooms, including the main computer, the PABX, BT and Mercury, and equipment rooms. Power needs and heat loads were calculated for equipment rooms and office areas. The horizontal cable distribution system was co-ordinated with other services sharing the underfloor void. Vertical communications distribution was via two main risers at opposite ends of the building and dedicated to communications.

Leading on from these strategic objectives, Arup Communications developed conceptual and detailed designs for each of the major systems. The detailed design described their required features, emphasizing the important ones and including detailed or schematic designs and performance requirements.

The main systems include communications cabling, telephone, dealer telephone, information delivery, local area network and the public network services from BT and Mercury.

Most of the new systems under consideration were employing state-of-the-art technologies not well proven in a banking environment, so thorough testing was carried out to ensure that old and new systems would work together. Systems were only chosen after a rigorous assessment process, often involving pilot installations in IBJ's premises.

1. Main entrance of Bracken House. (Photo: Martin Charles)

Cabling

The objective here was to provide an equipment-independent structured cabling system throughout the building. This removes the need for different cabling types for different communications and computing systems, and gives the flexibility to relocate offices and equipment without the disruption of recabling.

The voice and data cabling are each divided into two elements: primary, for distribution from main equipment rooms in the basement to equipment rooms on each floor; and secondary, from the equipment room to outlet points.

The data primary cabling is based on fibre optic technology, chosen to provide high speed communications, resilience, security, and to minimize the volume of cabling. The cables are installed to give a hybrid mesh and star topology, thus ensuring multiple routes between equipment rooms for resilience. Where, for a particular application, it is not technologically or economically feasible to use fibre for the primary cabling, there is an overlay of copper cabling.

Copper unshielded twisted pair (UTP) cable, now becoming the norm in buildings for supporting many different communications and computing systems, was chosen for data secondary cabling and for the primary and secondary voice distribution. Identical systems were installed for both voice and data for ease of management and with a view to integration when building cabling regulations are relaxed.

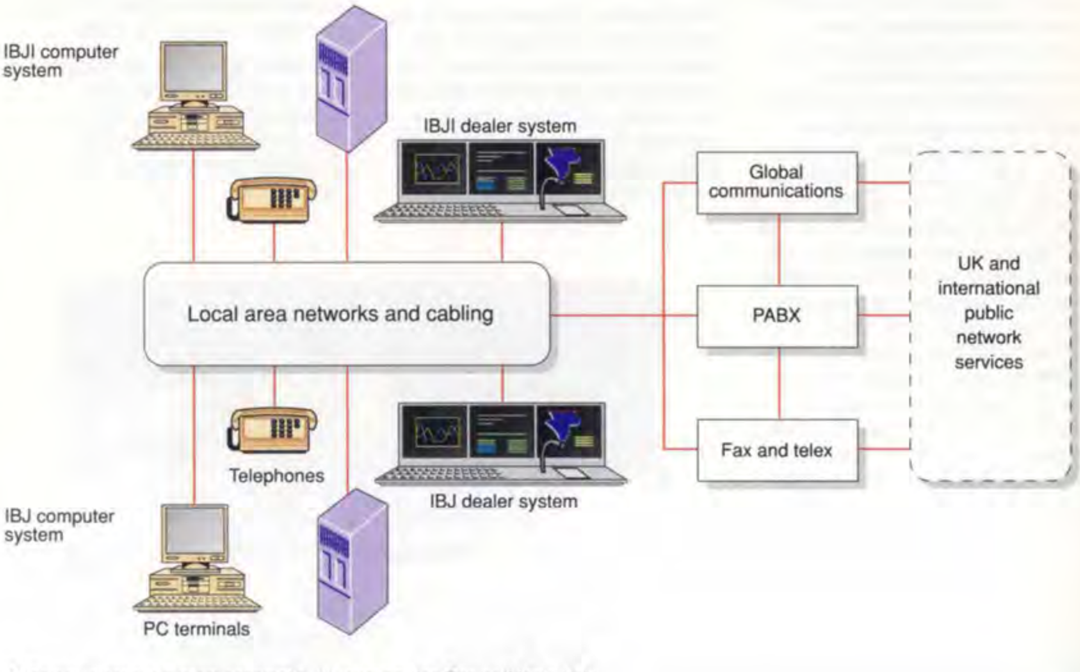
All secondary cables terminate in the equipment rooms where they can be connected to networking and other systems. Each outlet point is cabled to two equipment rooms for resilience.

The intensive communications requirements of the dealers required special treatment. Dealer cabling must be adaptable to accommodate many additions and changes in the shortest possible time, so the scheme provided fixed cabling between the basement communications room and each dealer desks, allowing for all foreseeable voice, data and information requirements and eliminating any need to add further cable for new services or during relocations. Cables terminate on racks in the communications room and on a moveable panel at the dealer desk. Each panel has multipair copper cables for the dealer telephone, triple coaxial cables for video services, multicore cabling for miscellaneous systems, and UTP terminations for voice and data.

The panels can move up to 5m from a fixed point under the floor. New systems are installed by connecting central control equipment to the cable terminations in the communications room and terminal equipment to the panel at the desk.

Fibre optic cabling was considered for the dealers but not adopted. The potential advantages of a lower volume cable were offset by the high cost of optoelectronic devices and possible interface problems with systems.

▶



2. Communications system schematic. (Illustration: Jon Carver/Martin Hall)

Private Automatic Branch Exchange (PABX)

The building has a single telephone system or PABX, shared by all tenants, with consequent savings in capital and ongoing costs. The system is partitioned so that each tenant appears to have their own private telephone system, complete with internal numbering schemes, operator consoles, incoming lines, management terminal for moves and changes and a call logging system. The PABX is designed for up to 1500 extensions, and can be equipped with over 400 exchange lines. These use 30-channel digital links to both BT and Mercury exchanges. The PABX can provide digital extensions for voice and data communications, and also has comprehensive management facilities. The system terminal carries out most reconfigurations and gives details of the system status. A high degree of resilience was required and all critical components are duplicated.

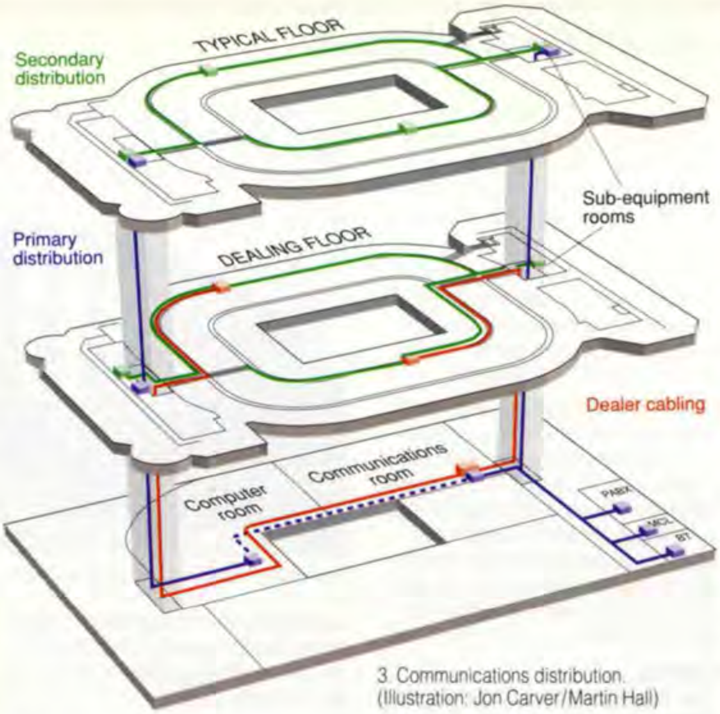
Dealer telephone

The dealer telephone is a specialised voice communications systems for the dealers, allowing them to set up several calls simultaneously, quickly and easily. For reasons of cost and management, a single system is used for both IBJ and IBJI, partitioned so that it appears each company has its own separate system with private voice circuits, exchange lines, extensions, management terminal and call logging system.

The total number of dealers is over 200, each with a dedicated exchange line and telephone extension. There are also over 400 dedicated private voice circuits to other dealing rooms.

The system is based on digital switching technology and digital communications between the central equipment and the public exchange. Signalling and voice channels between the central equipment and dealer boards are also digital.

During the selection period, dealer telephone system manufacturers were launching new digital systems to replace analogue ones, incorporating important new features. These centred on the ease and speed with which changes to dealer board configurations could be made. In the past, these changes involved re-cabling, relabelling keys, and was labour-intensive and slow. Work was usually done out of hours. Now, changes to the dealer board, such as adding new lines or changing its configuration, can be carried out remotely from the management terminal with little disruption or delay. Other requirements were pagination, which allows the dealer to call up different line configurations on the dealer board, intercom facilities and dynamic allocation of lines to loudspeakers. All critical components were duplicated to improve the resilience of the system.



3. Communications distribution.
(Illustration: Jon Carver/Martin Hall)

Information delivery

Information sources such as Reuters and Telerate give up-to-the-minute information on financial markets and are indispensable to dealers. They are available in video and increasingly in digital format also. The latter have advantages over analogue video systems, allowing information from several sources to be viewed on a single screen rather than on several as with video sources. Also, digital information can be processed directly by computers rather than manually inputted from video sources. The digital nature of the systems also means that system management and administration can be carried out form a central management terminal.

IBJ subscribe to a large number of information sources. The digital system delivers the bulk of information needs to 250 dealers and analysts, with remaining sources delivered to dealers using standalone systems.

The objectives adopted as part of the overall project were applied to the selection of the delivery system. The building local area network and protocols would provide the networking component. Dealer workstations and servers would be based on IBJ's existing hardware and software.

Servers carry out specific processing tasks such as handling the incoming digital feeds, system management, composite page formation and other functions.

The information delivery program which manages and distributes information from the digital feeds to dealers' workstations for presentation or to other computers for processing had to be compatible with this hardware platform.

The specification described the essential features of the system such as composite page formation, dynamic data exchange, data dictionaries, and dealer profiles — the latter set up for each dealer from the management terminal.

It determined the features available to a dealer and the information sources the dealer can access. If a dealer or group of dealers need additional features or access to information sources this can be carried out quickly from the management terminal.

Numerous digital delivery systems came on the market during the selection process; many were assessed in detail with in-depth presentations of the systems and their features.

4. Dealer station.
(Photo: Peter Mackinven)

Local area network

The building local area network interconnects all computing systems. The design criteria were to enhance the resilience of the network, maximize throughput, support the initial and ultimate number and type of devices attached, and provide a defined upgrade path.

The network consists of two sub-networks: Ethernet over copper twisted pair cables for the PC networks on the floor; and a high speed Fibre Distributed Data Interface (FDDI) backbone network connecting the PC networks. An Ethernet network acts as a back-up to the FDDI network.

The network has over 750 devices attached to it, including PCs, main frame and mini computers, asynchronous devices, printers, workstations and terminal servers. The network management provides status information on all active devices attached to the network and traffic levels.

Public network services

IBJ have a huge number of exchange lines, telex lines, fax lines, data circuits, private voice circuits and international circuits. Moving all these was a complex task, and an overall strategy was adopted for their relocation. Where feasible, new circuits and services would use digital technology. Both BT and Mercury have separate rooms for their termination equipment and dual entry points into the building for resilience. Services enter the building mainly using fibre optic cables, and a network of cables links the BT and Mercury rooms with other equipment rooms. To avoid running extra cables when new services are required in the office areas, the building structured cabling system are used.

Conclusion

The complexity and diversity of the communications systems made for a very interesting project, whose most significant aspect was the migration from analogue to digital technology. This opens up much greater control over the systems themselves and their use, and provides a much greater range of features. It is interesting to note that, despite the fast rate of changing communications technologies, the installations in Bracken House closely resemble the designs outlined at the conceptual stage.

Reference

(1) THORNTON, J. *and* BERRY, J. Bracken House. *The Arup Journal*, *27*(2), pp.3-7, Summer 1992.

Credits

Client:
The Industrial Bank of Japan
Project managers:
Axtell, Yates, Hallett
Communications consultants:
Arup Communications Bill Southwood, Jim Read, Patrick Bolger, Gordon Lland, Mani Manivannan, Priscilla Tang, Raymond Harmer, Stephen Pollard
Suppliers:
PABX: BT
Dealer telephone: Hitachi Europe
Information delivery: ACT Financial Systems
Local area network: BISS, Digital
Cabling: VDU Installations

Harrogate drainage area study

Graham Fardell

Introduction

The water plcs and their agent local authorities are currently undertaking a programme of drainage area studies, which will last five to six years. On 6 January 1992 Ove Arup & Partners' Leeds office were appointed by Harrogate Borough Council as sewerage agents for Yorkshire Water plc to undertake a drainage area study for the Harrogate North and North-east catchments (Fig. 1): set to run for seven months, this was the first in-house drainage area study undertaken by Arups.

What is a drainage area study? The United Kingdom has one of the oldest and most extensive sewer systems in the world. In 1977 the DoE/National Water Council Standing Technical Committee on Sewers and Water Mains published a national assessment[1] which suggested there might be serious problems of sewer dereliction, thus highlighting a serious lack of information about the sewerage system. The report gave alarmingly high estimates for the cost of renewals; approximately 95% of the sewer system is too small for effective manual inspection, and until the advent of CCTV sewer inspections in the 1960s, very little was known about the majority of the system.

In the last 20 years CCTV inspections have increased and with them an awareness of the needs for sewer rehabilitation.

In 1983 the Water Research Centre produced their 'Sewerage rehabilitation manual'[2], which sets out the procedures for investigating both the structural condition and hydraulic performance of an existing sewer system, and leads to the development of a long-term drainage area plan covering all identified needs.

The Harrogate drainage area

The Harrogate North and North-east drainage areas extend over 12.54km^2 with a present population of 36 500. The topography is undulating with levels varying from over 145m above ordnance datum (AOD) in the Duchy area of Harrogate to 60m AOD on the banks on the River Nidd. The commercial centre of Harrogate, residential areas, small industrial estates and parkland are included within the catchment boundaries. The sewerage network consists of two separate gravity systems — a Victorian combined sewerage system transmitting foul and surface water together terminating at Harrogate North sewage treatment works (Fig. 2), and the more recently installed surface water sewers which discharge through separate outfalls to the main water courses of Oak Beck (Fig. 3), Bilton Beck, Low Dyke Beck and Coppice Beck. The combined system is some 130km of sewer and the surface water is 81km in length. The combined sewerage system contains 23 combined sewer overflows.

The sewerage network in Harrogate has developed from the combined Victorian system of the original town centre (Fig. 4), moving northwards with partially separated areas built up to the 1960s, to the fully separated drainage system of the present day. The sewers have been constructed over a period of 100 years and are generally of concrete or vitrified clay, though some of the earliest sewers are of brick construction.

The first phase of the study included familiarization with the catchment.

The whole of the sewer network has been surveyed over the past three years and is available in a standard sewer surveying format, STC 25, and the results are presented on 1:1250 sewer plans. These were made available to Arups in disc format, together with historical data of reported flooding.

Numerous site visits were made to establish the characteristics of the partially separate and combined drainage systems. The age of properties draining to the various systems, together with the types of building drainage, were determined from the local Harrogate Building Control records, and by site examination of gutter connections and domestic foul waste pipes.

The other part of Phase 1 was the Critical Sewer Analysis. One of the key factors in the rehabilitation strategy produced by the Water Research Centre is that the majority of the costs in sewer network failures is associated with a few problems in the core of the system, so the strategy is to concentrate on critical core area sewers where the consequences of failure are severe. Critical sewers are defined by three categories A, B and C which reflect the cost and inconvenience incurred in the event of replacement of the particular sewer. The factors involved in assessing the critical sewer category are: (1) its physical properties — size and material (2) its situation — depth and ground conditions (3) its location — ease of access, disruption to traffic and trade, proximity to buildings (4) its function — foul or surface water. Category A critical sewers have a high cost of replacement whilst lower costs are associated with Category C.

To achieve the critical sewer analysis, traffic flow records were consulted and discussions held with the planning authority. With the study covering the commercial and retail centre of Harrogate, many of the roads are designated as highly important as major traffic delays are likely to result should renovation of the drainage system be required.

Model building

Having identified the critical sewers, the next stage is to have a confident understanding of the hydraulic performance of all the core area sewers. This involves building an hydraulic model which can be verified by collected data. Wallingford Software (part of Hydraulics Research) have developed a package of computer programs called WALLRUS, which models pipework and open-channel systems. One of these programs is 'The Simulation Method' which simulates time varying flow with surface flooding or surcharge for observed or synthetic rainfall events in an

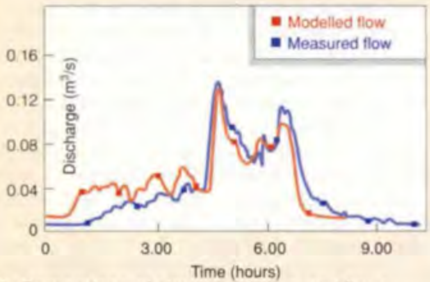
▲1. Catchment location plan.

▼2. Inlet to sewage treatment works.

▲3. Oak Beck.

▼4. Harrogate town centre.

5. Installation of flow monitors.



6. Comparison of simulated/measured flows.

existing or designed sewerage network. The latter may include overflows, storage tanks, pumping stations and flap valves.

To enable the model to be built, many visits were made to the catchment area to assess the impermeability of typical parts of it, e.g. terraced housing, new built residential estates, commercial and industrial areas. From the site assessment, the impermeable areas are measured on the available mapping and percentages assigned over the whole catchment. This is a very time-consuming process. Before embarking on building the full-scale WALLRUS model a skeletal model was built, consisting of the main sewers, i.e. the largest diameters and longest lengths — all of them being critical sewers. For ease of handling, the catchment was divided into subcatchments. The model contained a number of storm overflows which were treated as ancillary structures as on-line tanks. The skeletal model was run using a low intensity rainfall profile, and the output checked to ensure that there were no gross errors or anomalies. The program output was in the form of depths of flow and volume of water.

Once the skeletal model was performing satisfactorily, the full-scale model building could commence, by extending the skeletal model to include all the critical sewers. All areas were measured which contributed to a particular pipe run, and a typical percentage impermeability applied. Once the model was running we tested it by running synthetic rainstorms through it.

Verification

To verify the hydraulic model, a five-week flow survey contract was undertaken by Biffa Environmental Services to the Water Authorities Association model contract document[3]. A total of 11 raingauges around the catchment and 38 flow monitors (Fig. 5) were installed in strategic locations to record continuously the pipe flows. Unfortunately the five-week period during which the equipment was installed proved to be one of the driest periods of the year, but it was possible to record the minimum three 'significant' rainfall events required.

To facilitate verification, the model was divided into subcatchments of a more manageable size, ensuring that the outfall of each subcatchment occurred at a monitored site. Using the results of surveyed flows and rainfall data over the catchment for the three recorded storm events, the model verification process was begun. The monitored flow was compared graphically with the simulated discharges (Fig. 6). Where there were differences between the two output hydrographs the characteristics of the network upstream of the monitor position were re-examined. When reasonable results were achieved, the process of detailed verification, using the full rainfall events, commenced.

In the detailed verification it became apparent for the foul/combined network that the sewage overflows influenced the predicted flows and consequently the survey data was reviewed. It was discovered that several of the overflows within the system are fitted with screening devices which have the effect of limiting the flow over the weirs. Thus corrections were made to the model by modifying the lengths of these weirs. Other adjustments required included a re-appraisal of the drainage type within a residential area from partially separate to combined.

The resulting verified model was run for various synthetic return period storms and the Yorkshire Time Series Rainfall.

Structural analysis

Part of the Phase 2 drainage area plan procedures are to assess the structural condition of the sewer network, which includes inspections and structural assessment. CCTV surveys had been undertaken by contractors for Harrogate Borough Council between 1982 and 1992. Arups had to assess the structural condition, from Yorkshire Water Sewer Condition Advance Recording (SCAR) forms containing written reports from the survey contractors, together with coded defect scores in accordance with the Sewerage Rehabilitation Manual. From the SCAR forms, sewer lengths in the study area with defect scores above values pre-determined by Harrogate Borough Council were selected. The internal condition, structural grades and services grades were identified and recorded. Based on a study of the video tapes an assessment was made of the structural performance grade for the critical sewers in the study catchment. All of this exercise indicated that significant lengths of critical sewers had adverse structural grades.

Results

A table of the predicted frequency of flooding was produced which listed the street location, pipe reference, the system (whether foul/combined or surface water), and minimum storm event causing flooding. A comparison of recorded flooding incidents was made, which was also indicated in the table. In general a comparison between predicted and recorded flooding incidents indicates that the majority of recorded incidents are not due to the hydraulic inadequacies of the main sewer system.

Further work

Arups have now been appointed to complete the remainder of the phases for the drainage area study. These will address water quality of discharges and receiving watercourses, operational activities of Harrogate Borough Council, effects of development plans on the drainage network, and preferred solutions including associated costs to the problems identified in the hydraulic and structural analysis.

References

(1) DEPARTMENT OF THE ENVIRONMENT *and* NATIONAL WATER COUNCIL. Standing Technical Committee on Sewers and Water Mains. *DoE/NWC Report 4.* Sewers and water mains — a national assessment. NWC, June 1977.

(2) WATER RESEARCH CENTRE. Sewerage rehabilitation manual. Second edition, Revised 1986. Addenda issued 1990.

(3) WATER AUTHORITIES ASSOCIATION. Model contract document for short term flow survey of sewer systems. The Association, 1987.

Credits

Client:
Harrogate Borough Council,
acting as Agents to Yorkshire Water Services plc.
Consulting engineers:
Ove Arup & Partners' Leeds office
Flow survey contractors:
Biffa Environmental Services
Photos:
1: © Crown copyright
2, 3, 5: Douglas Thompson
4: Graham Fardell
7: Paul White Photography
Illustration:
6: Martin Hall/Kris Buglear

7. Harrogate: view of catchment area.

The Rural Village Water Supply Programme, Botswana

Keith Small

Introduction

Botswana has been widely acclaimed for many fine achievements, traditions and features. It is known for its peace and political stability, a particularly welcome trait in a world where anarchy, war and terrorism are commonplace; it is known for its racial harmony — largely due to the ideals of its first elected President, Sir Seretse Khama, who would not abide racism and who made sure that distinctions based on race, colour or creed would not be entertained within the new nation's boundaries; it is known for its economic prosperity, certainly a far cry from its situation at independence in 1966 when it was dismissed as 'the poorest country in Africa'; and it is known for its rich wild life. More lately Botswana has been called the fastest-growing country in Africa, awash with foreign exchange and 'the darling of the donor agencies'.

But unfortunately it is also known for its lack of water. Being a scarce resource, there is not much to say about it. Or is there? — This land-locked, arid country bordering Zimbabwe, South Africa, Namibia, Angola and Zambia has not merely survived and persevered but prospered, in spite of the serious constraints of water shortage. This paper describes just one measure adopted by the Government of Botswana to overcome the problem.

Background

Approximately 55% of Botswana's population of 1.3M live in small and relatively remote rural villages and even smaller settlements, with rudimentary services, if any. The provision of a potable water supply to 35% of this rural population through the Rural Village Water Supply Programme (RVWS) was initiated by the Swedish International Development Agency (SIDA), in the early 1970s. When the programme started it was fully funded by SIDA, but in 1991-92 the Government of Botswana provided 80% of the funds and in 1993 SIDA are due to withdraw from the project. The Ministry of Mineral Resources and Water Affairs (MRWA) and the Ministry of Local Government, Land and Housing (MLGLH) administer the project through the MRWA's Department of Water Affairs (DWA).

The 'rural villages' currently form a group of about 480 settlements gazetted as such by the Ministry of Local Government and Lands. Through the RVWS programme, around 300 of the original 340 rural villages targeted were provided with safe and reliable water supplies by the end of 1990. It was initially expected that the programme would be completed in 1988, but as a result of the 1981-1987 drought, resources had to be reallocated to urgent drought-related programmes. One of these, the Consolidated Emergency Water Programme (CEWP), started in 1988, with the aim of improving water supply to those villages hardest hit by the drought. 82 villages were selected by the District Councils, and by the end of 1990 almost all had been provided with more reliable sources of water.

Groundwater resources

Local groundwater resources are expected to provide the predominant source of supply to the rural villages in the foreseeable future. In over 80% of villages, demand forecasts can be met entirely from perennial recharge, and it is therefore not surprising that a close correlation exists between renewable groundwater resources and settlement location. In the North-East District, however, the use of surface water resources will continue along the edge of the Chobe River and the Okavango Delta. Botswana is also known as the 'home of the Okavango Delta', some 15 000km^2 of crystal clear, lily-spangled waterways meandering between papyrus-fringed islands, and one of the wonders of the world. (Though before this is taken out of context it should be remembered that the Delta itself has aptly been described as 'an island of water in a sea of sand': it is virtually surrounded by the Kalahari Desert.)

▲1. Empty water containers, often a sign that the water system has collapsed.

▼2. The large rural village of Otse. Arup Botswana supervised new works including upgrading an existing borehole and equipping a new one; corrosion protection of an existing 150m^3 tank and erection of a new 500m^3 one; and construction of 7500m of pipework and 10 new standpipes.

Estimates suggest that groundwater resources for the whole of the country may contain an extractable volume of approximately 100 000Mm^3, but it appears that less than 1% of this volume is rechargeable. Despite the significant problems associated with its abstraction, groundwater plays a vital role and currently contributes about 60% of Botswana's total water demand of approximately 140Mm^3. It becomes even more important during periods of drought when surface sources dry up.

Most groundwater extraction in the rural areas is either by individual borehole or small clusters of wells used for local supply. The scattered settlement patterns and the low transmissivity of most waterbearing substrata in Botswana mean that the development of supplies to individual centres is unlikely to be influenced by adjacent waterpoints.

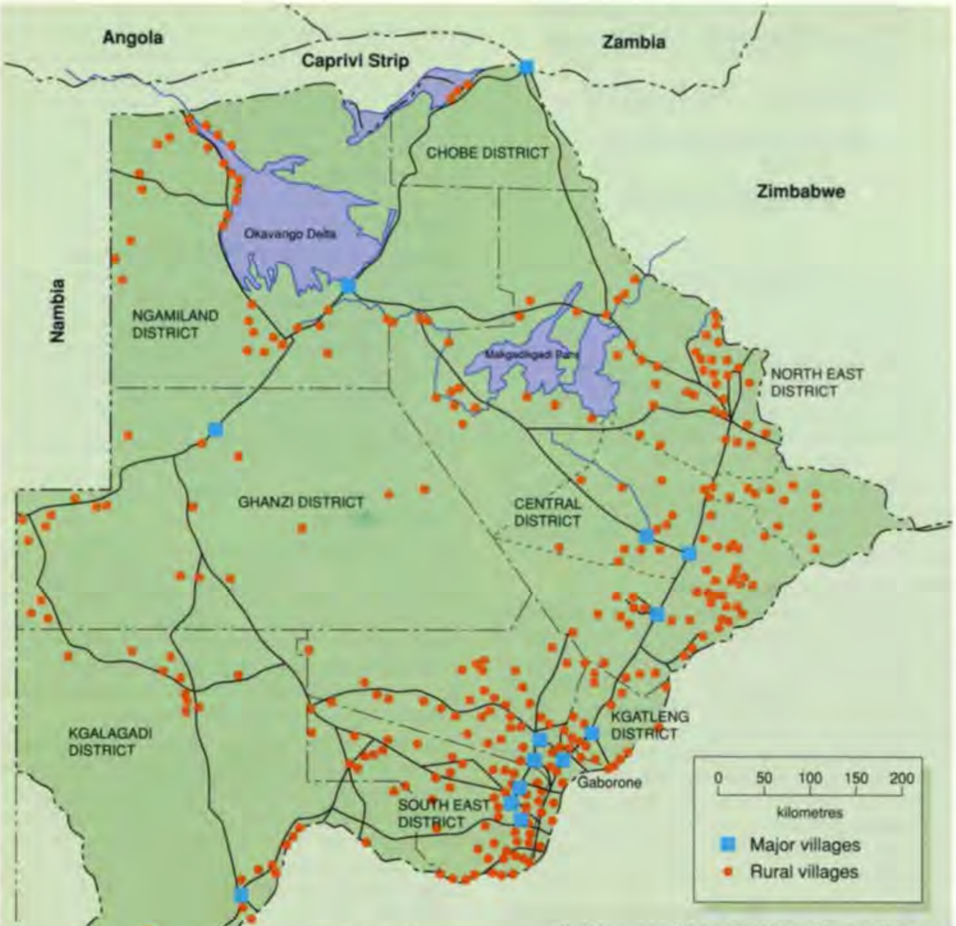
The only rural village where development appears to be seriously constrained by lack of groundwater is Middlepits in the Kgalagadi District, located on poor waterbearing strata. Elsewhere, the chief limitation to expansion of production capacity is likely to be the high cost of siting (exacerbated by a low rate of success), drilling, and the equipping of new boreholes. This is a particular problem in south-west Botswana.

Existing supply situation

The RVWS is a rolling programme driven by the need to:

- augment and/or extend existing schemes because of population growth and hence increase in demand
- rehabilitate schemes because of the effects of age, usage and in many instances corrosion caused by water
- provide new schemes as settlements are upgraded to rural villages.

In view of the limited water resources in Botswana and the rapidly rising demand, it was necessary to develop a regional and national approach to water development. A National Water Master Plan (NWMP) was formulated for the Government of Botswana and a draft produced in 1990. The investigations conducted to develop the NWMP were



3. Botswana National Water Master Plan. Location of villages.

very extensive both in space and time, in so far as they:

(1) covered the whole of Botswana geographically

(2) dealt with the needs for water of all sectors of the community

(3) embraced a time-span of 30 years from 1990 to 2020, and

(4) involved numerous engineering, scientific, and social disciplines.

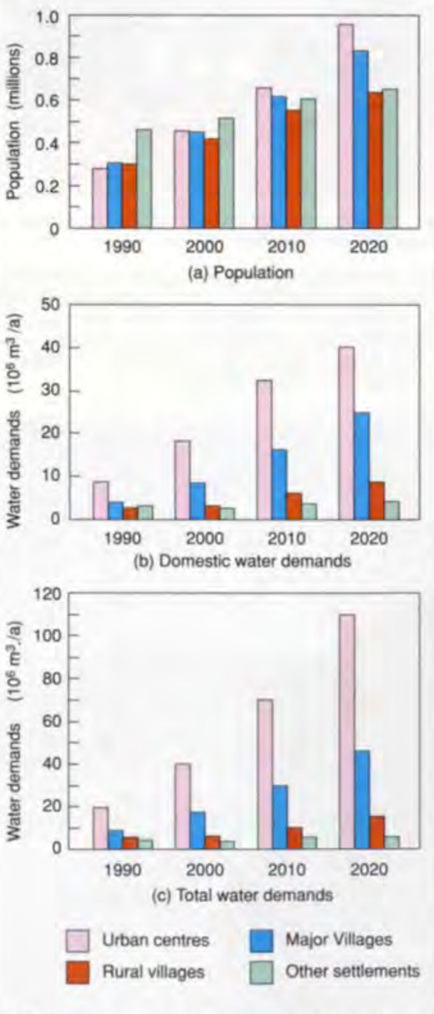
Included in (2) above was the identification of over 450 rural villages, excluding the 17 'major villages' defined as such by the Botswana Population Census that already have a formal water supply or are to be included in future extensions to the RVWS (Fig. 3).

A summary of the medium water demand forecast including population estimates for major villages, rural villages and other settlements is shown on Fig. 4. Forecasts for the five similarly-designated 'urban centres' — Gaborone, Francistown, Selebi-Phikwe, Lobatse and Jwaneng/Orapa — are included for comparison.

Arups' role

As a result of the urgent demand for basic water supplies, DWA decided in 1988 to involve the private sector in the design, supervision and construction of rural village water schemes. In 1989 Arups were appointed as consultants for nine villages located in the Kgalagadi and Southern Districts as well as one in the North-Eastern District.

The villages located in the Kgalagadi District are dotted along the Botswana/South African border. In each village designs for equipping boreholes and sizing pumping mains were required and, in addition, minor rehabilitation measures to the existing schemes had to be identified where necessary. The populations catered for varied from 335-4013 persons, with the corresponding estimated water demands ranging from 20-230m^3 per day.



4. Growth in population and water demands.

The construction works for four of the villages were undertaken by private contractors and the remainder by the Operations and Maintenance Unit of the DWA. Both Arups' preliminary and final design reports included substantial accounts of the state of the existing facilities, often in bad repair due to lack of maintenance and the effects of corrosive waters.

All the village water systems designed by Arups have diesel-operated boreholes supplying standpipes and a limited number of private connections through a reticulated system. In some instances solar-powered pumps have also been used and in the years ahead further consideration will be given to wind-driven and mosgas energy sources. (Mosgas derives from the degradation of raw organic matter, but at present seems unlikely to prove a viable energy source.) It is Government policy to provide each village (which currently is defined as comprising a minimum of 500 people, a primary school and health post/clinic) with at least two equipped boreholes to ensure security of supply. This target has yet to be fully realized.

The main supply point is through a public standpipe, providing a maximum of 100 people with water at no charge. The latest DWA standard allows for the provision of double-headed standpipes, each catering for the needs of 200 people. In addition, the walking distance to any standpipe is limited to 400m. Institutions such as schools, health posts and clinics have private connections. Government housing and a limited number of shops, businesses and private households may also be served (often at the discretion of an unregistered plumber). In some districts such as Kgalagadi, new private connections are forbidden in order to limit consumption.

The provision of a potable supply to over 400 rural villages only accounts for about 10% of settlement consumption. The average per capita consumption per day in these villages is low, about 34 litres. (In the major villages the per capita consumption for standpipe users has remained at about 15 litres a day, while consumption for yard and house connections is currently about 60 and 120 litres per day, respectively.)

Water quality

A review of groundwater quality in Botswana with reference to a range of parameters indicated that 60% of rural villages in Botswana have access to at least one borehole complying with World Health Organisation standards. These parameters include total dissolved solids (TDS); chloride, nitrate, and fluoride levels; iron and manganese content; pH and total hardness.

Severe contamination problems exist in the south-west around Bokspits and Middlepits in the Kgalagadi District. Local breaches of standards are also noted around Orapa (TDS) and Hukuntsi (nitrates), although these are unlikely to affect the future development of local groundwater sources.

Where boreholes are located close to or within village boundaries or within river beds, etc., and pollution of the source is suspected, Arups always request bacteriological sampling and testing. High on the priority list, before commencing the design, is a visit to the the local clinic/health post. The medical staff, who are extremely co-operative, are able to give a good indication of the quality of the water available, but their arithmetic is shaky and population figures can vary by 50% or more. In the absence of microbiological tests of the water, their information is often an indicator of whether further action is necessary by DWA, who are responsible for the sampling and testing of all boreholes.

Water tariffs and cost recovery

The NWMP revenue analysis for the major and rural villages was based on a tariff defined in

5. Old standpipe, with no soakway.

6. Stockade around standpipe.

7. Standpipe under construction.

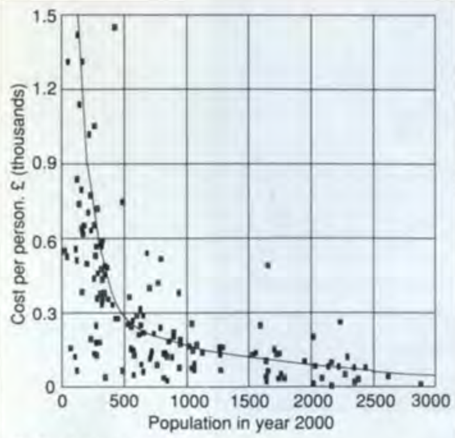
8. Construction of foundation slab for 500m^3 ground tank, with existing 150m^3 tank in background.

terms of connection type, rather than volumetric consumption bands. Domestic users were characterized by their access to standpipe, yard or house connections. Institutional and commercial users were combined in a single non-domestic category.

The average unit of revenue generated from the current tariff is 0.17£/m^3. This figure is significantly below the nominal recurrent cost to the consumer of 0.43 £/m^3. A substantial increase in real tariffs is therefore required if the Government is to achieve its stated aim of full recurrent cost recovery. Less than 20% of the total water currently consumed is delivered through standpipes, a figure which is expected to halve by the year 2020. Introduction of a charge for standpipe water would therefore have only a limited impact on total sector cost recovery but a retrogressive effect on the social benefits of the lowest income consumers. Nonetheless, the fundamental Government policy of providing water free of charge for basic needs remains unaltered.

Investment and recurrent costs

The annual investment and recurrent costs associated with the RVWS programme are estimated at approximately £6.5M and £3.1M respectively over the study period. The per capita costs of investment in rural village water supplies rise steeply for the smaller settlements, from £150/person for a village of 1500 inhabitants to over £715/person for a settlement of 250. The criterion used to assess the viability of a rural village water project is that investment cost should not exceed £285/person.



9. Cost per person: total cost.

Planned development 1991-1997

Proposed future developments for Botswana for the period 1991-1997 are incorporated in the seventh National Development Plan (NDP 7). The NWMP has estimated that water demands will continue to increase rapidly through NDP 7 and into the next century: in the rural villages served by district water supplies from 3.6×10^6m^3 to 6.3×10^6m^3 per annum by 2000, and 12.6×10^6m^3 by 2020; an average rate of growth of 4.3% every year. The population living in the rural villages is forecast to grow at an average rate of 2.6% per annum from 289 000 in 1990 to 629 000 by 2020. Taking into account the competing claims on resources, DWA's implementation capacity, and the capacity of District Councils to operate new schemes, the construction target for the outstanding small village schemes during NDP 7 has been set at 20 schemes per year. This is expected to clear the current waiting list by 1993/94.

A number of settlements, however, gained village status during NDP 6, and the figure is likely to increase following the 1991 population census. All these villages will require water supplies. Some of the large rural villages have been growing rapidly and their water supply systems can no longer cope with increased demand. Accordingly, major rehabilitation and/or expansion works will be undertaken during NDP 7.

Arups' on-going involvement was confirmed with a commission for the major rehabilitation of 16 villages in 1991, the brief subsequently extended by the inclusion of two more villages and a feasibility study to secure a reliable water source for a cluster of three neighbouring villages located close to the capital city, Gaborone. The programme is progressing well and a contract award for the construction of facilities for six villages is imminent.

Conclusion

Although the impact of the RVWS programme is significant, there is much work yet to be done since it is estimated that currently 35% of Batswana live in scattered rural settlements too small to be included in the RVWS. These communities are expected to rely on a variety of informal and traditional sources including hand-dug wells, rainwater harvesting and ephemeral pans and water courses. Cattle-post settlements usually make use of cattle watering boreholes operated by individuals or syndicates on a private basis. Although this proportion is expected to decline, the NWMP has estimated that the population in such settlements will increase from 447 000 in 1990 to 518 000 by the year 2000. The appropriate role for the Government in this area is being defined and is likely to involve promoting the development of appropriate technologies.

The obvious beneficiaries of the RVWS programme are the dispersed rural communities, but to overlook the benefits derived by the engineer would leave half the story untold; these include:

- a rare chance to witness the rural lifestyle in Botswana
- personal encounters with end users when formulating input into the design, through the village Kgotlas (meeting places), the traditional forums for consultation and democracy still used widely in rural areas. The Kgotla meetings specifically arranged to discuss aspects of the programme in the various villages have ranged from three members of the village development committee (the VDC), the chief or headman, and Arups' representative, to half the village! The former are always very brief and to the point, while the latter can take all day, with every individual having his/her turn to voice an opinion on the proposed water reticulation — and which invariably includes a request (with reasons) for placing a standpipe outside his/her compound. Some of the day's proceedings in Setswana (the official language) will occasionally be translated for the benefit of the engineer (unfortunately without the same enthusiasm and conviction of the original speaker). No votes are taken and the chief eventually will summarize the view of the Kgotla and the meeting will disband
- travelling to localities often remote from home, hotels, shops, etc., over terrain requiring four-wheel drive vehicles
- providing people with a basic need, a need exemplified by the bareness and harshness of the environment of most of Botswana.

Credits
Client:
Botswana Ministry of Mineral Resources and Water Affairs
Botswana Ministry of Local Government, Land and Housing
Engineer:
Department of Water Affairs
Engineer's consultant representative:
Arup Botswana Ltd, Keith Small, Clon Ulrick, Nikki Shaw, Amos Keabetswe, Sosome Sosome
Photos:
Mark Nesbitt

Palacio de Villahermosa

Museo Thyssen-Bornemisza

1

Architect:
Rafael Moneo Vallés

Philip Jordan
Tudor Salusbury
John Pullen

The Collection

Baron Hans Heinrich Thyssen-Bornemisza's paintings form the most important private collection in the world after that of Queen Elizabeth II. The Collection, begun in the 1920s by the Baron Heinrich Thyssen-Bornemisza, has been considerably expanded by his son, the present Baron, and now provides a unique insight into the history of painting. It covers the Italian and Flemish Primitives, Italian and Northern Renaissance, the Baroque, Dutch painting of the 17th century, Rococo and Neo-Classicism in France, Venice and England, Romanticism and Realism in Europe and the USA, French Impressionism, German Expressionism, and modern painting of the 20th century, including the experimental avant-garde.

The project

Some years ago Arups were involved with Stirling Wilford Associates in designing an extension to the Baron's art gallery at Villa Favorita, on the shores of Lake Lugano in Switzerland. This did not proceed, but early in 1988 Arups were invited by the Baron to Madrid to inspect a proposed new home for the bulk of his collection. The Spanish Government had successfully bid, against competing offers from West Germany, Switzerland and The Paul Getty Foundation, to provide a 'permanent' gallery for the collection. At present, 'permanent' means 9½ years — the period after which, under present law, works of art are not allowed to leave Spain.

The building

The building proposed stood on the corner of Plaza de Cánovas de Castillo, just a stone's throw from the Spanish Parliament, Las Cortes, in Carrera de San Jerónimo. The prestigious nature of the location is indicated by the presence on opposite corners of the Plaza of the Prado Museum and two five-star hotels, the Palace and the Ritz.

The building originated as the 'palace' (mansion) of the Duke of Villahermosa in the late 18th century, and its site can be traced back to the 17th century — originally part of an estate on the eastern boundary of Madrid overlooking a large park.

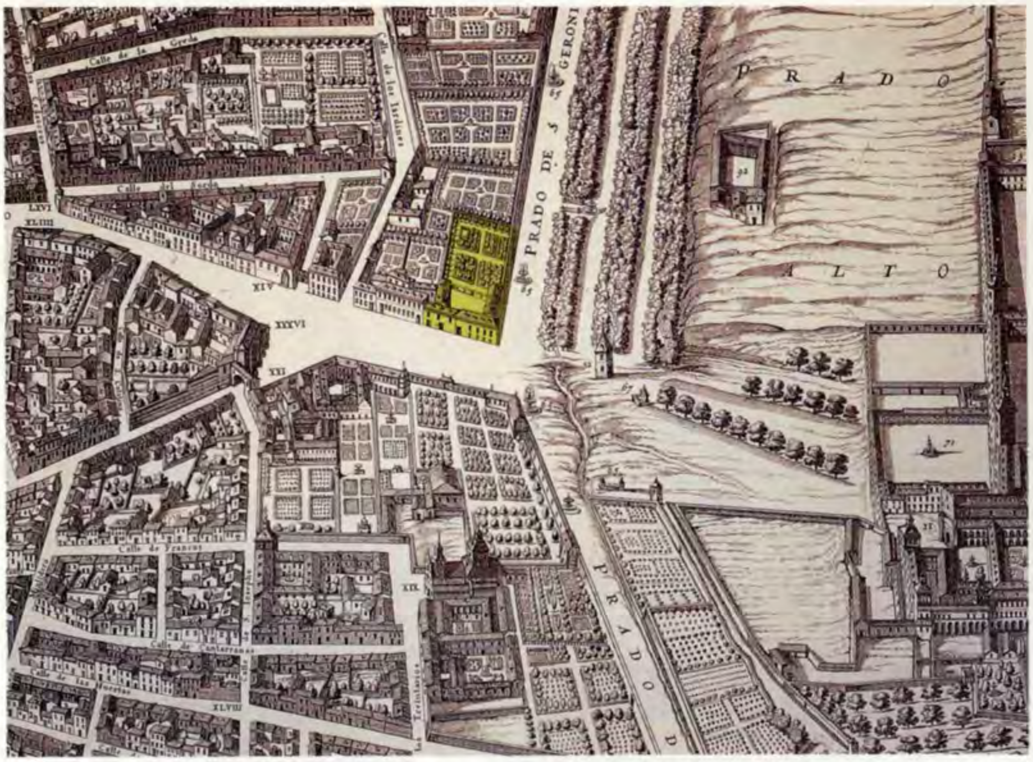
The façade walls on the north, east and south sides link back to major renovations carried out in the early 19th century for the Duke by the architects Silvestre Pérez and Antonio López Aguado. The latter was a leading disciple of Juan de Villaneuva, architect of the Prado, and the pleasing blend of granite-framed brick which graces the façade walls of the present gallery is characteristic of their style. During the 19th century the main halls housed meetings of the 'Liceo artístico y literario', a society dedicated to restoring Spanish culture. Masque-balls were also held and a wall plaque records a concert given by Franz Liszt. In 1970 the building became a bank headquarters and was entirely rebuilt within the existing façade walls in the mid-1970s. The original cross-wall masonry was replaced by a reinforced concrete structure with waffle-type flat slabs. The building was also extended down to three basement levels using diaphragm walling and substantial underpinning. Soon after, a banking crisis brought it into the hands of the Spanish Government, and it was used for a time to house temporary exhibitions for the Prado Museum.

The client and the architect

After its successful bid for the collection, the Spanish Government set up and endowed a Foundation (known as the 'Fundación Colección Thyssen-Bornemisza') to procure the new gallery and fund its on-going activities.

This became Arups' client and now runs the gallery. The Foundation's selected architect was Rafael Moneo Vallés, previously acclaimed for the Museum of Roman Art at Merida, and at that time Professor of Architecture at Harvard University.

The overall site area is 125m x 55m, including a garden area at the north end leading into the gallery. The building has a gross floor area of 18 500m^2 and contains 10 000m^2 of wall area to display the 800 paintings, arranged chronologically. There are 50 gallery rooms linked to form a continuous viewing route, starting at the second floor south gallery where the earliest medieval works (many painted on wood) are displayed.



2. 17th century engraving showing the site of the Villahermosa Palace.

Initial brief

The loan agreement between the Baron and the Kingdom of Spain laid down specific criteria for the internal environment, relating to control of temperature, humidity, air filtration and lighting levels, as well as security standards. From these criteria, Arups developed a detailed engineering design brief during 1989, drawing heavily on experience gained from other such projects including the London National Gallery extension.

The objective was to produce a gallery whose services installations were comparable with the best international standards, yet the brief also reflected three fundamental decisions affecting the design philosophy. Firstly, sophistication for its own sake was consciously avoided, with the end-user constantly in mind.

Secondly, water services were kept out of the main picture gallery and storage areas. Where this was unavoidable for certain roof drainage, an additional gutter was provided below the main pipework. Thirdly, maintenance requirements were to be 'designed-in'. Risers were to have walk-in access and be kept out of public areas.

The brief document formed the basis for the structure and services *Projecto Basico* design report, prepared in June 1989 and submitted with the architect's planning application later in the year. In addition to the engineering design, Arups gave early advice to the architect and client on fire strategy, on projected costs of the engineering works, and on several programme options to achieve alternative completion dates.

Unlike many Arup commissions in Europe, it was decided to carry out full detailed design of the structure and services, and to remain in touch with the job through construction to commissioning and completion. In practice, this involved Arups in producing most of the structural contract drawings and taking services information up to tender stage. However, sub-consultants were needed to ensure that the drawings and specifications accorded with Spanish requirements, to assist in the later design stages, and steer the project through the site phase.

Early progress

In Spain the two phases of design and construction are seen as more distinct than in the UK. Not only are contractors more active in proposing changes once they win contracts, but the development of architectural details, finalization of dimensions, and general adjustments to suit design development, are in the hands of a technical site architect called an *Aparejador*. Resident engineers are rarely used in building works. Initially the building could not be cleared of its remaining occupants until the end of 1989. This made the desired early strip-out impossible and the initial soil and structural investigations had to be carried out while the building was still partially occupied. Then, just as things got under way, the Managing Director of the Foundation, Sr Ignacio Cardinal, became ill and died. More than six months went by before he was replaced. By this time a main contractor, Entrecanales y Tavora SA, had been appointed on the basis of a demolition tender, a priced schedule of rates with approximate quantities, and percentage on-costs for the services packages. Soon after appointment the main contractor reviewed the entire demolition method statement, against which they tendered, and attempted to modify substantially the structural philosophy adopted for the building. In the event, Arups' solution was retained for most of the building except for the South end.

Existing structure

At the start of the project, contact was made with Agroman, the contractors for the 1975 reconstruction. They provided a full set of working drawings including details of the original design loads, material properties, etc. An initial investigation was nevertheless carried out to check the information on the drawings and the present strength of the concrete. Internally, the existing structure reflected the planning requirements for a bank headquarters. The structural grid was a fairly uniform 8.6m x 6.75m, and the 350mm thick floor slabs of in situ reinforced concrete with permanently embedded lightweight block 'waffles'. These were grouped in threes to make a 600mm X 600mm x 300mm deep waffle, spaced out to give a 120mm rib thickness at 720mm centres.

One of the areas where block samples were removed for density testing revealed a substandard area of concreting, but generally the original construction was of a reasonable standard. Except, that is, for concrete cover in the ribs. This was originally given as the bar diameter, as was typically used in *BSCP114* in the UK. Because of the number of bars in many of the rib soffits there were also many areas where bars were exposed. On both counts, fire and corrosion protection, additional cover was provided as part of the present refurbishment.

New structural works

The structural work necessary to suit the new architectural planning was not straightforward. It included infilling existing stair voids, breaking out large areas of slab for new stair cores, ducts and risers, and removing and relocating columns. An extensive network of underslung beams was needed to provide new supports for the existing slabs. The existing roof structure was totally removed and replaced to restore the roof slope existing prior to the 1975 rebuild.

A number of major transfer structures required the work on several levels to be carefully sequenced and co-ordinated. Arups provided method statements on the relevant drawings to guide the main contractor. The largest of these structures was a storey-height truss supporting four levels of structure, necessitated by the removal of two columns in the entrance area of the Museum, which the architect wished to keep column-free.

All these structural members were in steel, both for speed and ease of construction. New areas of slab, totalling 3000m^2, were provided using concrete on profiled metal decking, although this was used only as a permanent shuttering. Composite concrete floors are not yet common in Spain but, despite initial reluctance, the contractor provided shear studs on the steel beams to allow these to be designed compositely. These were welded directly into the top flanges of the beams, not through the decking as is usual in the USA and UK. ▶

3. Aerial view facing north-west: Plaza de Cánovas de Castillo in foreground.

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Plant layout and zoning

The stringent environmental brief defined by the loan agreement and the new internal layout established by the architect necessitated new building services throughout.

Two factors influenced from the start the plant organization and distribution of principal services within the building. Firstly, construction of the deep basement during the '70s restructuring allowed the third basement to be reused for siting most of the new plant. To provide sufficient space at basement level for services like air-handling plant is normally expensive.

Fortunately space already existed here, allowing a rational organization of plant within the basement and avoiding the need to locate a large amount of plant at roof level, which would have impeded the extensive use of natural lighting in the galleries.

Secondly, the overall size of the building led naturally to its perception as four quadrants from the point of view of services distribution.

The basement plant includes air-handling for picture areas, for the lecture theatre and for ancillary areas.

Chilled water is produced by means of three screw chillers (two duty and one standby); chilled water and heating pumps are also located here, together with a 300kW diesel generator set which provides supplies to fire and life safety systems in the event of mains electrical supply failure.

Heating is by three oil-fired boilers (again, two duty and one standby), adjacent to the car park at second basement level, where the main low voltage switchroom and sprinkler tanks are also located. The main LV switchboard is fed via busbars from the transformer substation located below the garden where easy access is provided off the ramp to the car park. Two 15kV supplies are taken from the electricity supply company and are transformed using two 1600kVA cast resin transformers and distributed throughout the building at 380/220V.

All services are monitored from a central control room, manned at all times. This houses control systems for:

- building management system (BMS) for air-conditioning plant
- lighting management system (LMS) to control artificial and natural lighting
- security systems, fire and voice alarms
- synoptic panels for fire detection and fire dampers
- displays and monitors.

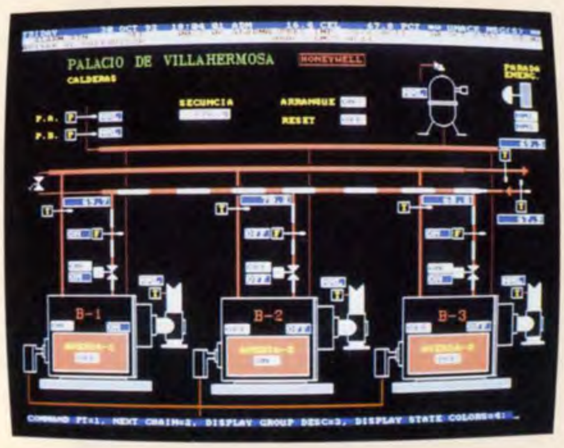
Temperature and humidity control

The loan agreement makes specific reference to the temperature and humidity levels demanded for all areas where pictures would be hung or stored. The basic requirement, in line with the generally accepted practice for art galleries of international standing, is to control humidity to 55% ± 5% and temperature to 24°C ± 1°C in summer and 20°C ± 1°C in winter, with a seasonal change to be 'gradually effected in a controlled manner'.

External design conditions in Madrid are 36°C dry bulb, 22°C wet bulb in summer and –4°C with 100% relative humidity in winter. The air-conditioning system had to be designed, therefore, to maintain a significant imbalance between internal room conditions and the relatively low external humidity levels throughout the year.

External air enters the building at roof level where it is pre-filtered and pre-heated. It is then drawn down a vertical shaft to a plenum along the length of the back wall of the third basement plant room, from where it is distributed via the air-handling plant to all parts of the building. The external air is expelled into an exhaust air plenum above the supply, and discharged at roof level.

Each of the three main gallery floors is served by a dedicated air-handling unit. These, together with the plant serving the temporary exhibition gallery at first basement level and the picture store and restoration studio, include two-stage gas filtration with



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A. Building Management System panel display.

B. Chiller (motor) control centre.

Structural design solutions

Arups originally hoped that a main contractor would be brought in early by negotiation to allow the development of the structural scheme to suit a fast programme. Much thought was given to the amount of demolition needed to ease the new construction process, even going so far as to consider total demolition within the façade walls down to ground floor level. In the event, the contract had to be awarded on a normal competitive basis and so Arups had to decide on the appropriate amount of demolition and rebuilding. At the south end of the building there was a requirement to demolish an existing line of columns and rebuild on a new gridline, as well as infill existing stair voids. The optimum solution appeared to be to demolish and rebuild the structure at ground floor and above, but the contractor preferred to keep the existing floors. A grillage of new beams was provided at each level to support the slabs over the longer span. In general, however, Arups' proposals were adopted by the contractor.

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4. Facing south: autumn 1990, with new steelwork in place within 1970s concrete structure. The opening is for a staircase in the former bank headquarters, later infilled.

5. Progress by spring 1991, from a similar viewpoint. The double skin interior walls and smoke ducts can be seen in foreground.

One of the key decisions faced on the structure was how to attach the new steel beams to the existing concrete columns, strengthening the latter where necessary to carry additional load. The effect of the revised column loads also had to be considered in regard to the existing foundations -bearing pressures and relative settlements.

A full soil investigation was carried out by Arups, and this showed that the silty clay underlying the site was capable of carrying a much greater bearing pressure than used in the original design. The controlling criterion became differential settlement. Only one base fell outside the normal settlement limits and it was decided, after checking its physical size as cast, that there was likely to be a greater risk arising from underpinning than from leaving it alone. In conjunction with the increase in bearing pressures it was fortuitous that the original pad footings were in structural quality mass concrete. An increase in bearing capacity required no strengthening to the base, which in turn allowed a resolution of the beam-to-column connection problem.

It was decided to add steel columns on two opposite sides of the existing concrete column where large additional loads required support. These were carried down the building to footing level, in most cases picking up additional loads at each level. Although these storey-height columns required grouting at their bases and dry packing at their cap plates, the beam/column connections could now become normal steel-to-steel connections using the fully capacity of high strength bolts. It also removed the need to assess the effect of additional loads on the existing concrete columns, allowed the steel columns to be installed as a discrete phase in advance of the beams, and provided an accurate control for the length of the new beams.

Unlike in the UK, the designer has to give full end connection details for steelwork. Because of the great variety of connection types and relative levels and sizes of beams, a considerable effort was required to produce the information.

To all appearances the internal planning of the public galleries suggests that the building is supported on very thick walls. In fact they are hollow and enclose the vertical structure as well as the supply and extract ducts which distribute air throughout the building.

the external air and recirculation air being filtered by means of activated carbon filters.

The location of the site by the Paseo del Prado, one of Madrid's busiest streets, together with the relatively extreme external conditions, led to the decision to limit external air volumes at all times to that required by the occupants. The external air quantity for each floor of the building is therefore controlled using CO_2 detection in the return air. During opening hours, these volumes vary between a fixed minimum of 10% to a maximum of around 30% of the total supply air volume for each zone.

Within the plantroom, each of the three main gallery air-handling units feeds a secondary plenum from which the supply ducts pass to each control zone of the corresponding floor. Humidification and re-heat takes place within the duct of each zone after this secondary plenum. In this way, both first and second stage temperature and humidity control are effected from within the plantroom. Air is supplied to the galleries at a constant volume flow rate, reduced at night, using two-speed motors for both supply and extract fans. Air movement within the galleries was studied carefully to limit air velocities over picture surfaces.

The BMS for control of the air-conditioning system is based on a Honeywell Excel Plus system with intelligent outstations.

Lighting in galleries

There is always a conflict in the design of lighting for galleries between producing enough light to see the paintings adequately without seriously damaging them and creating a space in which the public feel comfortable.

Also, from an operational point of view energy consumption and maintenance costs are important.

Daylight is used as the principal means of lighting in the second floor galleries via rooflights. The amount falling on the hanging surfaces is controlled by motorized louvres on the outside of the windows, in turn controlled by light sensors monitoring the incoming daylight levels. These systems are stand-alone but are switched on and off by the LMS. The central ground floor gallery is a single, 10m high, storey, with north-facing rooflights allowing uncontrolled daylight into the heart of the building.

The large façade windows in the galleries on all levels are fitted with louvred shutters to eliminate the effect of daylight but retain a visual connection with the outside. These louvres are openable for window cleaning or if special events so require.

The artificial lighting for the hanging surfaces is a combination of fluorescent luminaires, using high frequency dimmable ballasts and Philips colour 93 lamps, and low voltage tungsten halogen track-mounted spotlights fitted with UV filters and sculpture lenses to soften the beam edges. The colour temperature and colour rendering of the two sources are similar.

The second floor daylit galleries have light sensors viewing the walls which, via the LMS, control the artificial lighting to maintain illumination at the required level. These sensors also have a monitoring function, the LMS raising an alarm if excessive light levels are measured for more than a short period of time. In addition to picture lighting, circulation and security lighting are also provided, controlled by the LMS.

Fire and security systems

An analogue addressable fire detection system is installed using smoke and heat sensors together with breakglass units. This system interfaces with a voice alarm/public address system which will automatically broadcast alert and evacuate messages in three languages if a fire is detected and confirmed. The detection system also interfaces with lifts, mechanical plant and fire damper systems to initiate the relevant action in the event of alarm. Sophisticated electronic security systems are installed.

C. Main pump room.

D. Typical rooflight showing adjustable external blinds.

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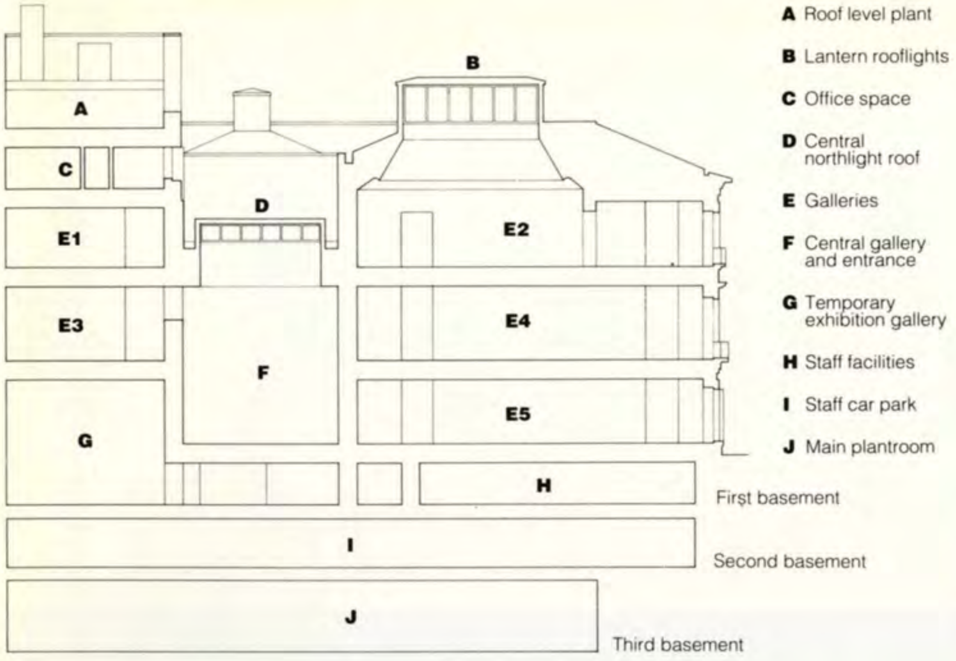

10. East-west cross-section through Villahermosa.

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6. 17th/18th century collection on the first floor facing north (E4 on section opposite).

7. 20th century (North American) gallery, ground floor facing west (E5 on section).

8. Renaissance paintings on wood, south-east corner gallery, second floor.

9. 16th century gallery near north end of second floor, facing north-west.

Sub-consultants

Arups collaborated with two leading independent consulting engineers with whom very good working relationships were maintained through the project. They were of particular help in interpretating Spanish codes of practice and during construction, when weekly meetings were attended by the sub-consultants with Arups present on a monthly basis. During the final six months, however, as the project entered the commissioning phase, Arups re-established a detailed involvement, providing technical expertise as and when required for commissioning the BMS and LMS, fire and security systems. The decision to carry out detailed design and stay involved right through the project was severely tested on more than one occasion, but the insight gained into the Spanish building industry more than compensated for any problems.

Opening celebrations

The gallery opened to the public in October 1992 after a week of special events, including an official opening by King Carlos and an all-night ball thrown by the Baroness. Members of the Madrid public gave the gallery an enthusiastic welcome by queuing around the block for the opening of the doors. 6000 visitors viewed the collection on the first day and one million are expected to visit each year.

For the first time the Thyssen-Bornemisza Collection can be seen as a whole in a permanent installation, with nearly 800 paintings, 20 sculptures, textiles, pieces of ivory, silver, and furniture on display.

The handsome two-volume catalogue of the paintings in the collection provides a worthy souvenir and also reveals why the effort of all those involved in the Project was well justified.

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Credits
Client:
Fundación Colección Thyssen-Bornemisza
Architect:
Rafael Moneo Vallés
Consulting structural and services engineers:
Ove Arup & Partners International Ltd.
Cecil Balmond, Tudor Salusbury, Philip Jordan, John Pullen, Bob Venning, Ross Sankey, Simon Oliver, Peter Hartigan
Structural sub-consultant:
Esteyco SA
Services sub-consultant:
J.G. & Asociados SA (Barcelona)
Contractor:
Entrecanales y Tavora SA
Mechanical sub-contractor:
Sefri Ingenieros SA
Electrical sub-contractor:
Crespo y Blasco SA
Fire systems:
Cerberus Ltd.
Security:
Tecosa SA
Lighting control:
Camesa SA
Photos:
1, 11: the client; 2: Peter Mackinven;
3, 6-9, 12, C, D: the contractor;
4, 5: Abdon Flores;
A, B: Tudor Salusbury

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