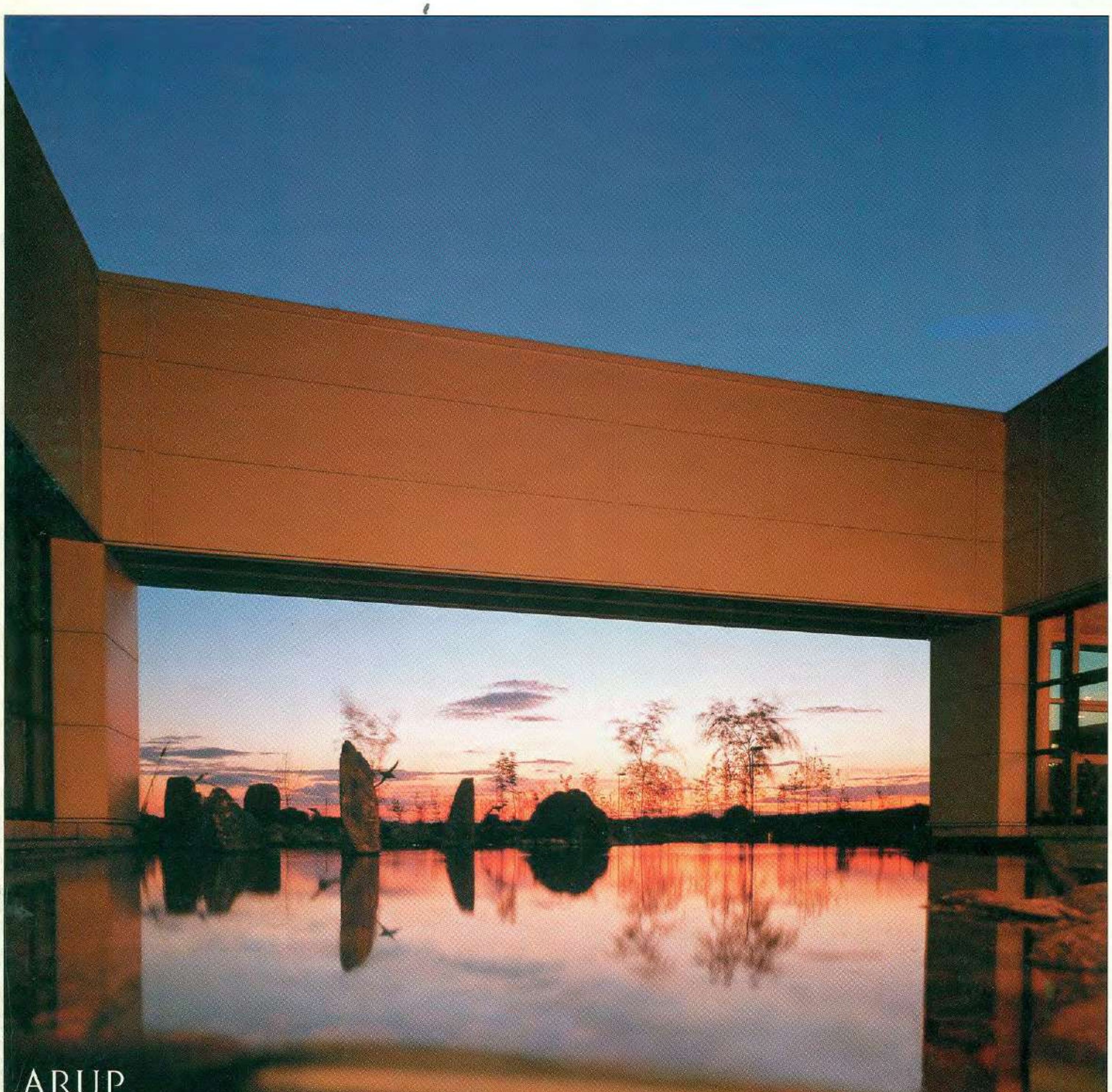
THE ARUP JOURNAL

3/1995



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Front cover:
Rockpool at the administration building, Sandoz Ringaskiddy, Cork
(Photo: Finbarr O'Connell)

Back cover:
Movie-set façade to the new film archive building at Warner Bros. Studios, California (see pp.15-19) (Photo: Tom Bonner)

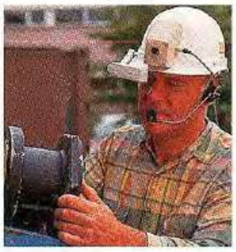
The Swiss pharmaceutical company Sandoz has established its largest manufacturing facility outside Switzerland on a 40ha site near Cork. Ove Arup & Partners Ireland were appointed for the civil, structural, architectural, and building services design of the non-process related parts of the project, and collaborated closely with the process design engineers in Philadelphia via innovative use of on-line 3D design software.

Over 4000 employees are accommodated in the new four-block headquarters of South Africa's First National Bank, probably the largest commercial building project in the southern hemisphere. Ove Arup Incorporated initially examined the viability of the Bank relocating from 28 separate buildings. Following acceptance of the new-build option, they undertook the civil, structural, and geotechnical engineering for the new buildings, as well as project management services.

Construction of Manchester's new Nynex Arena (to be featured in a forthcoming *Arup Journal*) on railway land necessitated the repositioning of main lines and platforms at Victoria Station. The structural, civil, and services engineering appointment for Arups' Manchester office included the design of three new footbridges over the tracks, and the systems for ventilating diesel locomotive exhausts from the partially-enclosed new station platform area.

The creation of environments to store and preserve the 20th century's vast legacy of photographs, film, and videotape is still in its infancy. Arups' Californian practice has designed film and tape archive facilities for two of the largest Hollywood studios, Paramount and Warner Bros. Their structural and building services design involved the creation of separate areas for the different media, exceptionally tightly controlled for temperature and humidity.

The dozen buildings at this campus designed by the great American architect Frank Lloyd Wright have suffered considerable structural deterioration. Arups have assessed various alternatives for levels of restoration (and designed a prototype replacement for some of the blockwork) and proposed a data management system for storing information about and maximising benefits from any restoration work undertaken.



For the last four years Ove Arup & Partners have been a research partner in an EC-funded and promoted R&D programme to investigate ways of improving communications between the various parties involved in the building process, with information technologies as the key enabler. This article outlines the pilot trials and conceptual modelling with which Arups has been involved.

Sandoz Ringaskiddy Ltd., Cork

Jerry Mehigan

Introduction

In a special issue of *The Arup Journal* produced in 1990 and featuring the Irish practice of Ove Arup & Partners, a brief description of the Sandoz project was included. Phase 1 is now complete, with a second Phase under construction. The present article outlines key aspects of the project and the involvement of Ove Arup & Partners Ireland.

1. The Ringaskiddy plant overlooking the harbour mouth.

Background

The history of Sandoz goes back to 1886 when the company was set up in Basle, Switzerland, to manufacture synthetic dyes. This was a natural progression from the city's long-established silk business, which trade had been of considerable economic importance for centuries. The company expanded and diversified, moving into pharmaceuticals in 1917 and agrochemicals in 1939. In recent years expansion has been accelerated by acquisition. Sandoz now employs approximately 60 000 people in some 55 countries, the pharmaceutical division being the largest, with 22 000 employees.

Sandoz' long-term strategy plan, drawn up in the 1980s, foresaw the need for a second main location for the production of active substances. This was not just the result of the relatively confined conditions in the Basle plant: having more than one site would mean a better distribution of risks as well as greater flexibility. Against this background, in 1988 Sandoz reviewed a number of locations worldwide, and eventually chose Ireland as the preferred option. The main reasons for the choice - and the Cork area in particular - were:

- access to the European Union
- availability of an industrially-zoned site with all necessary infrastructure and nearby airport and seaport
- availability of a highly-trained workforce and suitable educational facilities
- Cork's position as the hub of the Irish pharmaceutical and chemical industry and also home to many experienced suppliers of goods and services
- successful negotiation by the Irish Industrial Development Authority.

The Ringaskiddy facility, which produces bulk active ingredients for pharmaceutical/healthcare products, represents the biggest single investment in bulk pharmaceutical manufacturing ever made outside Switzerland by Sandoz.

Description

The development stands on a 40ha site in the industrial area of Ringaskiddy, 16km south of Cork city near the harbour mouth. It is centred around two main process buildings, the first of which is a multi-purpose plant for manufacturing a range of products.

A drug named Clozapine, which has created new life for schizophrenia sufferers, is the first product from this unit to receive approval from the Food and Drugs Administration (FDA) of the United States.

This is a major milestone for Sandoz Ringaskiddy as it allows them to sell this drug in the USA, the largest Sandoz market.

The second main building is currently under construction and is designed for dedicated processes - mainly for the purification of various peptides.

This second process building was structurally complete at the end of August 1995, with architectural fit-out continuing to April 1996. The first production runs from it are scheduled for early 1997.

A significant investment has been made in providing this greenfield development with the necessary infrastructure and support services. These include:

- utilities such as power,steam, water, etc.
- environmental controls including waste water treatment and on-site incineration
- administration facilities
- engineering support
- laboratories
- warehousing.

Site masterplanning

In the search for an optimal solution to the masterplanning of the site, several factors were considered so as to develop a balanced approach. These fell into five main groups:

- *Site constraints*

The principal one was a corridor of existing services crossing the site. The main site grid was set out parallel to this corridor.

- *Manufacturing requirements*

Clearly, the core of the project lay in the production buildings and all the masterplan options had as a central theme the supply of materials and services to, and the provision of facilities for, these buildings. Positioning the tank farm, warehousing, etc., with respect to production was a primary consideration.

- *Accommodation and movement of people*

Particular attention was given to the functional activities of Sandoz' personnel, as well as the ongoing operations of outside contractors and the accommodation of visitors, who would be numerous. Safety and security factors were also important.

2. A view from the nearby River Owenboy estuary.

• *Scope for expansion*
With a relatively high percentage of the capital cost invested in infrastructure and support facilities, a key consideration in the master-planning was provision for future expansion. It was essential to be able to construct additional process buildings and to extend existing buildings and facilities, without adversely affecting any of the existing operations.

• *Visual and landscape considerations*
Siting this major manufacturing facility in a predominantly rural landscape was a key challenge. The open aspect from the south and across the nearby estuary, together with the sharp rise in topography immediately to the north of the site and the continuation of the industrially-zoned land to the east, provided the remaining starting points for the development of the master plan.

Site layout/architectural concept

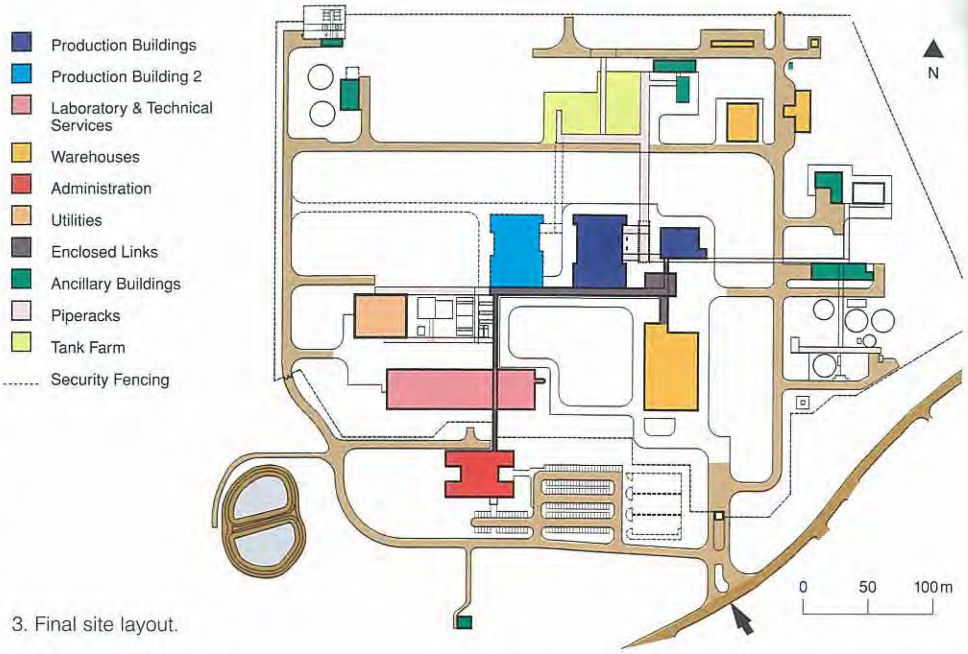
The final site layout is shown in Fig.3. The administration building is the entry point for all plant personnel and visitors, and contains security control over access to all operations on site except warehouse and tank farm deliveries where separate security control is maintained. The administration building is linked via a single-storey corridor to the laboratory/technical services building, which houses all the engineering and laboratory support services.

This building, in turn, connects via a two-storey corridor to the process buildings and the main warehouse. The upper floor of this corridor is for personnel circulation and the ground floor for material flow.

Unlinked buildings not involved in significant movements of people include various category warehouses, the environmental controls building and the tank farm area.

As can be seen from Fig.3 there is sufficient space for two further production buildings while the layout also allows for expansion of all existing buildings.

The building forms were conceived as a series of horizontal steps, the highest structures towards the rear of the site and smaller, pavilion-type buildings placed to the front. This stepped concept helps reduce the apparent mass of the seven-storey high process buildings. External appearance is largely in response to the local authority planning guidelines, the materials being mainly colour-coated steel cladding panels and aluminium-framed glazing systems. A variety of colours and profiles have been introduced to give a sense of scale to the building forms which have generally been designed as simple geometric shapes. Shades of green have been chosen to blend, as much as possible, into the surrounding landscape.



3. Final site layout.

Design of buildings and infrastructure

Arups were appointed for the civil, structural, architectural, and building services design of the non-process related elements of the project, and in turn appointed local architectural and quantity surveying firms as sub-consultants. The firm also had a key role in the project's planning and licensing requirements. The process design engineers are Raytheon Engineers and Constructors (RE&C) of Philadelphia.

It was a Sandoz requirement that all drawings including reinforced concrete detailing be implemented on CAD, the systems used being predominantly Intergraph-based. A leased line connection was set up between Arups, RE&C in Philadelphia, and the Ringaskiddy site for the electronic transfer of all design information. The second main process building is being designed using fully integrated 3D software with the capability to superimpose mechanical, electrical and process services on detailed 3D layouts of the structural and architectural model. This 'real life' model enables efficient design co-ordination of layouts and services on an interactive basis.

The structural and architectural elements of the model are being assembled by Arups using Project Architect software, and this model is then exported via the leased line to Philadelphia where the services, piping and equipment arrangements are superimposed. Clash detection software is used to check for any interference between structure and services. Conventional construction drawings are generated from the model and these form the basis for construction issue information. Fig. 4 shows a part view of the model before and after equipment installation.

Ground conditions/foundation design

The bedrock geology of the Ringaskiddy Peninsula is complex and understanding it is made more difficult by an extensive and varied covering of glacial drift.

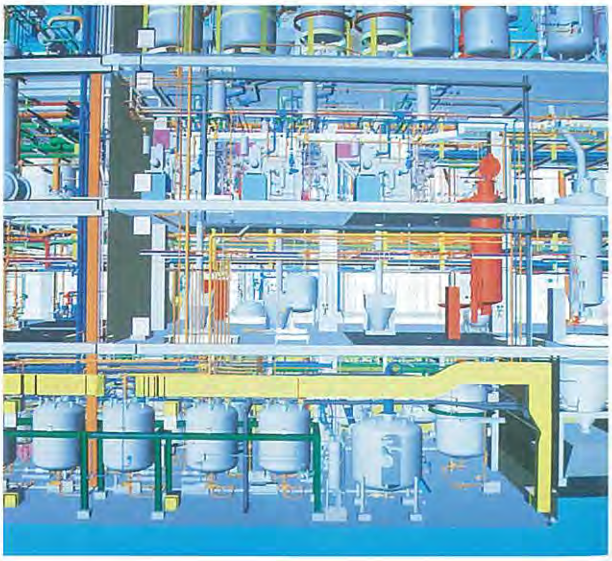
Within the site, the bedrock is predominantly Carboniferous limestone with an overburden depth ranging from zero to more than 25m.

A detailed site investigation was carried out, using boreholes, probe holes, trial pits and a resistivity survey, all of which indicated good quality glacial drift with a bearing capacity around $150kN/m^2$.

However, the cores drilled into the rock showed that the limestone had been subject to extensive karstic weathering. This involves the subsurface removal of rock in solution by groundwater, which weakens the rock and results in potential ground instability. While the engineering properties of the glacial drift made it suitable to support the foundation loads, the possible effects of karstic weathering had to be addressed. The final design was to found on the glacial drift but in specific areas of shallow overburden where karstic development could cause bearing instability, the foundations generally were designed to allow for a 3m loss of support.

(a)

4.
Part view of computer-generated architectural model,
(a) before
(b) after
equipment installation.



(b)

Specific precautions were taken both during and after construction to minimise the possibility of any karst development.

These included:-

- control of stormwater flows
- landscaping the site to avoid any concentrated inflows or collection of water
- control of excessive loading on overburden
- provision of an external impermeable apron around buildings
- avoidance of forced changes in groundwater level.

The foundation design for the process buildings demanded special consideration. Because of the heavy loads, piling was examined as an alternative to bearing on the drift but - due mainly to the very variable nature of the rock - this was deemed unsuitable, and a raft foundation was used. Due to the variable depth of overburden beneath the raft, bearing support was modelled using springs of varying stiffness, with settlement sockets cast into the structure to monitor actual against predicted settlements. The raft is 60m x 42m x 1.3m deep and involved 3300m^3 of concrete cast in four pours. Due to this large mass of concrete being poured with consequent heat of hydration, it was necessary to address the possibility of thermal cracking. A maximum temperature of 65°C was specified with an allowable thermal gradient of 20°C.

The formwork and the top of the cast concrete were insulated and thermocouples incorporated in the pours to monitor concrete temperatures.

The second main process building

One of the most interesting aspects of Sandoz Ringaskiddy has been the structural design of the second process building. Planning permission for it was granted as part of the overall development but construction of the building did not form part of Phase 1; the decision to proceed did not come until early 1994.

Several design criteria were laid down by Sandoz. Firstly, for the specific process being planned, a flat soffit for each floor would be required, thus maximising headroom within the overall height of the building - which could not exceed what had been granted by the planning permission.

Secondly, the slabs should have sufficient flexibility to allow future penetrations for additional equipment. The third criterion was that the proposed fit-out of the building would only take up two-fifths of the total plan area, so the remaining three-fifths would be designed as an open beam-and-column structure with infill slabs at some future date. A number of options for the structural design of the slabs were examined, but the only one that met both the requirements of a flat soffit and flexibility for future openings was a combination of post-tensioned beams and infill slabs. The post-tensioned system has been designed using bonded superstrand tendons with a minimum tensile strength of 1767N/mm^2. The beams have been designed on a 7.2m square grid so that the post-tensioning carries the dead loads, with traditional reinforcement supporting the imposed live load of 15kN/m^2.

5.
Second process building showing the post-tensioned beams and the beam-and-column structure in the open or reserve section.

6.
Post-tensioned beams: intersection detail.

The beams are 1200mm wide by 350mm deep and the infill slab depth varies from 350mm at the beam interface to 300mm, as most floors are laid to falls. Because of the shallow depth of the beams, the post-tensioning layout within each beam includes four oval ducts with four strands in each duct. The slabs are designed to provide a high degree of flexibility for future openings within the infill slab area. The boundaries between the beams and the slab area are delineated by *Unistrut* inserts and the beam soffits are painted red to ensure that no drilling takes place in this area.

In the open or reserve section of the building the structure comprises beams and columns only with starter bars for the future infill slabs. Permanent *Hy Rib* side shutters with starter bars punched through were used in the beams. The overall lateral stability of the building comes from the reinforced concrete cores. However, free movement of the beams - needed so as to ensure that the post-tension forces were adequately transferred - had to be considered. A sliding joint detail was designed at the cores to allow this movement during post-tensioning operations. The joint is designed for grouting up when the structure is completed, to facilitate transfer of the lateral loads to the cores.

Design of offices

Offices are located throughout the plant, though the main office area is in the administration building - which was the recipient of a regional award sponsored by the Irish architectural magazine *Plan*. Most of the offices have a deep plan layout with much external glazing, and therefore are air-conditioned. However, the production support offices located off the main corridor linking the two production buildings afforded an opportunity for a naturally-ventilated approach. Here a range of architectural and building services features allow the occupants to control their working environment according to the prevailing external and internal conditions.

7.
Entrance to the administration building.

Fig. 8 illustrates the design concept for the natural ventilation. The offices are south-facing and have a large glazed area, so to reduce direct solar gains during the summer months, external sun shades project 1m from the face of the building. In winter and in the morning and late afternoon the sun angles are lower and the sun can shine under the external shades. For this reason, perforated micro-blinds are provided, allowing diffuse light into the space.

Internal light shelves have been provided at the same level as the external shades. These shelves have a mirrored upper surface to reflect daylight deep into the space and reduce the need for supplementary lighting. Ventilation is provided by a combination of openable windows, trickle vents, and automatic roof vents.

The trickle vents - controlled by opening and closing the vent slot - have been provided in the lower section of the window, so that air can enter the space when the windows are shut.

The high level roof vents reduce the temperature of the space during hot weather. They have been designed to work in conjunction with a high curved ceiling to allow a layer of hot air to collect at high level in the space above the occupied zone (Fig. 9).

When the room temperature reaches a preset limit, the vents open automatically. The hot air which has collected in the top of the space dissipates through the roof vents and outside air is drawn in through the south-facing windows.The vents are fitted with a rain sensor and anemometer which prevent operation during inclement weather.

The offices are heated by perimeter radiators fitted with thermostatic radiator valves.

The overall scheme was modelled using Arups' ROOM software, which calculates thermal and comfort conditions in a single space under dynamic thermal loading. Different parameters such as size of solar shades, extent of glazing, and construction materials, were modelled to determine the optimum temperature and air flow conditions within the spaces.

Site services

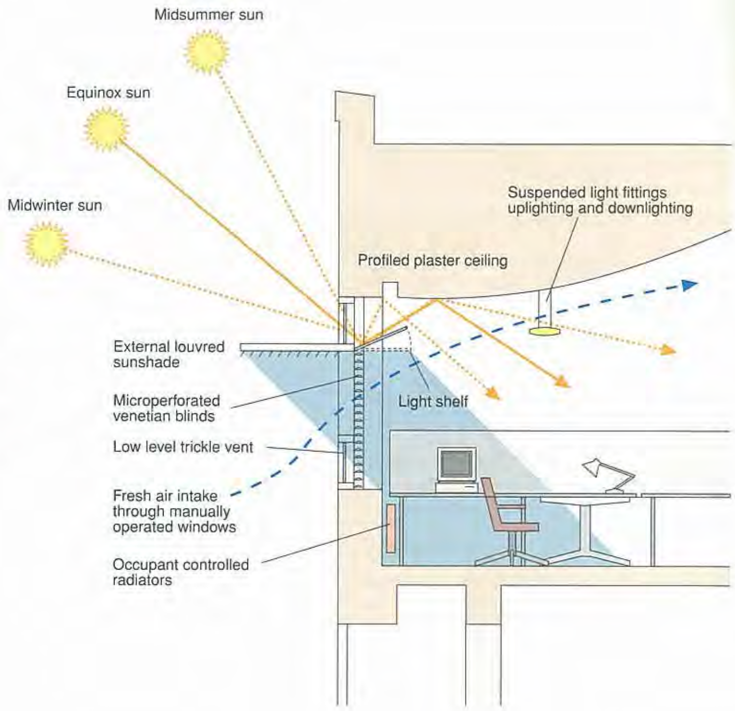
There is an extensive network of underground services, including power, natural gas, data cabling, potable water, fire mains, and a series of separate drainage systems.

Two of the more interesting features of the site services are the process sewer and the firewater retention pond. The former handles weak process effluent and wash downs from the production buildings and other specific areas of the site. It consists of a double containment polypropylene pipe system, jointed by plastic butt-fusion welding (Fig.11).

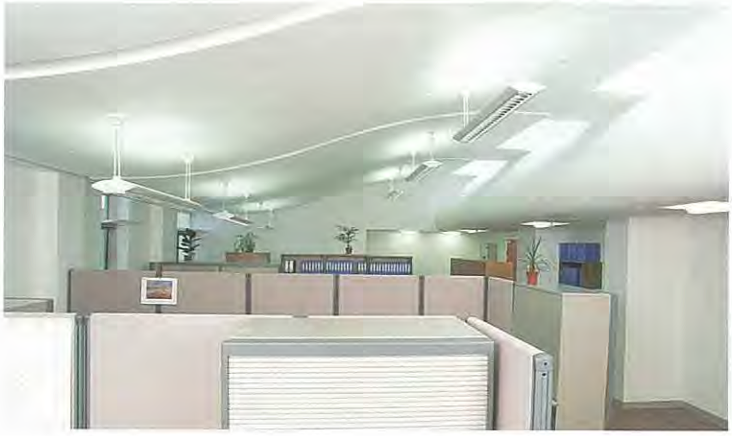
Both inner and outer walls are welded simultaneously. The inner pipe is fully continuous with access tees at each manhole, whilst the outer pipe, which provides a second line of defence against leakage, stops at each manhole. The manholes are lined with polypropylene and are designed as holding sumps, so that any leakage from the inner pipe to the annulus is intercepted in the next downstream manhole. These manholes are fitted with a leak detection system to allow for regular monitoring. This double containment system forms part of a very comprehensive environmental protection scheme.

The concept behind the firewater/stormwater retention pond (Figs.10 & 12) is that water used in fire fighting could become contaminated and cause pollution to groundwater or waterways. All buildings where a fire risk exists are, therefore, surrounded by an impermeable apron to intercept any such water or spillages in the event of an incident.

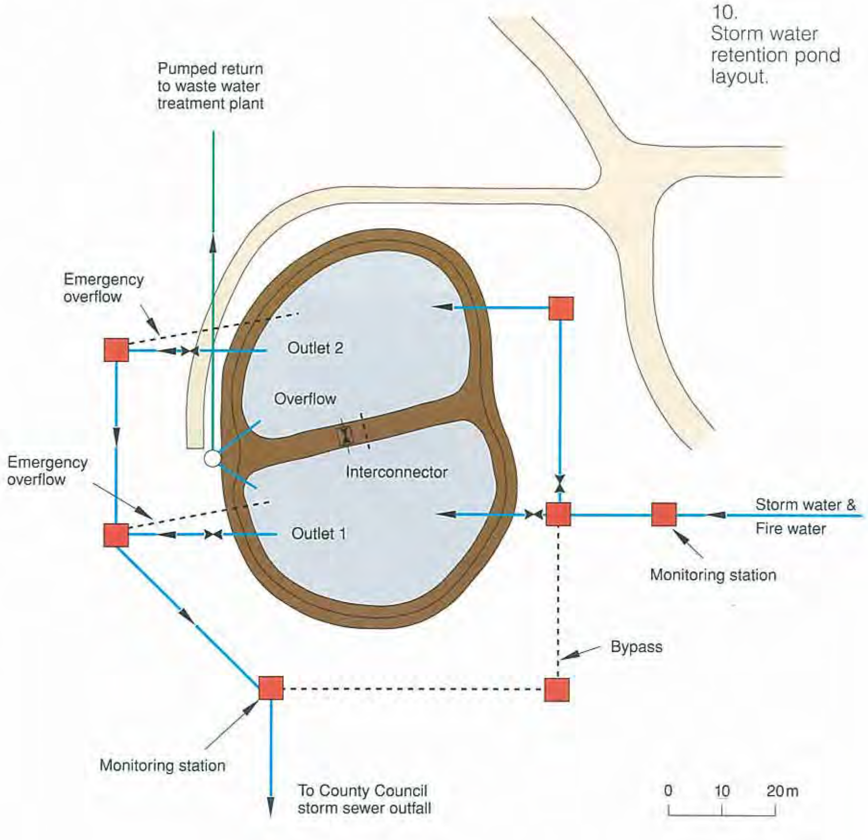
These aprons are connected to the site storm sewer network which drains to the pond.



8. Schematic of naturally ventilated production support offices.



9. Office with high curved ceiling and high level roof vents which dissipate hot air trapped above occupied zone.



10. Storm water retention pond layout.

Pipe sizes are designed for firewater flows where these exceed storm water flows. The pond, which is lined with a 2mm polyethylene (HDPE) liner and is divided into two sections for operational and maintenance purposes, is sized to contain two hours of the largest fire-water demand plus 20mm of rainfall over the site paved area.

The monitoring station at the inlet to the pond monitors pH and total organic carbon (TOC). Under normal operation, the water flows straight through the pond. If contaminated water is detected, the outlet valves automatically close. The contents of the pond can then be pumped to the site treatment plant for biodegradation.

Construction management

Sandoz were aware that a project of this nature would involve considerable overlap between design and construction, if the programme was to be met. To accommodate this they decided on a fast track construction management approach, with the many contract packages bid and let as the engineering work was completed, all managed and co-ordinated by a site-based construction management team.

The team was run by Sandoz in a 'hands on' manner and was organised on two levels, one carrying out the support functions such as project controls, contract administration, industrial relations and QA, etc., while the other provided the direct supervisory function.

Arups formed part of this team and were directly responsible for supervision of the civil, structural and architectural construction, while also providing personnel in the project controls and safety functions.

The total cost of the project is in excess of IR£200M, with spending of approximately IR£80M on buildings and infrastructure. Stringent cost controls are implemented by Sandoz, which ensures that the project is being completed on budget.

Artworks

As part of their contribution to the facility, a number of consultants and contractors donated specially-commissioned works of art for display to mark their involvement.

In many cases the commissions were important to the careers of young Irish artists. Arups' donation was a set of bronze moorland birds - the work of the sculptor Colm Brennan - perched on rocks in the rock pool feature at the Administration Building. Two of the set of 10 are shown below.

The concept of the sculpture is to recall the image and memory experienced by the artist, through literature, of a group of moorland birds feeding in sullen silence. Suddenly discovered and disturbed, the group of startled birds takes flight. The explosion of energy and sound is captured and frozen in the mind.

13.

11.
Section through polypropylene process sewer.

12.
Completed retention pond: this acts as a catch basin for all storm/fire-water run-off.

Credits

Client:
Sandoz Ringaskiddy Ltd.

Process engineers:
Raytheon Engineers & Constructors

Consulting engineers:
Ove Arup & Partners Ireland Tony Aherne, John Barry, Pat Burke, Ger Bythell, Sean Clarke, Kieran Cronin, John Deasy, Emmett Guest, Kevin Hegarty, Pat Hegarty, George Jordan, Tom Kenny, Peter Langford, Liam Luddy, Ria Lyden, Jacinta McCormack, Jacqueline Mitchell, Kevin Murphy, Donal O'Callaghan, Hugh O'Dwyer, John O'Mahony, Kieran O'Shea, Jeff Robinson, Malcolm Ryan, Frank Ryle, Sonia Scannell, Billy Sheehan, Paul Silke, Mark Vaughan

Architectural sub-consultants:
Billy Wilson & Associates

Quantity surveyors:
P. F. Coveney & Associates

Main contractors:
P. J. Hegarty & Sons Ltd.
John Sisk & Sons Ltd.

Illustrations:
1, 2, 5-7, 9, 11-13: Finbarr O'Connell.
3, 10: Maeve Sookram.
4: Ove Arup & Partners Ireland.
8: Trevor Slydel.

BankCity, Johannesburg

Neil MacLeod
James Oppenheim
Roland Orlopp

1.
Architects' model.

4
Right: One of the reception areas within the double-volumed atria

3. Street plan.

2.
Corner tower to one of the four BankCity blocks between Harrison and Fraser Streets.

Introduction

In 1986 the then Barclays National Bank (to become First National Bank after Barclays withdrew from South Africa) turned its mind to the future and banking's growing electronic needs. After thorough investigation it decided to build new corporate headquarters, and a process was set in motion which started to bear fruit when Phase One of BankCity, their new complex in Johannesburg's Central Business District, was completed in March 1992. The project, which has been described as the largest commercial building project in the southern hemisphere, is transforming the western sector of the District.

Planning the project

Arups' involvement started in 1986 when the Bank embarked on a study to establish whether they should build new headquarters or whether the many buildings then occupied could be upgraded to meet their requirements. Arups' role then was to assist in the technical and viability assessment of nearly 30 existing buildings and to consider the time and cost implications of various development options. This involved time/cost and financial modelling to enable the relative merits of the development options to be evaluated. The result was that the Bank decided to proceed with a new city centre headquarters.

The architect and urban designer Revel Fox was appointed to lead a team of four well-known South African architectural practices to develop the concept, and subsequently to carry out the detailed planning and design.

The complex comprises four externally similar eight-storey buildings with their central axes on Kerk and Simmonds Streets. These are linked in pairs by two four-storey 'bridges' spanning Kerk Street at the eastern and western entrances to the Square. At street level an arcaded walkway and planting separates pedestrians from the traffic on the streets.

The buildings have three and four levels of parking basements which are continuous beneath Kerk Street and are connected by tunnels under Simmonds Street.

Accommodating the client's spatial needs in a medium-rise building meant pushing out large floors to the boundaries. 'While recognising the needs of the space planners', says Fox, 'I wanted to avoid deep space, with people working a long way from windows, in favour of a more people-oriented internal environment.'

Relocating the Bank's divisions from 28 buildings around the city into a single site at BankCity entailed a significant shift in organisational culture, the near autonomy that had resulted from the geographical separation of divisions being replaced by an integrated group culture. Dysfunctional reactions to the upheaval were ameliorated by a careful review of what people required from their work environment.

The design team approached the project in a holistic way. Interiors were planned around employees' ergonomic requirements.

Traditional office planning where managers with enclosed offices dominated window space was reversed: offices with full-height partitions are located next to the cores, and non-managerial, open office plan areas line the outer perimeters of the floor plates, thus allowing natural light to enter the work areas.

Staff needs were addressed by introducing a range of amenities within the complex. These include a staff health and fitness centre, and dining and restaurant facilities in the bridges linking the buildings, as well as a first aid centre staffed by Bank-employed nurses.

BankCity's extensive retail component lining the buildings at street level is dominated by convenience shops including a medical centre, dry cleaners, various restaurants, and other service-oriented shops.

The intention is not only to attract the people of the city to the new head office complex, but to provide a comprehensive range of on-site facilities to the staff. More than 4100 employees will be housed in the four-block complex following occupation of the fourth block in August 1995.

Each floor, of approximately 3500m², is arranged around a central service core made up of book rooms, messenger facilities, storage rooms, patch rooms housing the vertical cabling, and conference rooms of various sizes. Crossing the core on each floor is a barrel-vaulted lift foyer which widens at both ends, receiving people in and funnelling them out. Two-storey atria placed alternately on the typical floors on the east and west sides of each building result in a U-shaped plan on each floor and a maximum depth of space from perimeter to core of 14m. The double-volumed atria serve as reception areas for the various divisions and subsidiaries of First National Bank housed in the building, and have their distinctive identities.

The four cores of the buildings are linked at first basement level, enabling staff to walk from building to building in a secure zone separated from service components.

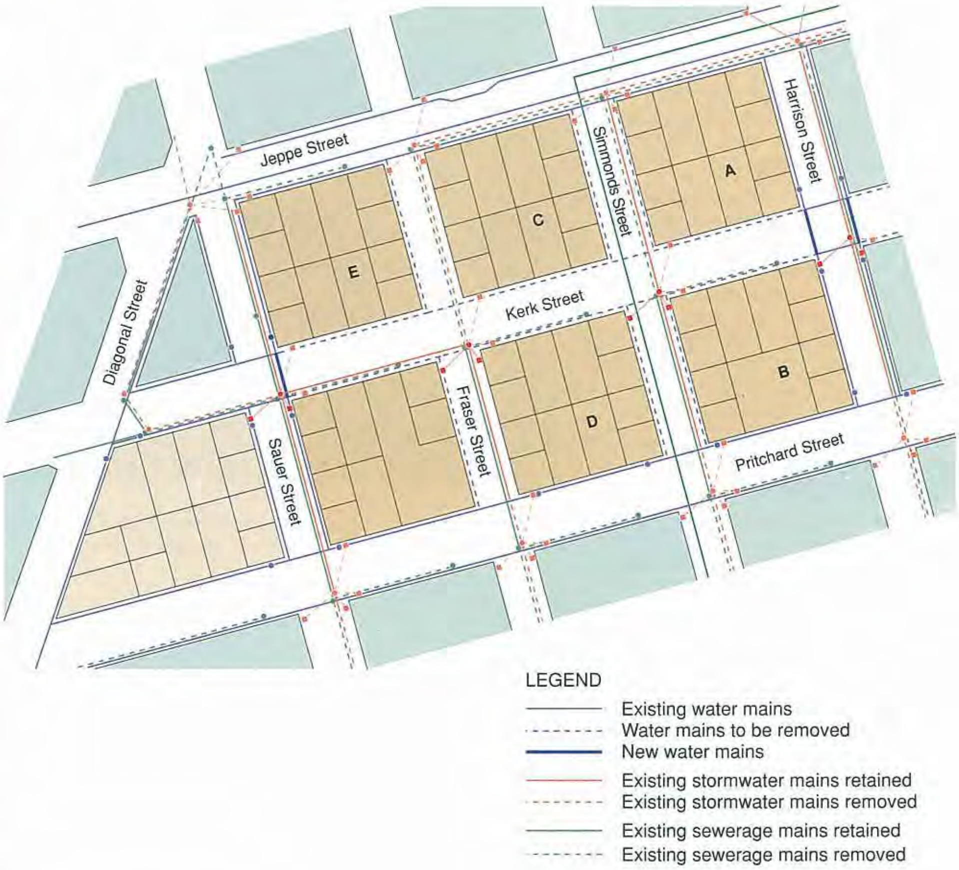
Particularly challenging was the resolution of elevational treatment for a façade almost 1km long. How was variety and interest to be achieved? The team worked through the possibilities and eventually proposed a wall architecture that would be clearly articulated; a ground floor arcaded along the sides, which would be open to the city; and, instead of great areas of glass, a series of smaller apertures. To make sense of the geometry of these windows in relations to the stone cladding, Revel Fox and his team drew on classical language, and refer to the result as a 'new classicism'.

Arups' role has been the structural, façade, civil and geotechnical engineering, and project management services.

Civil engineering

The size of the BankCity site, the variations in geology, the routing and re-routing of the subterranean services of the city, and the permanent closure of Kerk Street to motorised traffic have significantly influenced engineering decisions and dictated the form of the building's basements. Arups' investigation of service reticulation showed that, apart from telephone, gas, water and electricity supply lines and smaller sewage pipes, a large old main outfall sewer runs below Simmonds Street. This pipe drains approximately a quarter of the Johannesburg Central Business District. Consequently, whereas the buildings have been linked at first basement level beneath Simmonds Street by tunnels running above the sewer, basements two, three and four are linked on a north-south axis only, as the basements are continuous beneath Kerk Street.

The excavation beneath Kerk Street, and the construction of tunnels and access ramps, have necessitated the re-routing of services (see Fig.5).



5. Subterranean services.

The physical work has been undertaken by municipal departments in accordance with a master plan prepared by Arups, phased to coincide with stages in building construction.

Site preparation

Separate site preparation contractors carried out the demolition, excavation, lateral support and piling. Arups acted as principal agent for these site preparation contracts, which included the provision of power and water to the main contractor, to facilitate establishment on site.

For each phase of the development this work was undertaken before the main contractor was appointed. Thus the site was prepared for construction before the detailed structural design work was completed.

Most of the demolition has been by implosion. In April 1989 five buildings ranging from seven to 14 storeys on the south-east block of the site were imploded simultaneously. In terms of volume, this was the largest demolition of this type yet undertaken in South Africa, and is believed to be the third largest in the world.

6. Five buildings demolished by one implosion.

7. Collapsed buildings following implosion.

8. The cleared site showing excavation.

The depth of excavations varied from 10-14m due to changes in ground level, and because an additional basement has been created under the blocks to the west of Simmonds Street. Excavation for the basements and the building footprints extends to the site boundaries, and more than 200 000m³ of rubble and spoil were removed.

Lateral support used steel soldiers and ground anchors. Before excavation started, steel soldiers were installed in pre-drilled holes which were then filled with grout; as excavation proceeded, high capacity stressed ground anchors up to 15m long were put in place. These had to be designed to avoid damage to service lines and the main sewer below Simmonds Street, and were installed to close tolerances.

Permanent lateral support is provided by conventional reinforced concrete retaining walls cast against the excavated face. This was necessary as the basements had to be as large as possible, and column loads had to be located around the perimeter on top of the retaining walls.

Overlapping with the final excavation work, piling was carried out in the soft andesite lavas which occur beneath the northern half of the sites; groups of driven cast in situ piles carry column loads of up to 1500t.

The enlarged bases of the piles, which can be two or three times larger than the shaft areas, enable founding at a shallower depth than other types of piles - typically about 14m below the base of the excavation. The shorter shaft length allowed increased production rates to be achieved.

9.
Completed building. The façade utilises Paarl and Rustenburg granite in preference to the Naboomspruit Sandstone originally favoured.

10.
Lead-clad tower-dome detail and 'scooped' roof behind.

Structural engineering

A number of alternatives were considered in deciding on the structural system, including using steel framing on upper floors to speed up construction of the frame. However, investigations showed that the time gained would not be matched by the internal finishing trades, and that the complex stone cladding could not be more rapidly fixed. In all, up to 15 levels had to be taken into account - the plantroom at roof level, seven office floors, the mezzanine and ground floor, the basement mezzanine, and four basements.

The architects chose a 7.8m column grid as the best compromise between the office space planning requirements, as well as parking and circulation needs in the basements, while avoiding transition structures.

Studies undertaken locally and internationally showed that longer grid spans would have brought little benefit in adaptability of the office space. Columns on this grid carry 250mm and 300mm thick conventionally reinforced flat slabs in the basements, and above ground level unbonded, post-tensioned flat slabs are used. Downstand beams are provided at slab edges to limit structural movements in the plane of the façade. Stability is provided by the central cores, conventionally constructed of reinforced concrete using jump forms. Because the floor slabs are so large, faster core construction techniques were not necessary.

The relatively simple structural form chosen has enabled an economical design of minimum depth, which has been rapidly constructed to tight schedules. In minimising excavation depth and the height of the buildings above ground, the structural form has resulted in significant savings in excavation and façade costs. Most of the roof is formed by a flat concrete slab, waterproofed with a membrane system. However the curved roof of the outer bays is clad in lead. Lightweight fabricated steel 'bents' at 3.9m centres carry cold-formed purlins, supporting laminated curved timber beams and tongued and grooved timber boarding faced with lead laid on a geotextile fabric.The domes of the towers and the complex 'scoops' behind them are shaped in fibreglass and sheathed with lead. The double curvatures could be achieved in fibreglass which was clad in lead off-site, and then rapidly erected. There are no movement joints in the structure, even though the buildings are over 148m long.

These joints could be avoided partly because of the construction sequence adopted by the main contractor. The separate buildings were completed before the linkages across Kerk Street were built, at which stage much of the shrinkage and temperature-related changes had occurred. As much of the finishing work is in the core areas, the main contractor built a large part of the buildings before completing the links above and below Kerk Street.

For concreting and post-tensioning, each floor was divided into four sections. Readily available flat soffit formwork was used, and specially designed formwork for edge beams.

Reinforcing and post-tensioning materials as well as formwork were lifted and moved by tower cranes and concrete for floor slabs was pumped into place.

Formwork could be re-used because the structural forms are relatively simple and repetitive, and a floor cycle of as little as 14 days was achieved. Without disrupting the traffic flow, four tunnels have been built below Simmonds Street to provide service, pedestrian and vehicular links on east-west axes. These tunnels connect the first basements, and as they had to run above and close to the old outfall sewer, substantial pre-excavation and protection work had be carried out during partial occupations of Simmonds Street. To construct the deeper southern tunnels, rectangular precast segments, 3m x 3.5m x 1.2m long, each weighing 10t, were jacked across Simmonds Street, working from the pavement on the west side.

Spoil was removed through the jacking pit, and as work advanced, the tunnel segments were jacked forward.

To construct the shallower northern tunnels, this technique could not be used because the cover to the road level was only 900 mm. For these, augered cast in situ piles were installed to form the side walls and working from road level, the roadway was excavated to the level of the underside of the tunnel roof which was then cast on the ground on top of the piles.

The roadway was reinstated, and construction of the tunnel completed by excavating from one end beneath the protection of the roof slab and guniting between the piles. This technique allowed the tunnels to be built with only minor disruption to the traffic in Simmonds Street, as most of the work could be carried out during weekend occupations of parts of the road.

Façade engineering

An important aspect of the design and construction has been the exacting requirements for the façade. Initially the design team strongly favoured Naboomspruit Sandstone as the principal external material. This was the stone used for the Union Buildings in Pretoria, where the State President has his offices. Unfissured stone of good quality and sufficient quantity was located and samples were tested by Arups' materials specialists in

11.
BankCity in its location: Johannesburg's Central Business District.

Project management

Arups' initial involvement was as part of a team led by space planners appointed for a study to establish whether the Bank should build new headquarters or whether any of the buildings they occupied in the Central Business District at that time could be upgraded to meet their needs. Arups' brief was to consider the time and cost implications of various options available to the Bank.

Of the nearly 30 existing buildings, Arups undertook a detailed technical evaluation of 10. Arups' time/cost and financial modelling enabled the relative merits of the options to be assessed.

In 1987 it became clear to the Bank that the best option would be to build new headquarters on the present site.

Arups then helped to put together an implementation framework which considered, amongst other factors, how the project should be managed, the preparation of the brief, the participation of bank personnel, the need for one or more professional teams, the role of specialist consultants; and the implications of phased construction.

Analysis of this framework showed that the project should be managed by First National Bank, and that Bank management should participate at the highest level to establish policy and objectives.

It also indicated that the BankCity management team would have to contend with many financial and logistical pressures to enable site preparation and construction to begin long before the detailed design would be completed. Arups were then appointed to support the BankCity project team by setting up reporting procedures and systems to enable effective management by the Bank.

These involved:

- time-cost models for the strategic evaluation of options and phasing
- time and resource scheduling, including control of tender and construction documentation
- cost management and control based on the 'fixed out-turn cost' philosophy (a sum fixed near the outset which should not be exceeded at completion).

The management procedures and systems were set up to provide realistic assessments of the project's current and future performance.

A team of time planners seconded to the BankCity project office has assisted the project team over the period of eight years in controlling the design-construction interface. They evaluate the impact of changes and delays on the programme and advise on the effects these will have on targeted completion dates.

This entails continual interaction between the time planners and all members of the professional team as well as the contractors. In certain cases it has been necessary to conduct detailed production analysis studies of the contractor and sub-contractors, both on and off-site, to ensure that stated objectives will be met. The financial systems developed and operated by Arups enable the multitude of BankCity project transactions to be monitored and also provided an audit trail on the movement of funds.

Perhaps the most significant factor has been the recognition within the project team of the interdependence of scope, quality, cost and time, and all management reporting is structured around this.

Thus the project team has been able to monitor compliance with early objectives agreed to by the First National Bank board, crucial in a project which continues over a long period.

London. At the time, use of this stone could not be recommended, principally because there was insufficient time to test it for durability in a corrosive city environment. Suppliers also reported that it would be difficult to procure suitable stone in sufficient quantity in the time available. For these reasons the façade utilises reflective light-grey Paarl granite and a darker grey Rustenburg granite. An engineered and industrialised over-cladding technique has been used on all the building elevations. Sawn natural stone slabs are supported on aluminium rails and substructures bolted to the concrete, and cover waterproofed brick infill panels which, along with the windows, form the weatherproof envelope of the buildings. This system has enabled finishing work to continue while the elevational stonework was being fitted from exterior scaffolding.

The future

The project as completed and presently under construction comprises five city blocks. Three of the first four - completed respectively in October 1991, March 1992, and April 1993 - are already occupied by First National Bank, and the fourth was completed in April 1995. Piling has commenced on the fifth block. Other Bank developments in the area are currently under consideration and viability studies are under way.

BankCity represents a major statement of confidence by the Bank in the future of Johannesburg's Central Business District at a time when many businesses are relocating to sub-urban nodes. The project enjoyed the support and involvement of the Bank's Chief Executive and most senior managers and is perceived as an integral and important part of their business strategy for the future.

For their project management of BankCity, Arups received the 1995 Award from the South African Association of Consulting Engineers in the 'Any Other Branch of Engineering' Category.

Credits

Client:
First National Bank

Architects:
Architects in Association
(Revel Fox & Partners cc;
GAPS Architects and Urban Designers cc;
Meyer Pienaar Smith Inc
and RFB Consulting Architects cc)

Quantity surveyors:
Quantity Surveyors in Association
(Farrow Laing and Partners;
Southby Bihl Detert and Slade)

Time management/Structural engineers:
Ove Arup Incorporated Seth Amurath, Keith Baker, Ric Bennet, Barbara Black, Bruce Bulley, Tony Chuva, Eugene Goodall, Tony Hammond, Rob Lamb, Sariel Lefutso, Neil MacLeod, Nicholas Mdluli, James Oppenheim, Roland Orlopp, Brian Ratcliffe, John Sillitoe, Prakesh Singh, Craig Staveley, Kevin Swan, Abe Thela, Neo Tladinyane, Karen Wood

Mechanical engineers:
Consultants in Association
(Van Aarle and Herman;
Spoormaker and Partners)

Electrical engineers:
Claassen Auret Incorporated

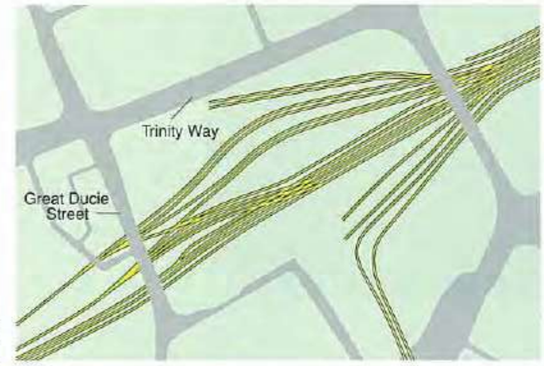
Space planning consultants:
B. I. Associates

Main contractor:
LTA Construction Ltd.
(LTA Building Witwatersrand)

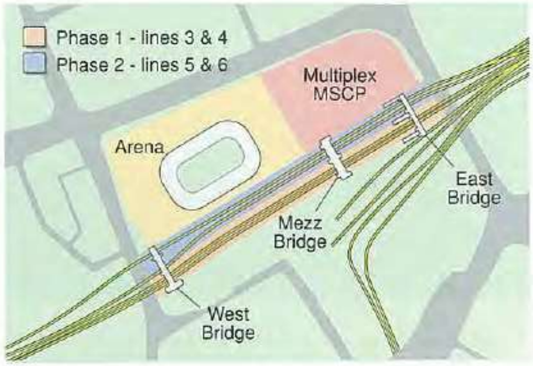
Illustrations:
1: Revel Fox & Partners.
2, 4, 6-10: BankCity.
3, 5: Denis Kirtley.
11: Wally Rossini.

Manchester Victoria Station redevelopment

Geoff Bickerton Mike Buckingham Steve Burrows
Alasdair Gibson Trevor Wheatley



1. Original track layout.



2. Post-development plan.

3. Aerial view from west on completion of station work: the Arena is on the left, the listed station entrance façade to the right, and the roof to the 'city room' top right.

Introduction

Located on the north-western side of the city, Manchester Victoria is one of two main line stations remaining from the four that existed and thrived in the Victorian days of steam. Manchester Piccadilly is the other.

Central Station was redeveloped in 1987 as the G-Mex Exhibition Centre - an earlier Ove Arup & Partners Manchester job[1]; the fourth, Exchange Station, closed in 1969 and in 1981 the site was reduced to surface car parking.

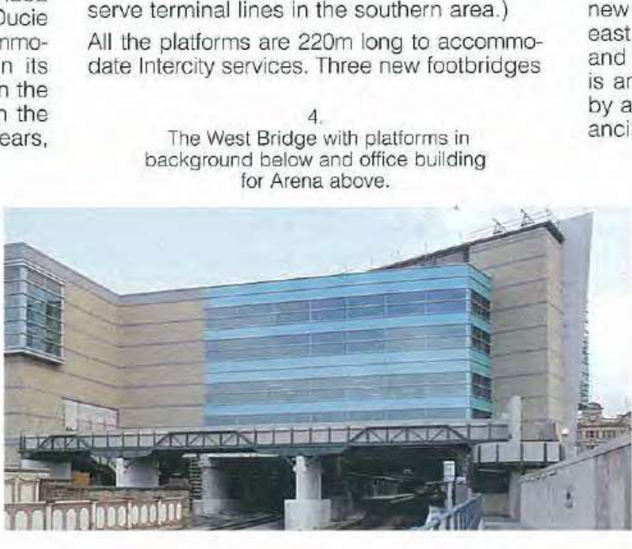
The original Victoria Station complex, bounded by Trinity Way, Victoria Street and Great Ducie Street, occupied about 14ha and accommodated a goods and shunting facility in its northern sector, six main through lines in the central sector, and four terminal lines in the southern sector (Fig.1). In recent years, use of the goods area fell into decline and left British Rail with a large piece of real estate virtually unused. After consideration of other sites in the city, an agreement was reached to develop the northern sector as a joint venture between Vector Developments and BR to accommodate the new Manchester Arena complex (this also is another Arups Manchester project). Existing main lines and platforms therefore had to be repositioned and realigned, and Arups were appointed by the client, Regional Railways, as structural, civil, mechanical, electrical and public health engineers. Manchester Arena began on site in summer 1992. Main line services had to keep going throughout the development, and to enable this the work was planned in two phases. In spring 1993 the two southern lines and platforms (Nos. 3 and 4) were closed for realigning and reconstruction.

After being reopened, platforms and lines 5 and 6 were closed in autumn 1993 and reconstructed (Figs.2 & 3). (Platforms 1 and 2 serve terminal lines in the southern area.)

All the platforms are 220m long to accommodate Intercity services. Three new footbridges were built for access/escape to all four new platforms. Those to the east and west are simple external open-access footbridges, but the mezzanine bridge is enclosed and also gives access to Vector's new 'city room' area: a collection space comprising the main Arena box-office and entrance to a multiplex cinema, retail and dining spaces, and entry to the multi-storey car park. All three bridges were constructed in two stages in sympathy with the phasing of the platform construction.

Parts of the Arena development straddle the new station layout, forming tunnels at the east and west ends for lengths of about 40m and 90m respectively (Fig.4). Between them is an open well, protected from the weather by a new canopy. The existing entrance and ancillary buildings to the adjacent station concourse are listed grade 2 and have remained unaltered. But the new owners, Railtrack, plan to refurbish them in the near future.

4. The West Bridge with platforms in background below and office building for Arena above.



Platform construction

All the new platforms have been constructed on solid ground, using imported granular fill consolidated to the new lines and levels. Below-surface pvc multiducts accommodate essential services with evenly spaced, well concealed, access manholes (Fig.5). All the platforms are surfaced in square

5.
Platforms 3 and 4 west, with new canopy and exhaust ventilation systems above.

terrazzo block paviors with precast edge copings to BR specification. A significant bridged access tunnel ran below the lines in the eastern area, the girdered deck of which was stripped off and the void backfilled, rather than reconstructing a new bridge deck. The edge-of-platform retaining walls are of in situ concrete - as chosen by the management contractor after considering precast concrete section and blockwork wall alternatives.

Track construction

The new geometry and levels for the track layout were provided by BR, who laid the tracks and specified and laid the sleeper ballast. Existing surface ballast, usually contaminated, was removed from site; new sub-grade and upper ballast materials to Arups' specification were imported and laid by sub-contractors to the new levels.

Bridges

The architect, Austin Smith Lord, prepared concept sketches from which Arups developed the detailed structure for the three footbridges. The east and west bridges have a clear deck width of 4.5m, whilst the mezzanine bridge is 7m wide to cater for a greater pedestrian flow; each bridge has two clear spans of 14m-16m. The superstructures are of steel, supported by concrete walls or columns: the trussed central span sections literally sit on cantilevers spanning from the supports (Fig.6).

These provide clearance in the central section for future electrification but keep the transfer deck levels above as low as possible. The access stair flights, also in steel, have intermediate tubular steel support trees (Fig.7 overleaf). The structures are unusual in that conventional I-sections have been avoided, all the elements being fabricated as compound sections. The decks are formed of flat plates under which stiffening ribs are welded to provide T-sections spanning the width of the bridge onto the side support beams or trussed girders.

By contrast, the centre-span girder trusses are fabricated in circular hollow sections with shaped plates at member intersections as an expressive detail. The cantilevered support beams are also compound sections, but use tubular top flanges with inverted plated T's to form web and bottom flanges. Inclined tubular struts are featured at concrete wall supports to reduce the effective cantilevered spans and avoid members appearing too bulky, though the overall architectural expression is designed to achieve a reasonably solid feel, giving a visual sense of security to the prospective user.

6.
Cantilevered main beam on Mezzanine Bridge.

Canopy

A space frame spanning about 18m forms the canopy over the open central section of platforms 3 & 4, with the above-platform areas covered by profiled metal decking to give protection from the elements. On the platform 4 side the canopy performed a dual function - providing a temporary crash deck while the Arena was being built.

Drainage installation

Completely new track and surface water drainage systems were designed and installed. The former has 200mm diameter polypropylene perforated pipes laid in bedding between the lines with catch-pits at regular intervals.

A pipe gradient of 1:200 was adopted to avoid saturation with ground/rainwater. A three-stage petrol interceptor collects fuel spilt on the tracks from the diesel units, before discharge into the nearby River Irk.

The new surface water system is limited to the four new platforms. Channel and grating runs are provided along them, with aluminium rainwater pipes from the new canopy discharging into a conventional under-slab drainage system of vitrified clay pipework and fittings feeding into brickwork manholes. The outfall is connected to the existing combined drainage system in Platform 3.

Given the limited platform facilities in the redevelopment, a new foul drainage system was considered unnecessary by BR.

Diesel exhaust ventilation system

Basis of design

Due to the construction of the Arena above, it was decided after consultation with BR that Victoria Station would be classified as partially enclosed, but not underground. The lines through the station may not be electrified for several years and it is currently only used by diesel locomotives. A form of ventilation was therefore deemed necessary to remove the emissions from these, both now and for some time in the future.

Although the new station is open-ended and has open sides in limited areas, it was considered that it could not be satisfactorily ventilated naturally - due to overall length, air flow restrictions from the low soffit height, the unpredictable and unreliable prevailing wind, and the effect of adjacent buildings. A mechanical ventilation scheme was thus proposed, to be funded by the developer.

Diesel exhaust emission data were obtained from BR locomotive engineers at Derby for the types of passenger and freight locomotives using Victoria Station (emission levels and exhaust positions vary greatly across the range of locomotives used). Timetable and operational data also helped with assessing the average worst-case situation for emission levels within the station. There are no defined design criteria for such a project other than the requirements of the Control of Substances Hazardous to Health Regulations (COSHH). In fact the only other such similar scheme in the UK is at Birmingham New Street Station, whose performance was taken into account while developing the proposals. The external influences from the environment - moving locomotives and the use of ambient supply air - made it difficult to model this system practically using computational fluid-dynamic (CFD) analysis. The design therefore relied on engineering judgement. It was found that the most onerous requirements in terms of ventilation rates were the exposure standards set for passengers by the Health & Safety Executive - based on, but more exacting than, those of COSHH. The ventilation rates required to achieve these criteria are also approximately 150% of the original levels at Birmingham New Street, and the designs were based on these higher levels.

The ventilation scheme

This comprises 12 zoned supply and extract systems (24 axial fans in total). The platforms are served by a common ambient fresh air supply system serving two circular ductwork branches mounted at high level from the soffit (Fig.8 overleaf). The outermost supplies air to positively pressurise the platform and provide fresh air for the passengers.

At present this has been omitted on cost grounds at the client's request, but it can be installed later if monitoring the system in action shows it to be necessary. The inner branch duct supplies air towards the tracks to entrain diesel fumes exhausted by the locomotives towards the extract duct.

7.
Mezzanine Bridge: stair landing support detail.

Dilute exhaust fumes are extracted via a flat oval ductwork extract system installed above the tracks (see Fig.8).

The fan and attenuator assemblies serving these systems are supported vertically by steel frameworks attached to adjoining buildings, concealed behind architectural cladding panels.The fans can be maintained from platforms within these enclosures accessed via acoustic doors in the external walls of the adjoining buildings. Fresh air intake is via louvres integrated in these cladding panels. Dilute exhaust fumes are discharged at high velocity via discharge terminals above roof level.

Following investigations with Arup R&D into various protective finishes, an epoxy paint was selected to protect the ductwork's internal and external surfaces against the aggressive environment.

Common cylindrical forms are used for both ductwork and lighting above the platforms for aesthetic and architectural reasons (Fig.9).

Acoustics
Acoustics treatment was applied to the rail sleepers and underside of the soffit to prevent noise transfer to the Arena and adjoining buildings.

The ventilation systems are designed to achieve NR50 at 1.5m above the platform, so as to ensure audibility of the public address system throughout the station.

Automatic control system
Several methods of control were considered, in association with BR. The system chosen was a gas analyser/monitoring system commonly used in pharmaceutical and petrochemical industries. This senses carbon monoxide and nitrogenous oxide emissions along each platform and activates the extract systems when conditions exceed specified exposure limits.

Installation
Careful programming and phasing of the works was needed so that the station could remain operational throughout construction period. Track possessions had to be obtained from BR which resulted in most of the installation work being carried out at night.

Electrical engineering services

Lighting installations
Both the general and emergency lighting installations for covered platform areas are contained in a 200mm diameter, four-compartment, tubular system and comprise fluorescent luminaires with the emergency function operated by integral batteries and inverters on 25% of the general lighting lamps. Open platforms are lit by low energy discharge lighting in column-mounted lanterns with separate, self-contained, low-voltage projector emergency lighting.

The east and west bridges have purpose-made, recessed, fluorescent luminaires at dado height in the walls for both general and emergency lighting.

8.
Platforms 5 and 6 central with exhaust ventilation ducting above.

Again the latter are supplied by battery and inverter during mains failure. The general lighting installations are controlled automatically, enabling a pre-programmed switching sequence to be selected to match the station operation. Artificial lighting levels can also be varied in response to changes in ambient light levels.

The emergency lighting is automatically tested and monitored in operation by an addressable emergency lighting control system. A record of events is available as a print-out at the system control panel.

General purpose power installations
These comprise customer information services monitors, CCTV and clock supplies, their power outlets being mounted within a dedicated compartment of the 200mm tube system. The remaining two compartments of the latter were provided for the station operators' audio/visual requirements.

9.
Diesel exhaust ventilation duct: transition to riser detail.

Fire alarm system
This has its own dedicated control panel, automatic detection, signalling and interface facilities, and is arranged to detect in three zones: mezzanine bridge, services enclosures and lifts. Signals provided by the system will control certain ventilation installations and the lifts in the event of a fire. The system is interfaced with the existing station building's fire alarm system to alert staff to any problems in the protected areas.

Mechanical ventilation supplies
These are provided from the new LV switchboard to mechanical services switchboards installed adjacent to the ventilation fan units at high level above the platforms. An automatic control facility has also been installed to operate the ventilation, with a 'system status' indicating panel at platform level.

Passenger lifts
These are situated adjacent to the mezzanine bridge, in the covered area of the station; the lifts allow alternative access onto the bridge to transfer between platforms for people and goods unable to use the staircases.

Contract

All the works for the new station redevelopment were tendered and constructed under a management contractor basis. This arrangement worked well particularly bearing in mind the extent of adjacent work being done on the Vector Project. The value of the building/civil works, excluding track laying, was c.£3.05M. Ventilation systems and lifts, funded by Vector, were around £0.9M and £0.15M respectively.

Reference

(1) McGRATH, J. G-Mex Exhibition Centre, Manchester. *The Arup Journal, 23*(1), pp.22-23, 1988.

Credits

Client:
Regional Railways Design & Construct
Vector Investments

Architect:
Austin Smith Lord

Quantity surveyor:
Gleeds

Consulting engineers:
Ove Arup & Partners, Manchester
Geoff Bickerton, Mike Buckingham, Steve Burrows, Alasdair Gibson, Ashraf Issak, Paul Kay, Andrew Marsland, Tom Rice, Keith Rudd, Trevor Wheatley, Iain Clarke (Arup Acoustics), Graham Gedge (Arup R&D)

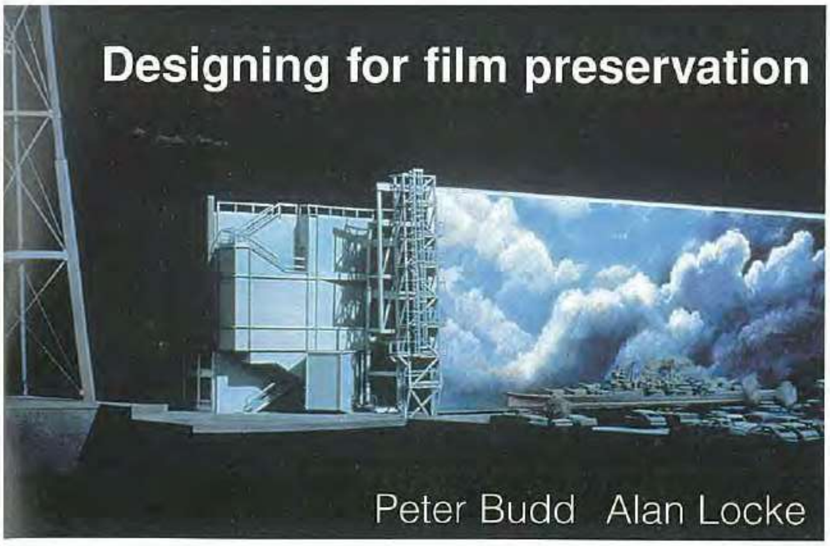
Management contractor:
Bovis Construction Ltd.

Mechanical sub-contractor:
Drake & Scull

Electrical sub-contractor:
Fairbrothers

Illustrations:
1, 2: Trevor Slydel.
3: Courtesy Bovis.
4-9: Peter Mackinven.

Designing for film preservation



Peter Budd Alan Locke

1.
Model of Paramount archive.

2.
Paramount archive under construction.

Introduction

For centuries the world has recognised the need to preserve its cultural heritage for generations to come; art works, typically, are contained and exhibited in spaces with close control of temperature and humidity, ensuring minimised environmental impact. In recent years it has been recognised that the modern art forms of film and photographs must also be preserved. 20th century history has been recorded in visual media that reach billions.

The motives to preserve film are cultural and historical, but perhaps most urgently, economic. The assets of motion picture companies are not only in property, in the latest movie production, or in the movie's start, but in stockpiles of film from generations past. Much of this is inadequately stored, and archive projects are being initiated by studios to better protect and preserve their assets. In addition, film history bodies such as the National Archives Committee on Film Preservation, and local organisations like the Japanese American Society in Los Angeles, have risen to the challenge of protecting documentaries and home movies telling the history of the American people that will be lost to future generations unless a clear protection policy is initiated. Designing such archive facilities is technically challenging for engineers, who have to understand not only the complication of individual trades, but the implications for architecture, planning, film media, and film distribution. It is truly a multidisciplinary effort in all aspects.

Current preservation standards

Picture images were, and still are, captured on film designed to meet the requirements of production, not preservation. Archivists and preservationists are faced with a multi-headed adversary: not only the attrition of time, but lack of agreed standards, research, and proven information about film preservation. They deal with many media types, from explosive nitrate-based materials to relatively inactive but short-life video tapes.

Manufacturers like Eastman Kodak, and industry organisations such as the Society of Motion Picture and Television Engineers (SMPTE) and American National Standards Institute (ANSI), have in recent years voiced concerns to the motion picture studio industry and the American National Archive Committee about the limited life expectancy of film outside of archival conditions, and urged them to take quick action to preserve their irreplaceable assets. Both SMPTE and ANSI have recommended provision of closely environmentally-controlled vaults for film storage. Concerns include dye instability, colour film fading, shadowing film corrosion though the 'vinegar' (acetic acid) effect, and excessive moisture. These are currently being investigated by film manufacturers, and recommendations are being made. However, to date no clear uniform criteria for preservation have been accepted by all parties and thus interpretation is still necessary (Fig 3). Even with this lack of clarity, archivists, film preservationists, manufacturers, and engineers like Arups have agreed a series of interim strategies for film preservation:

- *Environmental controls for differing storage time periods must be maintained within tight tolerances in a variety of vault configurations.*
- *Consistency in control of temperature and humidity is critical - film cannot withstand 'shock'. Stability is a key determinant in avoiding film deterioration.*
- *Pollutants from the outside environment, such as ozone and sulfur, affect film detrimentally and must be minimised.*
- *Film gives off a gaseous acetic acid which in turn corrodes the film. This must be minimised.*
- *Dry fire protection is critical. Moisture destroys film, the smallest amount of moisture over a long period of time, the largest amount immediately.*
- *Over-drying film causes cracking and irreparable damage.*
- *The protection facility must be secure in every aspect, from day-to-day security to protection against environmental impacts such as climate and earthquakes.*

The aim of the two projects in Los Angeles detailed in this article was to reduce and where possible arrest deterioration of film and tape by providing the most consistent environment achievable within the clients' budgets. It was also to bring together, in one secure but easily accessible space, the studios' stockpile of recent and historic movie pictures. Both projects, besides meeting the clients' briefs in every aspect, also met their budgets. It is important to note that the buildings operate 24 hours a day and thus require reliable maintainable systems with stand-by where appropriate. Energy conservation is important, but only if it does not jeopardize the preservation requirements.

	Recommended temperature set point	Recommended relative humidity set point
Offices	23°C ± 3°C (74°F ± 5°F)	35-60%
Short-term storage	20°C ± 1.8°C (68°F ± 3°F)	50% ± 5%
Medium-term storage		
Silver gelatin	10°C ± 1.8°C (50°F ± 3°F)	40% ± 5%
Colour	4.4°C ± 1.8°C (40°F ± 3°F)	27% ± 5%
Extended-life storage		
Silver gelatin	10°C ± 1.8°C (50°F ± 3°F)	27% ± 5%
Colour	-1.1°C ± 1.8°C (30°F ± 3°F)	27% ± 5%

3.
Current standards for temperature and relative humidity for various film storage facilities.

Paramount Film and Tape Archive Facility

Introduction

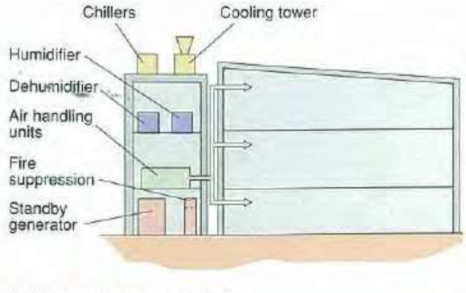
Ove Arup & Partners California were approached by the architects Holt Hinshaw Pfau Jones to join Paramount Construction Management Group in providing the studio with a 3700m² (40 000ft²) building for a film archive, a film and tape distribution centre, and an editing facility. Two upper floors were to house the medium and long-term storage vaults, with short-term storage and distribution facilities on the first floor and film processing and editing suites in a mezzanine. The building also had to support the famous 'Paramount Sky' and future studio lot sets.

Design process

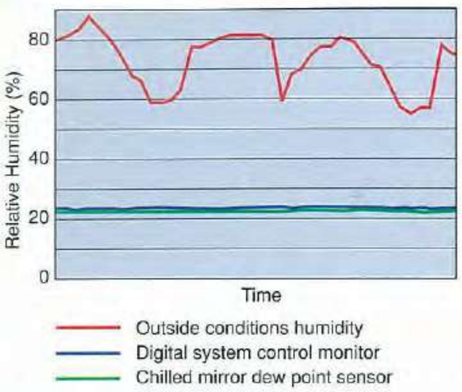
All members of the project team were involved from the outset, analysing design options against the proposed budget developed in house by Paramount. The budget was re-apportioned during the early phases to allow sufficient monies for the complex mechanical and fire protection systems needed to maintain the tightly-controlled low temperature and relative humidity requirements for film storage. To ensure the project kept on schedule, weekly design and subsequently construction meetings were held. Resolution of issues, shop drawing review, and construction issues were all solved on a weekly basis, thus minimising delays. The schedule was to complete the design in six months, construction in eight months, and to commission the systems in two months - which was subsequently extended to three months. The commissioning process was extremely time-consuming, especially the need for fine-tuning the sensitive controls and identifying and resolving issues which had detrimental effects on the vault condition.

Design concept

This project was the brainchild of Paramount's Media Distribution Department, and in particular Milton Shefter and Phil Murphy, who in the four years prior to the project design became keenly aware of three issues that were affecting Paramount's operation and film assets: lack of suitable storage space for film, the need to streamline their operation to make it more cost-effective, and the threat of fire under existing conditions – one studio lot fire could have rendered their collection lost for ever. The project site, behind the Paramount Sky backdrop, was constrained by a water tower on the west and a street used for street scene filming on the north, all of which imposed limitations to the design (see Figs 1 & 2).

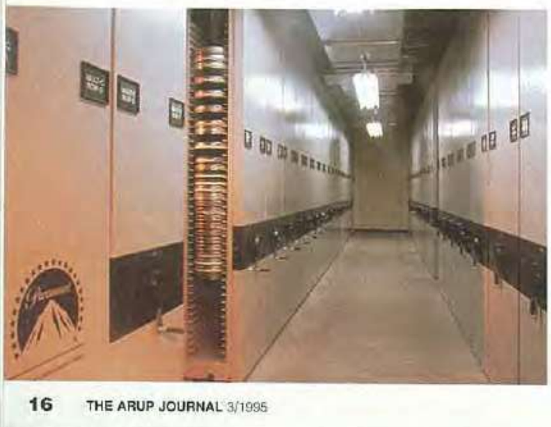


4. Vault systems concept.



5. Actual monitored temperature and humidity readings in vault.

6. 'Sky'/mechanical tower structure.



7. Compact shelving system in vault.

The height restriction was 15m (50ft) above grade. The soil was contaminated, and required detailed analysis, removal, and replacement.

As well as its given functions, the building had to support film sets to the north as well as the Paramount Sky to the south. For security reasons access - in particular to the film vaults - was severely restricted, which had a major impact on the organisation of the programmed spaces and means of escape.

The final design concept separated the building from the mechanical equipment (Fig.4), with a steel structure housing the latter and supporting the 'Sky'. Services penetrate the south wall of the building horizontally, level by level. This strategy also gives flexibility to accommodate future additional equipment, as well as minimising major distribution routes of piping and ducting.

The main building was to be of precast concrete. This allowed rapid construction, accommodated the heavy shelving load requirements, and, combined with an integrated mechanical distribution system, minimised floor-to-floor heights.

The location of the various vault types was influenced by operational dictates, security, and most important, varying environmental requirements. The short-term storage vault (for regularly-used material) occupies the ground floor, close to the distribution department. Medium-term storage is on the second floor, with two vaults for black/white and two for colour. Separation was critical to ensure both maximum flexibility and fire safety, with different media in different vaults under a gas suppression fire protection system. Long-term storage (the archive) is on the third floor. Corridors on the second and third floors, as well as corridors and editing suites on the first, supply thermal separation between the vaults and the mechanical equipment tower.

Building fabric considerations

The fabric was designed to minimise the effect of external heat gains and moisture content on the vault environment and the air-conditioning loads. It is important to realize that in the archive (long-term storage vault) internal design conditions of 4.4°C (40°F), 25% RH has an air moisture content of 22g of moisture per kg (10g/lb) of dry air. This dry air condition is extremely susceptible to moisture influx from the exterior, as well as being very difficult to maintain within tight tolerances (Fig.5).

The walls are 300mm (12in) high-density concrete with an interior vapour barrier, R19 insulation, and plasterboard interior. The concrete gives a time lag of between six and eight hours, thus minimising the external heat gain effect on the air-cooled chillers. Arups' BEANS software was used to analyse moisture and temperature movement through the exterior and interior walls. The vapour barrier has 0.002 permeability which reduces moisture movement into the vaults. Spray-on insulation to the underside of the floor structure does provide some moisture movement protection, though not as much as the perimeter wall and roof barriers.

Of particular note was the provision of thermal and moisture barriers between the exterior walls and the frame of precast concrete T's. Commissioning showed leakage occurring at these weak points, which particularly affected the low temperature/low humidity vault conditions. It was extremely difficult to install the vapour barrier around column-to-perimeter beam connections.

However, the mechanical systems were able to overcome the leakage to maintain the desired vault conditions.

Structure

The structure for the archive building reflects the different uses of the spaces: though the vault is concrete, the 'Sky' and support space structure are open steel framing from ground to third floor (Fig.6). The vault carries a heavy live load (15kN/m²/ 320lb/ft²) to account for the weight of the film, which is denser than stored paper (Fig.7). This generates high seismic loads, which fact, along with the need for thermal insulation of the vault, led to the selection of a perimeter cast in situ concrete shear wall structure with the floors and roof framed by precast doubleT's with a topping slab. Special care was taken to co-ordinate with the high density storage manufacturer's tolerances and the precast deflections. The structure supporting the 'Sky' is a narrow band, 4.6m (15 ft) wide, running the length of the vault and connected to it at discreet points. As well as the mechanical systems, this houses corridors and stairs. The steel braced frame gives open areas for air flow around the units, and its relatively light weight has low seismic forces. The foundations for the building are drilled cast-in-place piles with grade beams.

Mechanical

As well as accommodating the various vault requirements, the mechanical systems had to meet a very tight construction budget. Commercially available equipment and controls were adapted for what could be considered an industrial application, and are located on the 'Sky' support structure, forming the 'utility tower'. This ensured that penetrations into the building were horizontal and not vertical through the roof (Fig.8 right).

A low temperature (-9.4°C/15°F supply; -3.9°C/25°F return) chilled water system was provided from air-cooled chillers on the upper deck of the utility tower. A 35% glycol/water cooling medium was utilised to avoid chiller and cooling coil freezing. Conventional roof boilers, also on the utility tower's upper deck, supply the reheat hot water system. The vault organisation allowed air-handling units (AHUs) and dehumidifiers to be installed on a level-by-level basis (Fig.9 below right). Each series of vaults is served by a separate air-conditioning system.

A direct digital control (DDC) system throughout ensures not only accurate control but the critically important alarm and early warning system.

Due to the low temperature air supply needed to maintain vault conditions, careful attention was paid to all system components. The ductwork was insulated internally and vapour-coated; all ductwork and AHUs were tested for air-tightness to ensure maintenance of the systems' integrity; all building penetrations were sealed both for air movement and moisture; and the ducting distribution was minimised, through integration with the vault shelving, to reduce construction cost and running costs, and to maximise vault capacity. The AHUs served as the gas suppression fire protection exhaust system.

Paramount's strict acoustic criteria were respected in the utility tower and mechanical equipment; the latter's enclosure is acoustically shielded on all sides so that noise does not spill out horizontally to affect either sound stage or street scene filming.

Electrical

The electrical distribution consists of an on-site pad-mounted transformer which steps down the high voltage cables to 480V/277V, three-phase, four- wires system.

The electrical distribution was designed with all major electrical conduits running in the service corridor and integrated with the main mechanical distribution. Due to the impact of the environmental conditions in each film storage vault, all conduits are sealed to avoid condensation. Special fluorescent lighting ballasts are used for the low temperature environment, with a timer in each storage unit for energy conservation.

Due to the value of the building's contents, there is a sophisticated security system, with fully automated detection and fire alarms. An on-site emergency generator is provided for 100% of the mechanical load as well as life safety equipment in the event of a power failure.

Fire protection

A total flooding gas suppression system protects the storage vaults, and pre-action sprinklers the remainder of the building. The detection system was designed to use both ionized and photoelectric detectors, each covering 18.6m² (200ft²). Due to the film's value, a time delay of 30 seconds and an array of abort stations, as well as manual pull stations, were provided.

Storage capacity

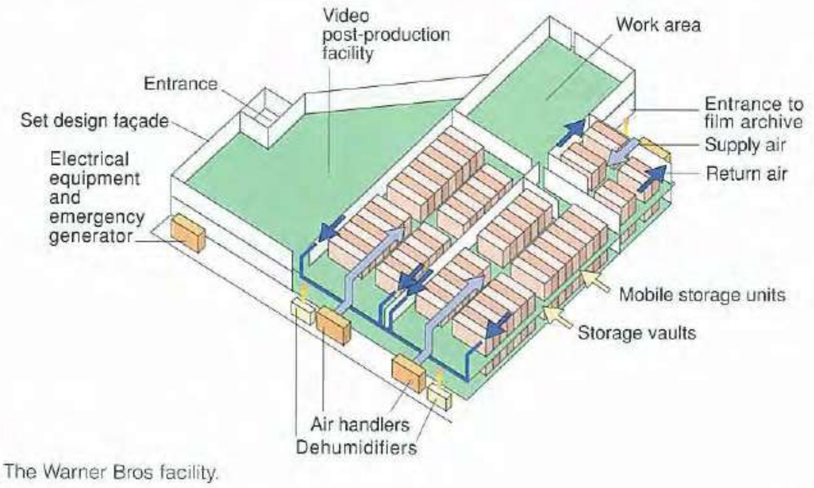
The Paramount Pictures archive has a capacity to store 750 000 to 1 million items including 35mm motion picture film, 35mm magnetic audio tracks and various formats of video tape. The building was originally intended for 750 000 items, but accommodates more as formats for the film and tape material continue to get smaller.

Paramount archive:

8. Horizontal ductwork and piping distribution.

9. Level-by-level mechanical distribution.

Warner Bros Film and Tape Archive Facility



10. The Warner Bros facility.

Introduction

While the Paramount project was being built, Warner Bros Studios executives began research into the film and tape assets stored throughout their studio and off-site. As with Paramount, their studies highlighted a need for an on-site secure environment in which the studio's current and past movies could be stored and easily accessed. Arups were selected with the architect Archisystems and Turner Construction Management (also involved in the Paramount project) by the then Vice President of Warner Bros Real Estate, Judy Frank, to provide design services from concept through commissioning. As with Paramount, the client was concerned with maximising return on investment and proposed a multi-use facility to meet not only the needs of film storage and distribution, but also to give much-needed on-site office and editing spaces.

The project comprised a 4590m² (50 000 ft²) facility, on a tight site amongst the studios and on lot filming streets; the building was designed to accommodate future construction of film set façades. During concept design the team provided the client with lists of design alternatives and system provisions, so that they could select the building systems and design which met the project's programmed needs and budget. Lessons learned from Paramount greatly helped decision-making, and the result was a relatively simple, two-level structural and architectural solution with shell space for a video post-production facility including a telecine operation, and sophisticated, environmentally-controlled storage. Autonomous areas for both these uses were designed to maximise security and minimise cost.

The project was relatively fast-tracked through design and construction, with weekly team meetings to avoid delays in solving issues. The team partnering spirit prevailed throughout the project, positively adding to the experience.

The client was an active participant throughout, and indeed was integral to the project's success, making well-thought-out strategic decisions which enhanced the design and construction process.

Design concept

The building houses approximately 3215m² (35 000ft²) of storage and distribution areas and 1375m² (15 000ft²) of video post-production facility, the latter fitted out in a subsequent contract. Each function has its own independent entrance (Fig.10). It was vital that none of the mechanical and electrical equipment be located on the storage vault roofs, so instead it was placed above the west side of the building in an equipment compound (Fig.10). The building exterior was constructed of a lightweight plaster on concrete blocks, insulated throughout, and provided with 0 perm vapour barriers on all exterior and interior walls.

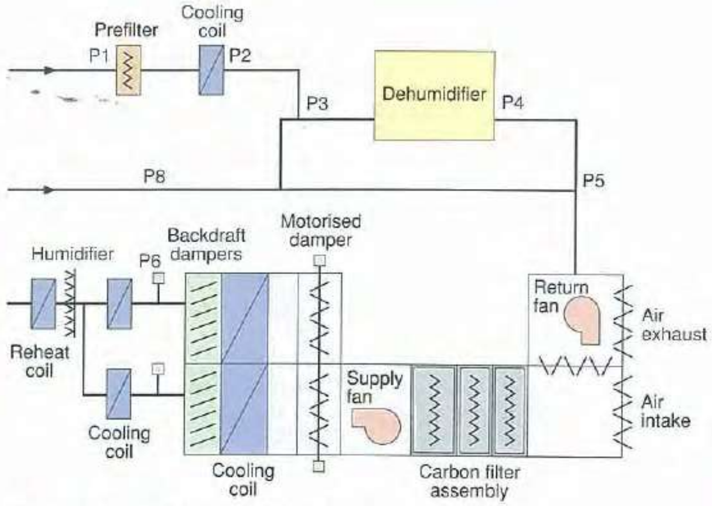
Structure

The fundamental structural design criteria were the ability to carry heavy film storage loads, speed of construction, and economy. The structure is precast concrete with hollow-core prestressed slabs, and a 75mm (3in) topping slab capable of carrying a 21.5kN/m² (450lb/ft²) live load, resting on prestressed precast girders and precast columns. Bay spacing was set at an economical 7.6m (25ft) span, which also co-ordinated with the shelving system layouts. The lateral seismic system design capitalised on the need for solid walls at the vaults by making them of concrete blockwork, which is both economical and provides thermal mass for the HVAC systems.

Mechanical

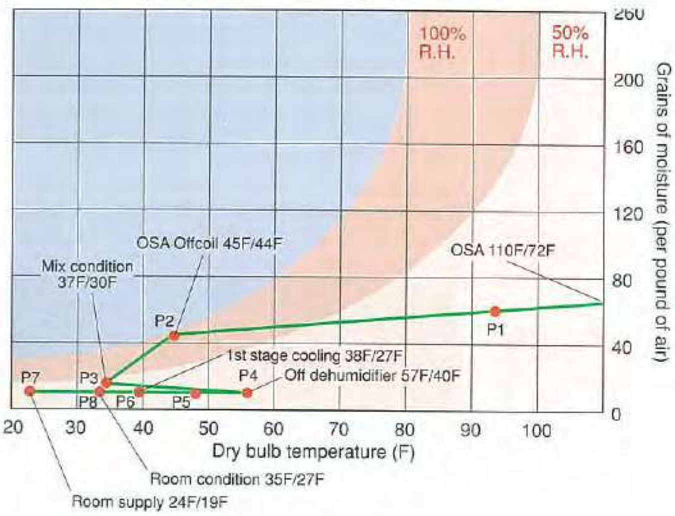
Early discussions with the client showed that the mechanical systems had to be of the highest quality within the total design/construction budget. The tightly-controlled internal conditions required suitable industrial-type systems, combining continuous reliability with ease of maintenance. Almost 30% of the total construction budget went towards the mechanical systems. An enclosed rooftop mechanical area houses water-cooled chillers, pumps and water treatment (Fig.11). A cooling tower was located nearby together with the post-production facility AHU and two of the smaller vaults' air-conditioning systems, and the large vault air-conditioning systems sited in the equipment compound. Two chilled water systems were designed, one providing low temperature chilled water (-9.4°C/15°F) to the archive facility AHU coils, the other a

11. Cooling towers.



12. Archive storage air-conditioning diagram.

13. Long-term storage psychrometric chart.



14. Video post-production control room.

15. Medium-term storage vault, showing shelving/structure/services.

16. Chiller room.

higher temperature chilled water (5.6°C/ 42°F) to the post-production facility AHU and medium- and short-term storage vault AHUs. A centrifugal chiller produces the high temperature chilled water, with a screw chiller for the low temperature applications.

The systems were both provided with 35% glycol solution and interconnected, which allowed a short-term standby operation for the low temperature vaults when the screw chiller was being maintained or overhauled. Each vault air-conditioning system has a double wall air-handling unit containing supply and return fans, low leakage dampers, primary and secondary cooling coils, reheat coil and filtration.

The dehumidifier and humidifier components were duct-mounted (Figs.12 & 13).

Gas-fired dehumidifiers were provided, to help minimise energy consumption. The filtration component was carefully analysed before a final selection was made. It was agreed that the vault environment should be protected from both internal and external contaminants like acetic acid (internal) and the normal external pollutants such as sulfur and nitrogen oxides, ozone and carbon gases. The filter selection contained 30% prefilters, 85% final filters, and charcoal filters, the latter arranged to remove all the contaminants identified in a site analysis, and which were harmful to film. Air-quality monitoring was provided in each air-conditioning system to identify pollutant levels and indicate when filters should be replaced. All external ductwork was insulated and vapour-sealed to minimise condensation; ductwork within the walls was internally lined. The ductwork was co-ordinated with the structure and external systems to maximise the height available for shelving (Fig.15). 2.74m (9ft) of compact shelving was achieved within the floor-to-floor height.

The archive was provided with a building management system to optimise system operation, and monitor vault conditions and importantly, on-site and off-site alarm capabilities.

Electrical

An outdoor service yard houses a step-down transformer and distribution equipment. The facility's electrical system divides into two sections: one for the film storage areas, the other for offices and editing departments. Electrical distribution runs in service corridors and is tapped into each film storage area. All conduits penetrating these areas are sealed to protect environmental conditions. Electrical outlets are provided in each storage area for charging the batteries of the electric car which handles film materials, and time clocks control lighting. An emergency generator is provided for the critical HVAC equipment and for the life safety equipment. Panelboards are located in electrical rooms adjacent to the film storage rooms.

Fire protection

Warner Bros requested a waterless fire suppression system, but the local Fire Marshall considered that only a wet sprinkler system was reliable. After long negotiations between Arups and local fire authorities on the one side and the owner on the other a compromise was achieved. The vaults were provided with total flooding gas suppression fire protection systems, whilst the remainder of the building has a double interlocked pre-action system; as a compromise, a dry sprinkler system with a manual shut-off valve was also provided.

Storage capacity

Warner Bros currently has 165 000 cans of film stored in the building which has a total capacity for storage of 600 000-650 000 cans depending on the film size.

17. Film editing room.

18. Video post-production facility: the Telecine Equipment Room

The future

Currently many motion picture organisations have or plan to build archive facilities like these two.

(Some existing facilities do not meet the standards outlined by either SMPTE or ANSI.)

It is widely recognised that preservation of film is a necessity and that facilities will need to meet a basic standard if film libraries are to survive the test of time.

Development will happen in a number of ways:

- *Upgrading inadequate facilities*
- *Developing longer-lasting film stock designed for preservation, not just production*
- *Transferring nitrate stock to more stable and current film media*
- *Sharing archive facilities between the larger user groups*
- *Building small collection-specific archives.*

The preservation of film requires investment on behalf of film owners. It also requires an agreement on standards between the subscribing institutions and, most importantly, needs building techniques to be developed which result in cost-effective, energy-efficient and protected environments for a major historical asset of the 20th century.

Credits

Clients:
Paramount Pictures Corporation
Warner Bros Studios

Architects:
Holt Hinshaw Pfau Jones, San Francisco (Paramount)
Archisystems, Santa Monica (Warner Bros)

Consulting engineers:
Ove Arup & Partners
Peter Budd, Jacob Chan, Alan Locke, Dan Ursea
Nancy Hamilton (Paramount only)
King Le Chang, Jacob Tsimanis (Warner Bros only)
Richard Bussell (Acoustics, Warner Bros Telecine Area)

Main contractor:
Turner Construction

Mechanical contractors:
Southland Industries (Paramount)
Acco, Glendale (Warner Bros)

Special acknowledgments:
Milt Shefter (Paramount)
Peter Gardiner (Warner Bros)

Illustrations:
1, 11, 14-18: Tom Bonner
2: Holt Hinshaw Pfau Jones
3, 7: Ove Arup & Partners California
4, 5, 10, 12, 13: Trevor Slydel
6, 8, 9: Mark Darley

Florida Southern College

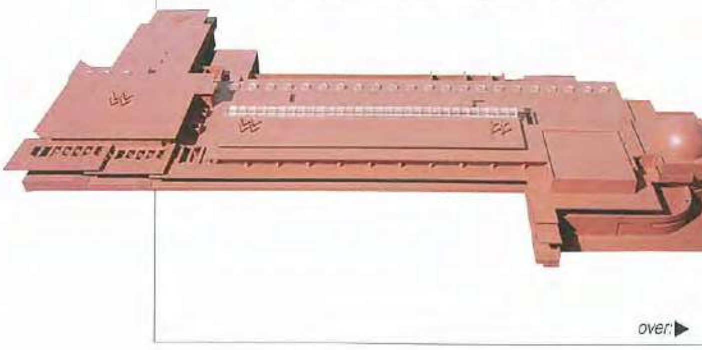
John Figg Kendrick White

Introduction

Polk County Science Building (PCSB) is the largest of the 12 buildings designed by Frank Lloyd Wright at Florida Southern College on the north shore of Lake Hollingsworth, Lakeland, Florida. It was completed in 1958, only a year before Wright's death, but in common with other Wright buildings on the campus, it has suffered deterioration due to inadequate or inappropriate maintenance actions. Together with the architects Troughton McAslan Ltd, Arups were invited to formulate, model, and illustrate the decision-making process required for restoring PCSB and for its subsequent management and maintenance. If this was successful, it would be regarded as an exemplar for restoring all the Wright buildings on the campus.

1.
Polk County Science Building includes the only Wright-designed planetarium (on the right). Here, furniture designed by Wright is to be retained. The PCSB is in most need of maintenance, and was the focus of the Arups/Troughton McAslan study.

2.
Model of PCSB by Troughton McAslan.



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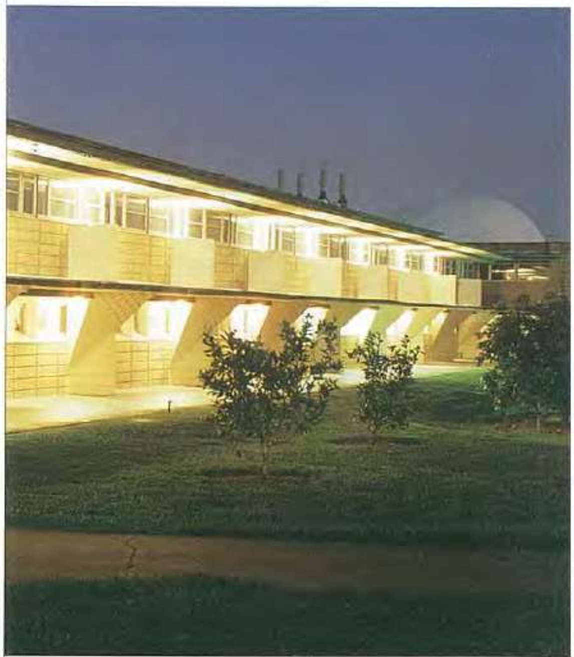

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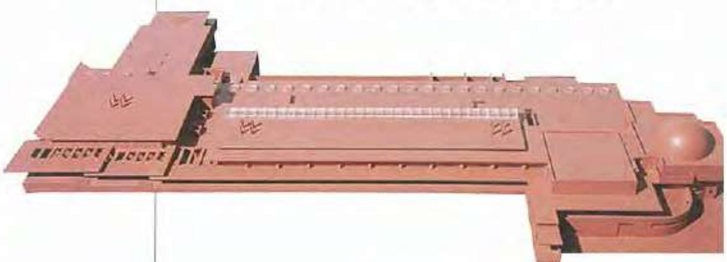

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Methodology

The approach adopted divided the study into three areas:

- Definition of actual restoration work required and subsequent maintenance, including establishing what further detailed surveys and studies would be necessary to supply competitive tenderers with necessary information. Estimates of capital costs and likely in-use costs would give the financial scale to the decisions to be made.
- Definition of possibilities and constraints on undertaking the restoration, leading to prioritisation of the work packages and preparation of a construction programme with a cash flow prediction.
- Application and field development of the Data Spine Management System (a computerised method of storing and retrieving information about a building) to customise it to the College's requirements, along with the development of an explanatory manual.

3. Annie Pfeiffer Chapel, the first Wright building at FSC, completed 1941

Conflicts of philosophy

The first step was to understand the differing philosophies about restoration and then make judgements on what could be sensibly proposed for the PCSB. Purists hold the view that once a building by a famous architect has been finished, it becomes a monument and nothing must be done to change any part of it: in effect it is a living museum until it falls down, when it becomes an architectural heritage ruin.

A more practical approach is to try and return the building to its original appearance using modern but sympathetic materials in defective areas, and to remove causes of deterioration by means which do not spoil the original architectural vision.

A further, more controversial, step is to try and enhance the building by introducing architectural features to overcome problems found in use.

Whilst purists would reject any such proposal outright, heritage buildings which are still in everyday use may not comply with current health and safety practice.

Therefore a judgement has to be made. In the case of the PCSB, sensitive restoration using modern materials was proposed, together with options on possible enhancements involving architectural aspects which might be acceptable to the restoration authorities in southern Florida.

Information gathering

The information on which the prioritisation study was based came from reports by Troughton McAslan, Arups in New York, and Arup R&D in London, plus responses by the College and other Florida bodies to a lengthy questionnaire.

A large selection of photographs were available from various sources, and local architects provided expert knowledge of conditions, materials, and regulations affecting restorations in Southern Florida.

Levels of restoration works

Arups suggested three possible levels:

(1) Minimum-cost, 'must-do-now', covering only absolutely essential work on a 'patch-and-paint' approach. Such an approach could lead to greater and continuous expenditure in future years.

(2) A 'sensible' approach to the restoration, carrying out the work necessary at a reasonable cost to bring the building as close as possible to the original condition.

(3) Possible enhancements to the building and the surrounding area, following the College's wish that the building be fully restored by the Millennium. This basis expanded the work content of (2) and was therefore considerably more expensive, but the College would get the new facilities and the other improvements that were on their 'wish list'. Five-year capital expenditure plans (1995-1999) were prepared for each of the three options, with (2) being worked up into a practical programme of construction work sequenced to take account of the periods when the College was fully operational and when it was vacated.

30-year asset management plans were also prepared to give indications of each option's long-term financial consequences in terms of likely annual maintenance and cyclic replacement costs.

Prioritisation of work packages

From all the information to hand, it was evident that moisture was the prime cause of deterioration; it was penetrating roofs and damaging the building interior, and wind-driven rain had got through the external skin of structural blockwork.

The roofs were without adequate falls, there was ponding, and some slight deflection had occurred. The roof membrane had failed and been patched in several places.

Providing falls and re-covering the roofs led the prioritisation study and this was followed by, in sequence:

- Retaining structural integrity of the block walling, coupled with some limited internal replanning to provide improved means of escape and a computer laboratory
- Replacing the environmental services
- Repairing and in some cases replacing the finishes generally, and
- Replacing fittings and furniture.

However, health and safety factors led to a fire alarm system being recommended, and an immediate check on any obstructions to the existing means of escape.

History

Florida Southern College was established on its present site in 1922. At that time it was a small, struggling, liberal arts college sponsored by the Methodist Church. The College's go-getting President, Ludd Merl Spivey, realised that progress would only be possible by expansion, and determined to embark on an ambitious building programme with a new chapel as the focal point of the campus and the focus of fund-raising activities. Accordingly, in April 1938, having been told that Frank Lloyd Wright was the greatest living architect, President Spivey telegraphed him:

'DESIRE CONFERENCE WITH YOU CONCERNING PLANS FOR GREAT EDUCATION TEMPLE IN FLORIDA STOP WIRE COLLECT WHEN AND WHERE I CAN SEE YOU.'

Such flowery language was just Wright's style and the two short-stature, visionary men hit it off immediately. Wright agreed to prepare a master plan and detailed drawings as necessary for a flat fee of $13 000 (as ever he was short of money, particularly as at this time he was involved in construction of his winter school, Taliesin West, in Phoenix, Arizona). President Spivey was to pay by $200 instalments as fund-raising permitted. Wright used this opportunity to design a college campus that expressed his ideas of 'organic architecture' with the buildings constructed of local materials tailored to the sloping orange-grove site.

4. Dr Spivey and Frank Lloyd Wright.

5.
Annie Pfeiffer Chapel is constructed of structural reinforced concrete with 'textile' block infill walls.

Blockwork

The main construction components at FSC were textured and patterned precast concrete 'textile' blocks, sometimes having coloured glass inserts and in places pierced to admit light through deep-hued glass lenses. The exposed block faces are reminiscent of the coquina stone which is the only indigenous building stone in Florida (seen to advantage in St Augustine, NE Fla). The blocks were stack-bonded with butted horizontal and perpend joints, and reinforced horizontally and vertically with steel rods, surrounded by cement mortar, in grooves cast in the edges of the blocks. The cavity walls were constructed fair-faced both sides and the leaves were tied together with U-shaped reinforcing rods set in the perpend joints. The blocks themselves were made with a fine, almost single-size, quartz sand (median size c.1-2mm) with a small proportion of coquina shell, mixed white and grey Portland cements, and yellow-buff pigment. The semi-dry mixed material was hand-rammed into the moulds. In the early years the blocks were cast by students who were working their way through college and who were paid 10c per hour! After World War 2, when student grants were more readily obtainable, blocks were made commercially by a Tallahassee contractor. The blocks are porous and permeable due to the less-than-optimum sand grading and poor curing and they have high moisture movement due to lack of coarse aggregate. This has resulted in deterioration of the blocks where cycles of wetting and drying have occurred. Inaccurate positioning of the steel reinforcement and failure to surround the steel completely with mortar/grout have allowed it to rust and this, in turn, has led to spalling of the textile blocks.

6.
The original blocks are weak and friable, with high moisture movement due to absence of coarse aggregate. Wetting and drying can lead to surface breakdown.

7.
Blocks are stack-bonded without mortared joints. Reinforcement is horizontal and vertical in edge grooves, grouted with a fluid cement mortar.
Rusting has led to spalling.

8.
Use of chevron corner blocks and insufficient movement joints has caused unsightly cracking, allowing water ingress.

9.
In front of Annie Pfeiffer Chapel, a prototype replacement block, designed by Arup R&D to a specification including a polymer-modified facing mix with a concrete core.

Data Spine Management System

In order to maximise benefit from restoration work on the PCSB and the subsequent buildings, a full record must be kept of the steps carried out, and the results on a continuous basis, so that later restoration can be optimised and any unsuccessful work logged and not repeated.

Over the life of a building, not only do technologies and materials evolve, while others disappear from the market-place and new ones appear, but people are promoted, change employers, become ill from time to time, and eventually die. Thus the body of knowledge must be defined and held in a comprehensible and easily accessible form, and continually changed and enhanced over a long period of time.

Arups' Building Performance and Cost Management (BPCM) system provides the basis for initially generating, and then holding and developing, this body of knowledge over the life of the building. The concept put to the College was to implement a paper-based version of the Data Spine Management System, one of the key elements of the BPCM system.

A customised version of the building data spine was prepared for the College as the basis for their long-term building asset management system. A floppy disc provided macros in Quattro Pro 6 for a five-year capital expenditure plan, plus a 30-year financial asset management program with an amortisation facility. A CD-ROM was also provided containing some 80 images of the Wright buildings, the types of dilapidation, and the proposed replacement blocks.

This package provided the College with a structured approach to the overall restoration of the Wright buildings and to securing data for ongoing management and maintenance. Demonstration discs which illustrate how the BPCM system in software form could enhance and facilitate this were submitted to the College with the suggestion that they might find it beneficial to collaborate with Arups in a further development stage.

The decisions of the College President and Board of Trustees are awaited.

Credits

Client:
Florida Southern College

Consultants:
Troughton McAslan
Ove Arup & Partners John Figg, Liam O'Hanlon, Kendrick White

Illustrations:
1, 3, 5-9: John Figg.
2: Peter Mackinven.
4: Florida Southern College.

BRICC

Tom Fernando

Introduction

BRICC (Broadband Integrated Communications in Construction) is a four-year construction sector R&D project, part-funded by the EC and a pan-European consortium including Ove Arup & Partners, for testing advanced methods of communication in actual construction projects.

It will be completed in December 1995. A proof of its success is the spawning of three new construction sector R&D projects, also part-funded by the EC, commencing in September 1995.

The background to the project, the work done in it, and the benefits to Ove Arup & Partners from participating in it, are described below.

Industry background

Construction projects have increased in complexity over the years:

- Products are more demanding, in terms of appearance, structure and services.
- More sophisticated materials and technologies are being used.
- The number of specialist designers and contractors on any one project has increased.
- Project participants are often located in corporate centres in different countries.

In addition, an increasingly global and competitive marketplace demands very strict adherence to constraints of performance, budget, and time. In this environment, it is becoming increasingly accepted that rapid progress of technologies usually referred to as Information and Communications Technology (ICT) can be a key enabler.

An EC initiative

In 1992, the business turnover of the construction industry was approximately 600M ECU. This represented 11% of the total EC GDP, providing employment for approximately 7M persons, about 7% of the total EC labour force. Hence, not surprisingly, the EC decided to make this important sector more competitive in the international marketplace by bringing to it the benefits of advanced communications methods.

As part of its multi-million ECU R&D programme called RACE (R&D in Advanced Communications in Europe), in April 1992 the EC set up the 9M ECU project BRICC to run for four years. It was to be funded partly by the EC and partly by a pan-European consortium of construction users, PTOs (public telephone operators), construction and communications R&D units, and management consultants:

BICC/Balfour Beatty (UK)
Bovis Construction (UK)
Bouygues Construction (France)
BT Laboratories (UK)
Institut CERDA (Spain)
Dioguardi (Italy)
MIXER (Italy)
Ove Arup & Partners (UK)
Telesystèmes (France).

Arups were represented by Arup Communications, with occasional assistance from other parts of the Partnership.

Pilot trials

BRICC is essentially about conducting pilot trials. Advanced methods of communications are used in actual construction projects, with the intention of testing the benefits and opportunities which these methods can bring to the European construction sector.

The project commenced with a rapid survey of communications needs in construction. At an initial workshop in June 1995 in London, real requirements as perceived by construction users were identified.

In parallel with this study of needs, particular service prototypes based on emerging communications technologies were planned, developed, and tested in the laboratory.

Various advanced communications services (which soon began to be called 'BRICC services') have been, and are being, trialled in several European construction projects. These include two in which Arup engineers are directly involved: the Commerzbank building (Germany), and the ISPRA Eco Project (Italy). Others are the A2 road widening, the A13 road extension, Barking Power Station building, Heathrow building (UK), and the JOSI building refurbishment (Belgium).

The pilot trials are extensively evaluated for their technical and economic-strategic potential from the point of view of the organisations participating in them. A key concern has been that the construction users benefit only, and are in no way hampered, by the introduction of new communications methods. The reaction of Arups' engineers involved in these trials was decidedly positive.

Advanced methods of communication

BRICC has focused mainly on three ways in which advanced methods of communications can facilitate work in construction:

- *by bringing the construction project closer to remote participants.*

  BRICC services enable remote participants to see all the information they require to appreciate the current project configuration, including the physical state on site.

- *by bringing remote expertise closer to the construction project.*

  BRICC services enable remote experts to intervene effectively on the basis of their view of the project.

- *by bringing construction participants closer to each other.*

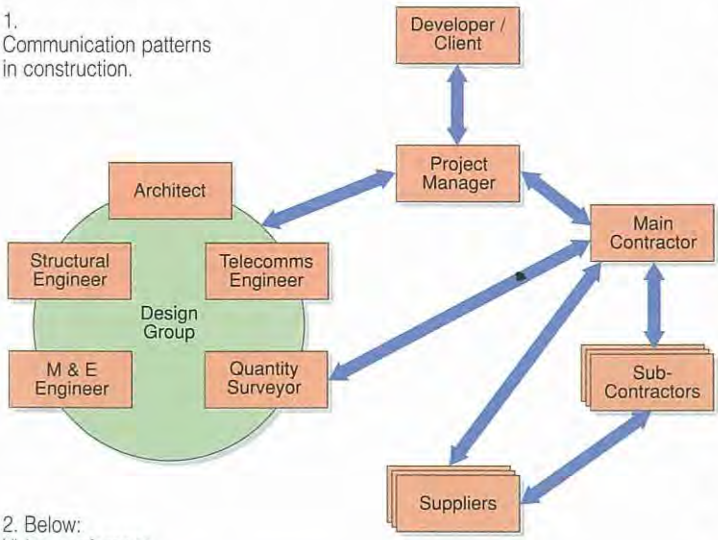
  BRICC services enable participants to interact with each other by sharing information as easily and as effectively as possible.

The advanced methods of communications trialled included the use of the ISDN (Integrated Services Digital Network). This provides users with a digital communications link into public communications networks.

The particular methods of communication used in the trials were:

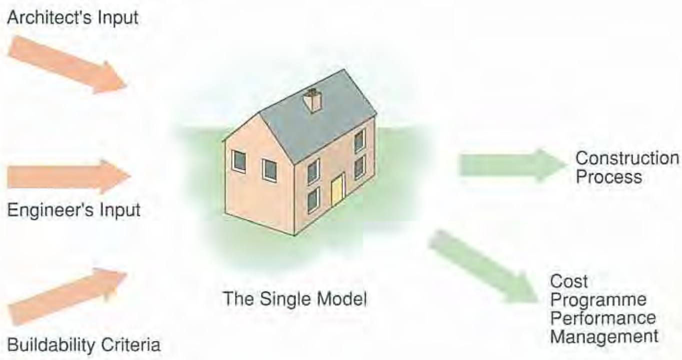
- Transferring 2D and 3D CAD files internationally
- Sharing a centralized database for storing, circulating and 'red-lining' 2D CAD drawings
- Collaborating between design and site offices by viewing and commenting on the same file which appears simultaneously on remotely- located computers in design and site offices, respectively
- using audio and video conferencing between site and design offices, nationally and internationally.
- using audio and video communications between the site office and persons moving around the construction site.

1\.
Communication patterns in construction.



2\. Below:
Video conference in progress.

3\.
The potential offered by technology.



Due to the particular phases in which the construction projects were at the time the trials were conducted, Arups' engineers were able to have first-hand experience with the use of CAD file transfer and audio/video conferencing.

Construction process modelling

In parallel with the pilot trials, the design and procurement processes in construction were modelled. To check the utility of BRICC services, it is possible to load data related to these services into the model, and use the model to compare the use of these services against 'as is' scenarios. Results obtained using the model have confirmed user data and perceptions gathered in the evaluations of the pilot trials.

Key deliverables

BRICC has already produced a number of deliverables: reports, demonstrations, infrastructure architecture specifications, and pilot trial specifications. In addition there are three key deliverables in the form of reports which will be completed by the end of the project:

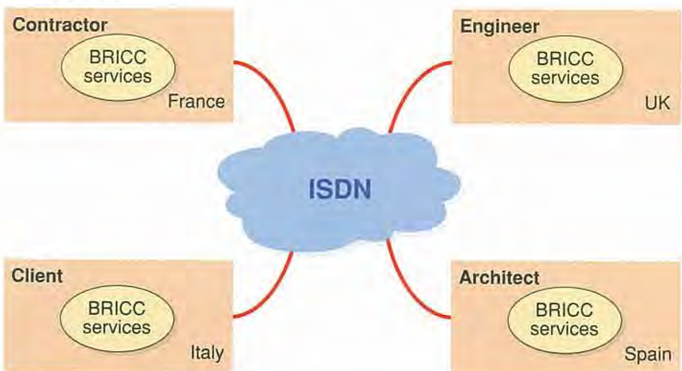
- Modelling the design and procurement processes in construction
- Communications requirements in European construction
- Functional architecture specification of the communications infrastructure required for European construction.

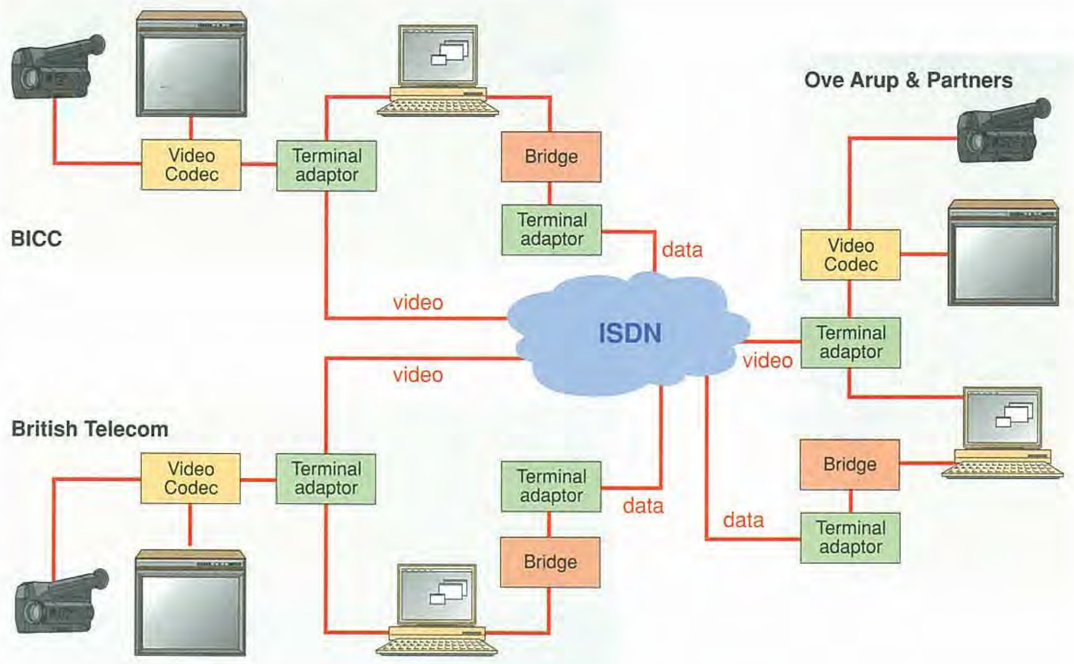
Results dissemination and exploitation

In keeping with the overall objectives of the RACE programme, a key EC requirement of projects carrying out communications experiments in the programme is that the results are disseminated in Europe as far and wide as possible, to maximise benefit to the sector. To aid this, demonstrations of 'BRICC services' were held in EC countries with a large construction sector: France, Germany, Italy, Spain, and the UK.

The UK demonstration - the last to be held - took the form of a presentation of the findings and achievements of BRICC to the construction sector in June 1995.

4.
Typical
pilot structure.





5.
Model for pilot study.

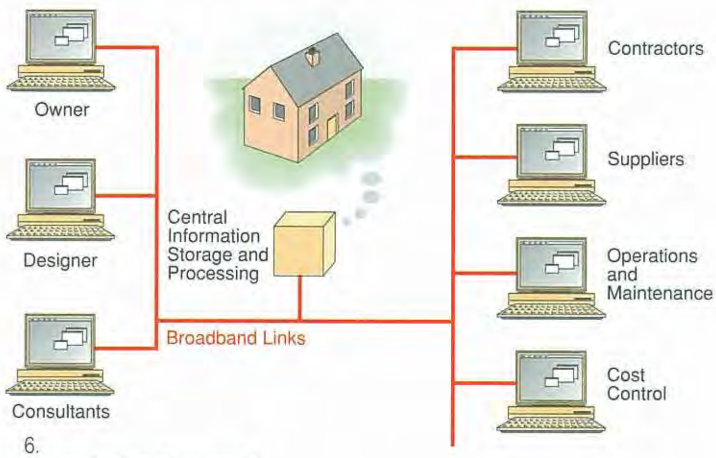
Commercial exploitation of the experience gained and the pre-competitive developments made during the project is another key EC requirement in projects in the RACE programme. Each member of the consortium has been asked to say how this will be done within their own organisation.

Benefits to Arups

Arup Communications have to all intents and purposes single-handedly represented the firm in the BRICC project. It has, in any case, taken on completely the financial burden of carrying out a project which is only part-funded by the EC.

The key immediate beneficiary has been Arup Communications, which has enjoyed:

- First-hand access to the best in communications in Europe, thus expanding the knowledge base and technical expertise of the group.
- Direct experience of R&D in communications in the construction sector, thus consolidating and enhancing the group's skills in a particular area of communications consultancy: communications in construction.



6.
The realisation of the model.

- Useful project management experience in working closely with other European construction and communications organisations on a multi-national and multi-disciplinary project.
- Invaluable exposure in Europe, thus gaining marketing benefits.
- Experience of the ins and outs of working in collaboration with the EC in Brussels.
- The opportunity to be a member of a new pan-European consortium and play a key role in a new part EC-funded project called CICC (Collaborative Integrated Communications for Construction) which will test other advanced methods of communications in actual construction projects.

  The CICC contract has been awarded and the project commences in September 1995.

The benefits gained by Arup Communications by its participation in BRICC are clearly benefits for Arups as a whole.

However, there have been additional more direct benefits for the rest of the Partnership:

- Through direct participation in BRICC pilot trials, a few Building Engineering units have gained both performance, time and cost benefits on their projects, and useful experience in using emerging methods of communications suited for construction.
- Through the expertise gained by Arup Communications in communications in construction, there is a reservoir of in-house expertise which can be tapped for the whole firm's benefit.

Credits

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European Commission
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