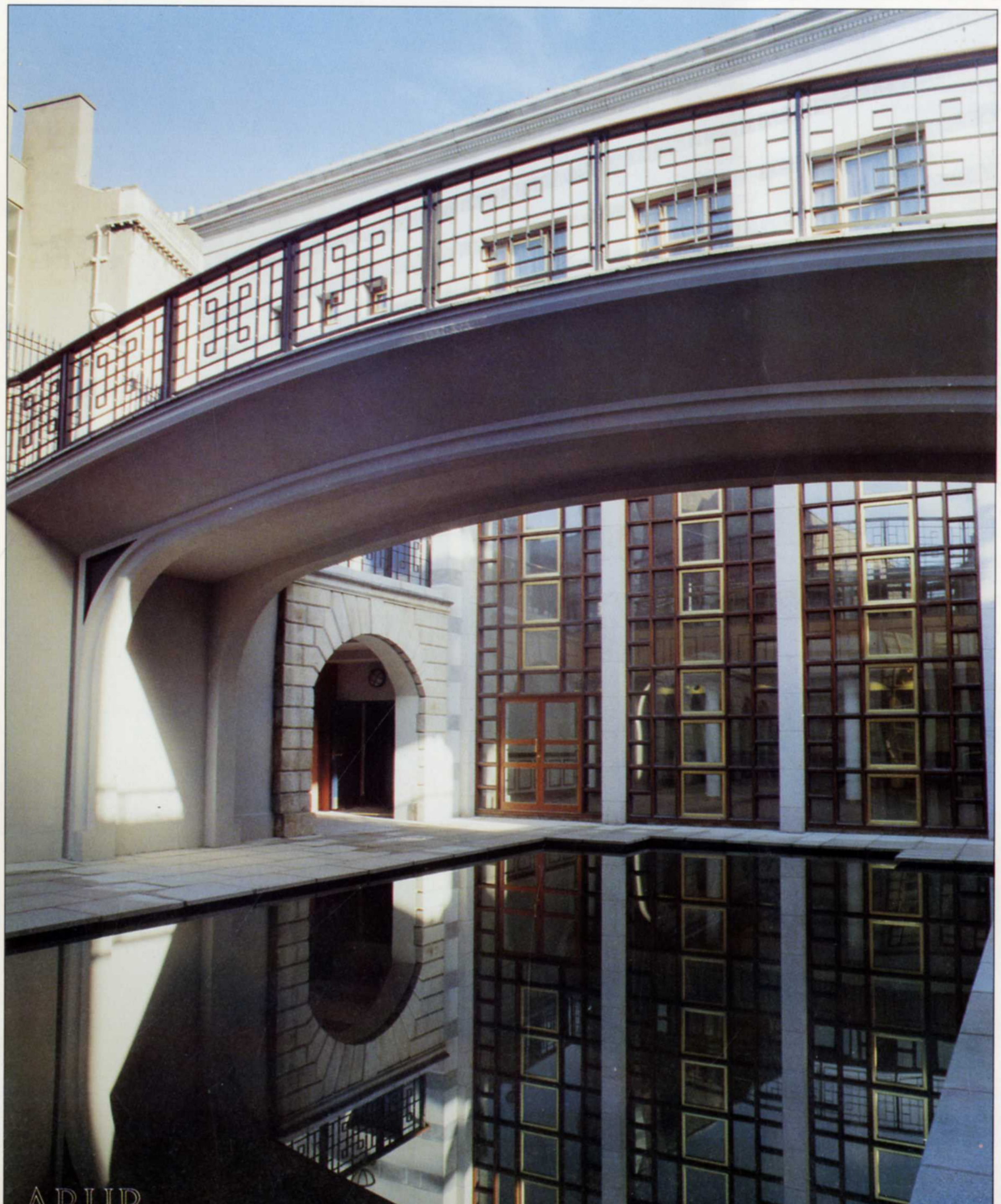
THE ARUP JOURNAL

OVE ARUP & PARTNERS IRELAND

1990



THE ARUP JOURNAL

Ove Arup & Partners
Ireland 1990

Published by
Ove Arup Partnership
13 Fitzroy Street,
London W1P 6BQ

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Foreword

Arup Journals have featured Irish work before, but this is the first time that an issue has been devoted to Ireland. We hope that the projects included will convey a good impression of the variety of work that we undertake in our Dublin, Cork and Limerick offices.

If you look at the aerial photograph of the Custom House Docks site on p.5 you will see, in the foreground, the Dublin Bus Station. This was designed in 1946 and is now part of the folklore of Ove Arup & Partners. One could argue the relative merits of the architecture displayed but we believe that the quality of the structural engineering and the professional standards of the firm are the same now as then.

If you look through the articles you will get a flavour of the variety and content of the work we now undertake. There has been a dramatic change over the past 10 years. Buildings still account for the greater part of our work but we now have a lengthening portfolio of bridges, roads, infrastructure, sanitary services, marine engineering, and gas pipelines and their associated facilities. We are becoming more involved in project management, particularly in larger industrial projects of which Sandoz is a good example. This, and similar projects, are now very high profile here in Ireland because of increasing interest in the environmental effects of such developments. Environmental Impact Assessments are now mandatory for all major projects in Ireland under EC regulations and we are developing our capability to carry these out.

To meet the increasingly complex needs of our clients would be difficult, if not impossible, without the help which is available to us from the central technical services groups of the Partnership in London, and our association with these groups down through the years has been most beneficial to us. It has enabled us to develop our own expertise in areas such as bridges, roads, and geotechnics, to mention but a few in a long list. We have, for instance, been working with BE6 in London to provide building engineering services for the Custom House Docks Project, and are currently in the process of creating our own building engineering group here in Dublin. We have carried out work in Ireland to help some groups in the London office in recent times.

All of these activities have one unifying aspect: they enable people at nearly all levels in the firm to establish personal relationships with those in the UK Partnership offices. I only wish it were possible to extend the experience world-wide. We believe that these relationships are an essential part of the Arup ethos.

So what of the future, 1992 and all that? The Single European Market will doubtless open new doors for us and the opening up of Eastern Europe and the USSR may also offer opportunities, such as the hangar project we are currently completing in Moscow. The future can only be secured by having talented, well-motivated people working together in an organization which cares about what it does, how it does it and the way it affects peoples' lives. We have these people now and we can travel hopefully. We may not have the right to command success but we can do what is necessary to deserve it.

From one to whom age has brought more golf than wisdom, I can only say 'May the road rise with us'.

Frank Lydon

John Mitchell (1941-1990)

For the past 10 years John Mitchell, who died tragically in an accident in London on 14 September, was principal geotechnical advisor to Ove Arup & Partners Ireland. His work took him to many parts of the world and it was our great good fortune that Ireland, too, was in his bailiwick. His abiding strengths were his knowledge, integrity, total commitment and ability to communicate; but more than that, he was to us a colleague, companion and friend. Throughout this time his advice was sought on most of our major projects; many are portrayed in this *Arup Journal*, which is dedicated to his memory.

Ralph McGuckin

The Custom House Docks development, Dublin

Architects:
Benjamin Thompson & Associates
Burke Kennedy Doyle & Partners

Morgan Sheehy

Fort of the Dane,
Garrison of the Saxon,
Augustan capital
Of a Gaelic nation,
Appropriating all
The alien brought,
You give me time for thought
And by a juggler's trick
You poise the toppling hour
O greyness run to flower,
Grey stone, grey water,
and brick upon grey brick.

Louis MacNeice: 'Dublin'
from *The closing album*

Introduction

In November 1986 the Irish Government established the Custom House Docks Development Authority with a mandate to bring about the construction of a financial services centre as part of a complete redevelopment of the Custom House Docks under the direction and control of the chairman, Frank Benson. In a very short time, by June 1987, the Authority published its planning scheme for the site and invited prospective developers to put forward their proposals.

The planning scheme required three main elements: an International Financial Services Centre (IFSC) with associated commercial development, probably financially orientated; retail and amenity facilities with an emphasis on speciality shopping, restaurants, and culture in the form of museums and other formal outlets; an international hotel, conference centre and residential accommodation. Adequate car parking would be required, and the whole development would be of a very high standard, duly respecting the riverside setting and the large expanse of water in George's Dock and the Inner Dock.

Eight major submissions were received from Irish and international developers and, in October 1987, after detailed examination of the entries, the Government announced that the selected developer was the Custom House Docks Development Company Ltd., a consortium of Hardwicke Ltd., McInerney Properties plc, and The British Land Company plc.

The professional team retained were as follows: architects and planners, Benjamin Thompson & Associates, Boston, a firm internationally known for its pioneering designs in the restoration and renovation of waterfront areas in Boston, Baltimore, Minneapolis and New York, and Burke Kennedy Doyle & Partners, a leading Irish architectural practice; building engineering, Ove Arup & Partners Ireland; quantity surveyors, The Bruce Shaw Partnership, and letting agents, Jones Lang Wootton.

History of the site

The Custom House Docks site adjoins James Gandon's celebrated Custom House and extends along a strip of reclaimed land eastwards from the old Dublin Bay shoreline along the northern bank of the Liffey.

The construction of a breakwater, and the start of land reclamation along the shoreline north of the Liffey, is depicted on Charles Brooking's 1728 City of Dublin Map (Fig. 1). By 1756 reclamation of a large area of land for agricultural use had already taken place.

The building of Carlisle Bridge (now O'Connell Bridge) between 1791 and 1794 deprived the Dublin merchants of the use of the quays upstream. The present Custom House was already being built; until then it had been located near Essex (now Grattan or Capel Street) Bridge and when the adjoining dock and warehouses were completed the Government considered that the merchants would be amply compensated. This dock, later called the Old Dock, was capable of receiving 40 vessels: it was completed in 1796 and the surrounding warehouses by 1811.

In October 1813, the Treasury Commissioners approved the reports, plans and estimates for a further Basin dock and stores for the Custom Department, Dublin. This development was not only considered to be of advantage to Dublin's trade, but would also bring in additional customs revenue. The Treasury Commissioners accepted the recommendation of the Customs Commissioners that John Rennie's plan for the docks could be modified to include both the Basin Dock (to be renamed George's Dock) and the Inner Dock.

Although these docks were officially opened by King George IV on a visit to Ireland in 1821, work was still continuing on them and other premises up to the early 1830s. The total cost amounted to over £700 000. In August 1833, fire gutted the sugar and rum bonded stores in the Old Dock of the Custom House. The fire, which was believed to have been the greatest that had ever taken place in Dublin, was graphically described in the *Freeman's Journal*, 12 August 1833.

The Dublin Port and Docks Board in whom the Port was vested in 1867, entered possession of the warehouses in September 1869 when stacks A, B, C, D, V and W had already been built. Stack A is described in G.N. Wright's *An Historical Guide to the City of Dublin* (2nd edition, 1825):

'To the east of the new basin is the tobacco store (500 feet by 160 feet capable of containing 3000 hogshead) the plan of which was given by John Rennie Esq. In this store, which is now completed and in use, there is not one particle of wood or other combustible matter.

There are nine vaults beneath which altogether afford perfect and convenient storage for 4500 pipes of wine, allowing a walk behind the heads of the pipes as well as between them; these vaults are lighted by means of thick lenses set in iron plates in the floor of the tobacco store; but this is not sufficient to supersede the necessity of candle light.

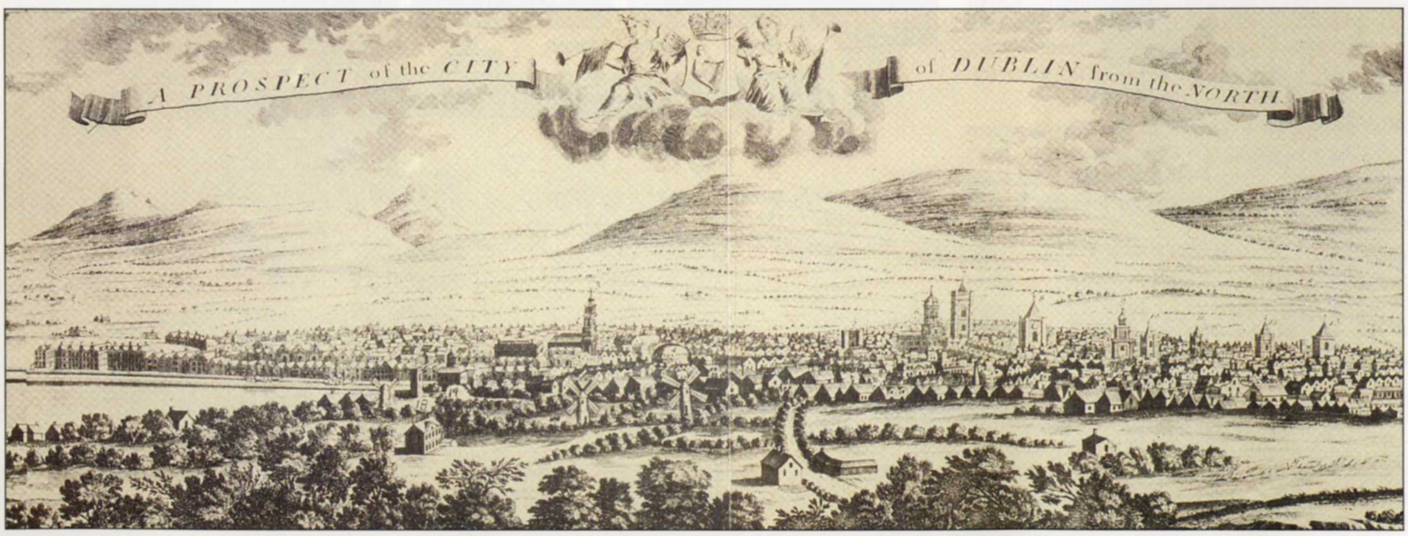
The interior of the tobacco store is extremely curious and interesting; the roof is supported by metal framework of an ingenious construction, and, at intervals, long lanterns are inserted, the sashes of which are also metal; the entire framework is supported by three rows of cylindrical metal pillars, 26 in each row; these rest upon piers of granite, which are continued through the store floor into the vaults beneath.

All the iron work was manufactured at the Butterfly foundry in Derbyshire.'

It is not certain at what dates stacks B and C were constructed. Wright describes a store to the east of the Custom House 'for general merchandise and . . . 500ft in length, by 112ft in breadth', but this could have been a warehouse destroyed in the fire of 1833. In 1884, the frontage of stacks A, B and C were cut back by about 5m to widen the riverside roadway and make it a straight line from the Old Dock to Common Street.

When the Dublin Port and Docks Board acquired the Custom House Docks, warehouses, etc., in 1867, it became responsible for the upkeep and repair of the bridges over the entrances to the Old Dock and George's Dock which had formerly been the responsibility of the Board of Works. In 1860, a new patent balance rolling bridge had been erected over the entrance to George's Dock,

1. City of Dublin 1728: map by Charles Brooking.



constructed by the owner of the patent, Messrs. Turner and Gibson of Hammersmith Iron Works, Ballsbridge, the same Turner whose ironwork graces the glasshouses of Kew and Glasnevin Botanic Gardens. A new swivel bridge was, however, commissioned and opened to the public on 12 February 1884; the saving of time compared with the old rolling bridge was about 2½ minutes each time the bridge was opened, an important consideration even then. The total cost of constructing the bridge and approaches was about £6700.

The warehouses known as Stacks A, B and C were still in active use up to 1986 and both the Inner Dock and George's Dock are still open. The original Custom House Dock, the Old Dock, was backfilled in the late 1940s prior to building the Central Bus Station.

The site

At the earliest stage of the planning of the current project, a desk study was undertaken for the entire Custom House Docks Development (CHDD) site. Data on the historical development was recovered from old maps, documents and engineering publications, primarily from the Institution of Civil Engineers in London, the Institution of Engineers of Ireland, and the archives of the Dublin Port and Docks Board. The Board, the former site owners, provided a great deal of information, both from old files and drawings, and in discussion.

Further historical data was established from Ordnance Survey maps, dating back to 1838. A review of available aerial photographs was undertaken, but revealed little additional information as no significant changes had occurred on site from the time the first photographs were taken up to the time of this study. The Geological Survey provided valuable information on the ground conditions within the site and in surrounding areas from geological mapping and reports on site investigations conducted in the area for earlier developments.

Prior to the development of the harbour, the site lay well beyond the original shoreline of the northern flank of the Liffey Estuary.

Ground level would then have been around mean tide level, about 0.0m OD Malin, and the near-surface geology would probably have consisted of estuarine silts and clays.

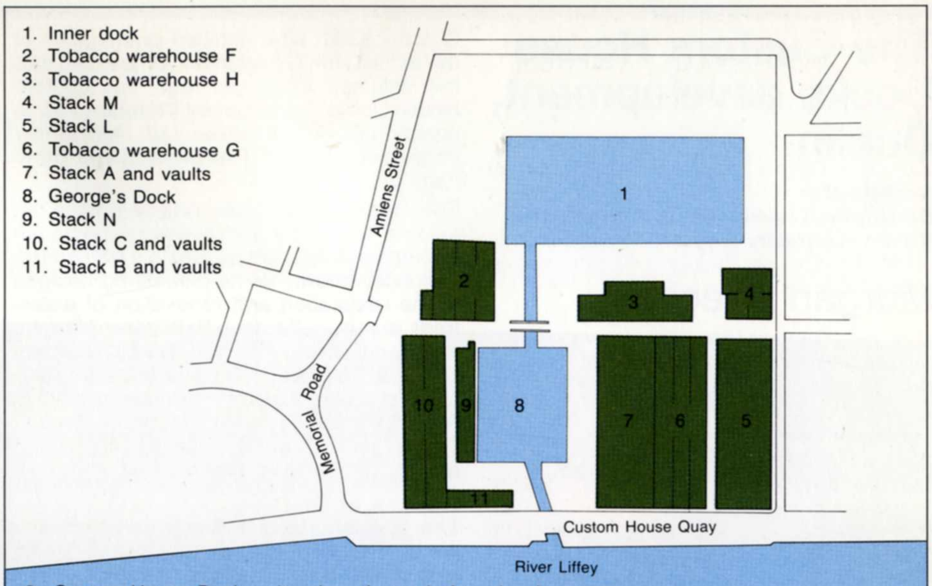
The underlying geology as determined from historical and recent boreholes is of glacially deposited boulder clays and sands and gravels, over a limestone bedrock: rockhead levels for the site were found some −10.0m to −20.0m OD.

With present day site levels at about +4.0m OD, it is clear that a substantial amount of filling took place during the development of the area with several structures being built and later replaced. Since the construction of the Custom House in the 1790s, the site has always been used for port and docks purposes, handling primarily sugar, tobacco, tea, liquor, timber, coal and cattle.

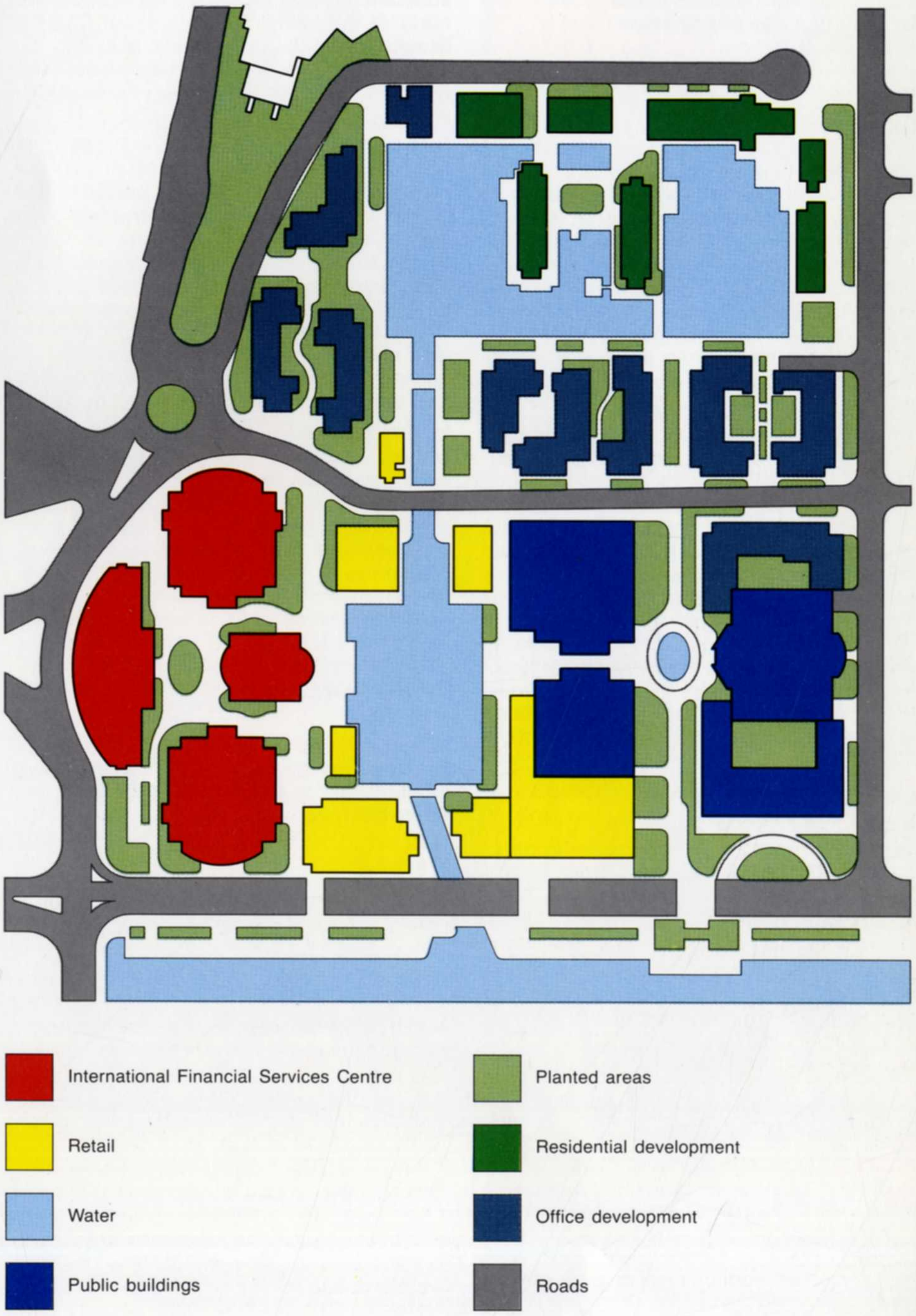
The details of the extensive site investigation have been described in a paper by John Higgins and Sean Mason[1]: the resulting foundation design included both piling and pad footing.

The plan

The layout of the accepted proposal is as in Fig. 3, wherein the IFSC at the western side of the site is the anchor of the scheme, a cluster of four office blocks of five and six storeys totalling 50 000m² around a landscaped garden court. Of these the west block, purchased outright by AIB Banks plc, follows the curve of Memorial Road and was completed in March 1990. The south, central and north blocks are presently under construction and due for completion in 1991.



2. Custom House Docks: site plan of area before development.



3. Layout of accepted development proposal.

Harbour Master Place 1 and 2 are also under construction, part of a further 40 000m^2 of office development. Parking for 2000 cars is provided beneath the buildings.

Stack A, earlier described as 'extremely curious and interesting', and located across George's Dock from the IFSC, will be reserved for cultural and entertainment facilities with museums, art, science and folk exhibitors. The hotel, with 300 bedrooms, and the 1500-seat conference centre will be east of Stack A.

The George's Dock area will thus become the focus of the development, forming a square around which will be located most of the retail and public activities, giving opportunities for dining, refreshments, shopping and entertainment, day and night. Around the Inner Dock will be 200 residential apartments in a series of four to six storey blocks; a new water purification scheme will maintain and improve the water quality in both docks.

Above all else it is intended that the development be a place for people, so very detailed attention has been given both to the integration of pedestrians within the scheme and the separation of through traffic; a new bridge on the central spine of Mayor Street, and pedestrian bridges elsewhere are included. Access is available from the quays, from the bus and train stations and from adjoining streets. As part of the scheme it is proposed to have a riverside park and riverside walks.

The Authority is mindful that many of its services such as water, sewerage and road access are provided by the local authority. It is also sensitive to the need for integrated planning of the area, and is committed to ensuring that its operations act as a catalyst to promote the best possible standards. This commitment has led to the use of the best materials throughout, and to a conscious effort in the carrying out of the work to preserve the best of the old and enhance it wherever possible.

There has always been a lot of traffic entering and emerging from the site at the Amiens Street entrance gates. An integral part of the winning submission is the closure of the North Quays at Customs House Quay, thereby allowing the new development to embrace the campshot and the area out to the water's edge along the Liffey. These plans are, however, tempered with the knowledge that Dublin Corporation owns the right of way over the road on the North Quays, and that without a new bridge across the Liffey, at or around Spencers Dock, it is not feasible to close the North Quays. However, it is still hoped that development of a new access route to Dublin Port which avoids the city centre and the provision of a new bridge over the Liffey will allow the quays to be closed to vehicular traffic.

4. (right) View to the south west and 5. (below) to the east.

The execution

To facilitate speed of construction and occupation, management contracting has been adopted, thus reducing the lead time to a minimum and providing maximum flexibility in planning.

The IFSC was the first complex to be considered for detailed design. Each of its four blocks is approximately 11 500m^2 in area. There is a common basement and podium with each building springing independently from the latter. The basement slab is a 400mm deep flat slab spanning between pile caps under the west building and pad foundations under the other buildings; each is separated at podium level by a movement joint.

Thus, apart from the connection at basement level, the buildings are structurally independent. The basement, largely car parking, is designed according to CIRIA *Guide 5* for a utility grade basement with no external membrane; an internal drainage system in the form of *ACO* channels feeds to a petrol interceptor and pumping chamber where the water is pumped to high level into the gravity system. The site investigation indicated that there were sulphates in the ground and class 3 concrete was therefore required, so sulphate-resistant Portland cement is used in all the concrete mixes in contact with the soil.

The podium and ground floor slab is a 500mm thick, solid concrete flat slab designed for HA loading, as it will be subjected to light traffic loading and fire service access. The superstructure floors in each building are 500mm deep waffle slabs and are designed for a superload of 6.5kN/m^2 which includes 2.5kN/m^2 allowance for finishes.

The waffle slab solution was chosen because of its flexibility to cater for spans varying from 7.5m up to 10.5m. This variation of span length was required to fulfil the architect's requirement for 7.5m perimeter bays and the client's needs for large, column-free areas internally. The waffle slab also provides ample 'soft spots' for services, essential in a shell-and-core building of this nature which will be so highly serviced in its final state. In the development of the structural form, structural steelwork was also considered with spans up to 15m bridged by tapered beams and trusses of various forms. When the costs were evaluated, taking account of the very tight overall programme, the outcome favoured reinforced concrete. Despite the use of concrete for the main frame of the buildings, secondary elements are in structural steelwork such as the plantroom walls and roof, glazed areas of the stair towers, and atrium roofs.

Structural stability for each building is provided by the cores which extend from the foundations to above the plantroom roof. These are constructed of 200mm thick reinforced concrete walls ground to roof and 250mm thick reinforced concrete walls basement to ground. The proportion of glass in the walls increases with height.

The basement of the IFSC formed an independent contract from the superstructure and it was constructed by McInerneys (Contracting) Ltd. with concrete supplied by Roadstone Ltd. G & T Crampton Ltd. are acting as management contractors for the superstructure contracts. The sub-contractor for the main frame is Walsh Maguire & O'Shea Ltd. with concrete supplied by Readymix Ltd. and mechanical and electrical sub-contractor is H.A. O'Neills Ltd.

6. The west block of the IFSC.

The second series of buildings to be considered for detailed design is the Harbour Master Place office blocks (spine A, B & C) which are located to the west of the inner dock. They are more conventional, commercial office blocks designed to a high modern specification.

The basement slab and retaining wall of Harbour Master Place are similar in form to the IFSC. The superstructure is a 325mm deep solid flat slab with spans ranging between 6m and 7.5m, with a perimeter downstand beam to support cladding. Structural stability is again provided by the cores. Spine Block B comprises two separate buildings above podium level with a courtyard between; its superstructure consists of a ground floor plus six storeys and a plantroom above.

The basement has a 400mm thick reinforced concrete suspended slab spanning between pad foundations. Formation level is at approximately −1.5m OD with mass concrete blinding from formation to underside of pads. The site investigation indicated that here there was a high level of sulphates in the ground and class 4 concrete was required; sulphate-resisting Portland cement was again used in all the concrete mixes contiguous to the ground.

The basement and superstructure form two separate contracts, the former being constructed by McInerney (Contracting) Ltd. John Sisk & Sons Ltd. have been appointed as management contractor for the superstructure. These two blocks will be completed by the end of 1990.

Harbour Master Place houses both the Telecommunications Centre and the building management system for the entire site. There is a basement under part of the building, designed to the CIRIA *Guide 5* for habitable basements. The walls are of 300mm thick reinforced concrete outer leaf lined on the outer face with 1200 gauge bituthene protected with *Korkpak,* 100mm drained cavity and a 100mm thick block inner leaf.

The superstructure consists of 300mm deep reinforced concrete slabs on ground plus three floors and roof. A steel structure is suspended from the main structure over the inner dock. Transfer beams are provided at ground floor level to allow the building façade to line up with the face of the dock wall.

The site investigation indicated that the loadbearing stratum is some 5.0m below ground level, and a pile foundation similar to the west block of the IFSC was chosen. The ground floor is a 250mm deep suspended slab with 1200 gauge bituthene to protect the structure against groundwater.

Conclusion

At present, there are five major office buildings at varying stages of construction on the site and the whole place is a veritable hive of activity. This is the first time for over 100 years that an opportunity has existed to redevelop an entire city block in Dublin and the challenge and the opportunity are not lost on those involved. All are acutely aware that the confidence of many Irish people depends on the success of this venture. So far, over 100 firms have indicated their willingness to trade from the Custom House Docks area: success, though never assured, is in sight.

References

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Photos: 1: National Library of Ireland
4, 5: Peter Barrow
6, 7: Richard Beer Photography

7.

The Shannon Bridge, Athlone

Michael Conroy
John Higgins

Introduction

Following a commission for geotechnical advice for the embankment design at the River Lagan crossing in Belfast, Ove Arup & Partners Ireland, assisted by Arup Geotechnics, were appointed as advisers for two other projects of embankment construction on weak soils, one at Galway and one at Athlone, for a bypass to cross the River Shannon on a major bridge.

As a result of these appointments, some of Arups' UK bridge work was shown to the County Manager and County Engineer of Westmeath, and a proposal made for the design of the new bridge. The fact that Ove Arup & Partners Ireland was an Irish consultant was an essential factor in the appointment, but they had only designed a couple of small bridges a long time ago; Civil Engineering Bridges had the track record, so we proposed to put the two together with engineers from the Irish practice working with CEB in London to develop the preliminary design. When it came to the detailed design the centre of activity would shift to Dublin, with engineers from CEB providing help and advice.

The proposal was accepted and Ove Arup & Partners Ireland was appointed for the design of the bridge. Our effective client was the County Engineer of Westmeath and we reported to a committee which also included the County Engineer of Roscommon and the Bridge Engineer and highway engineers from the Department of the Environment. Our preliminary design for the bridge was prepared in 1980/81 and construction work on the embankments started in 1981. Because of the very weak soils the embankments have had to be built very slowly and allowed to settle, which has delayed the construction of the bridge. (As a direct result of this project we were appointed in 1984 to design the Liffey Valley Bridge, already open to traffic a year before Athlone.)

The site

Athlone itself, with the existing road bridge, is built on an esker, the only good bit of ground for many miles up or downstream.

The existing bridge is a substantial bottleneck on the Dublin to Galway road, causing traffic delays of up to 45 minutes at peak periods.

The site of the new bridge is 1km upstream of the existing road bridge and rather more downstream from Lough Ree, one of the large lakes which are strung along the Shannon in a wide, flat, rather bleak flood plain.

The river has a well-defined sunken channel with flat and reedy edge slopes. The width thus varies a lot with water level, but is typically in the order of 150m (see Fig. 1).

Navigation clearance is required for the large number of pleasure cruisers which ply the river and is related to the predicted water levels. This is sufficient to ensure that the bridge is not unpleasantly close to the water. Otherwise the nature of the lancscape and the difficulty of raising high embankments require that the bridge should be kept low.

Geotechnical considerations

A geological cross-section of the area indicates deposits of very soft lacustrine clays overlying glacial tills on moderately weathered Carboniferous limestone bedrock (see Fig. 2). The dense glacial tills which directly overlie the rock vary in thickness from 8m to 14m and these deposits are under artesian pressure.

The site investigation established that it would be possible to found either in the glacial tills or the rock, depending on load requirements. For larger foundation loads, such as those to be expected in a bridge with large spans, it would be necessary to use end-bearing piles supported on the bedrock.

Embankment construction

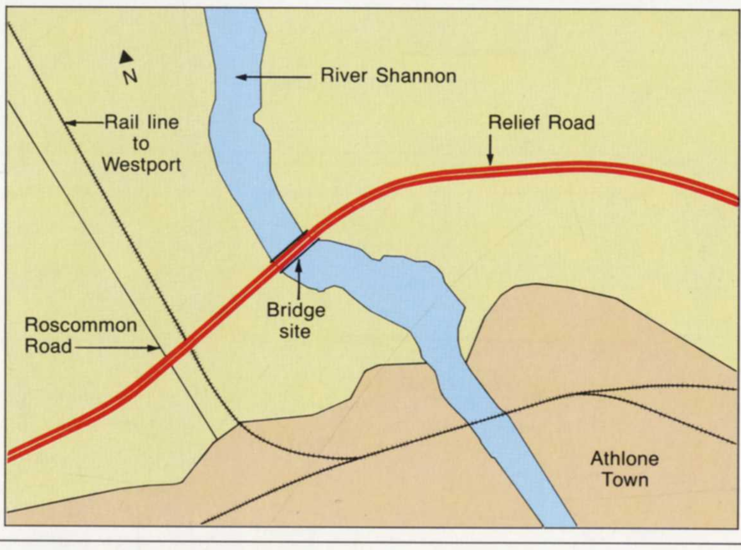
The soft clays on which the approach embankments are built are among the weakest in the world with a shear strength as low as 4kN/m^2. A decision was taken in 1980 to use locally-won, naturally well-graded glacial gravels. Before the final embankments were constructed, two trial embankments were built, one being later loaded to failure in order to verify the theoretical design parameters derived from in situ and laboratory testing. The other was built as the main embankment was intended to be built, using vertical drains and stage construction, in order to study on a larger scale pore pressure effects and predicted rates of settlement. To prevent destabilization of either the embankment or the underlying clays, careful monitoring of pore pressure build-up was carried out by means of an extensive piezometric instrumental array, movements of the embankment and the ground being observed by inclinometers and settlement gauges situated on the river banks. The monitoring was undertaken by staff of Westmeath County Council in consultation with Ove Arup & Partners who set the limiting parameters within which embankment construction could be executed.

Construction of the embankment was completed in 1988. The centre of the main embankment was expected to settle by up to 2.7m due to the weight of embankment material during construction, and this settlement would have to take place before construction of the river bridge could begin. Actual measured settlements have tallied well with predicted values.

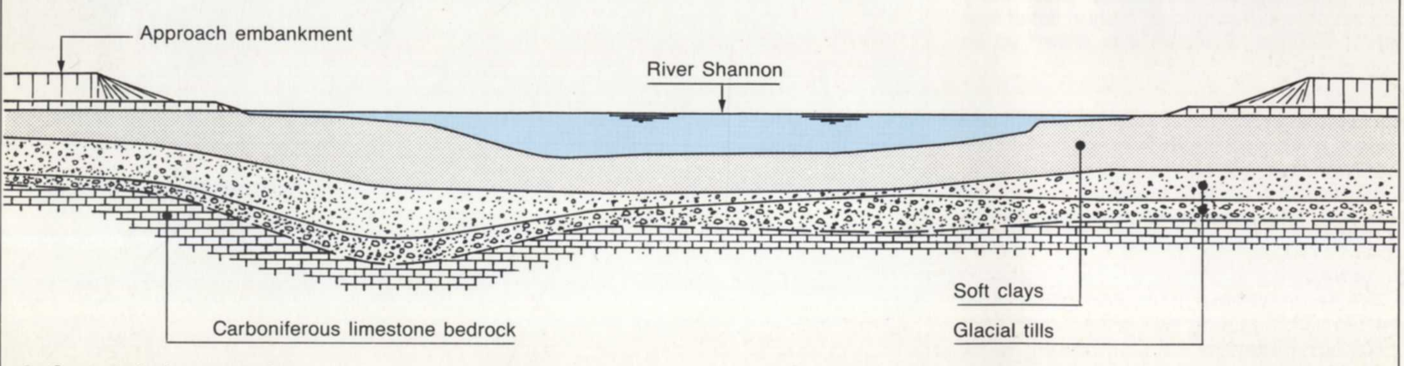
Preliminary design of the bridge

To avoid failure of the river banks the embankments had to be kept well back, which was also desirable for aesthetic reasons. The Office of Public Works, which controls the river, also insisted that the river section should be interfered with as little as possible. This suggested a total bridge length of between 195m and 200m. All options considered were consequently of that length, or greater.

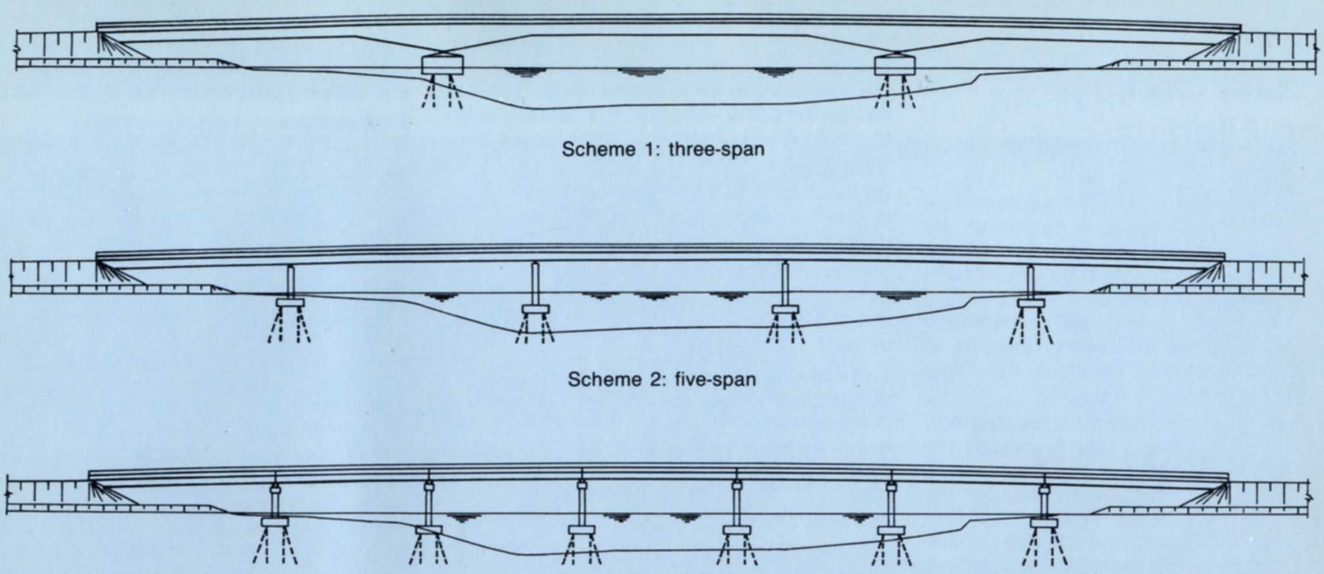
Navigation and road alignment requirements dictated that the navigation channel was to be a minimum of 25m wide, with the shallowest depth of water at any time 1.7m. The lowest allowable deck soffit level over the navigation channel had to be a minimum of 3.81m above the highest recorded river level. The vertical road alignment was also influenced by the minimum headroom required in crossing the major road and rail link alongside the river. Aesthetic considerations suggested that the crown of the vertical curve in the road alignment should be roughly in the middle of the river.



1. Location of the Shannon Bridge.



2. Geotechnical cross section.



3. Comparison of the various considered schemes.

Substructure

In considering structural foundations, three options most likely to be suitable were examined in detail. These were driven steel H-piles, driven steel tubular piles, and precast concrete driven piles. Bored concrete piles and caissons were deemed inappropriate from the earliest stage.

Our initial intention for the piers in the river was to have a pile cap in the riverbed, which is potentially more durable than a pile cap at or near the surface.

However, this would have had to be built inside a cofferdam. We had grave reservations about the difficulties in the riverbed and there were also the problems of how best to deal with the soft clays that the cofferdam would displace, and ensuring stability of the riverbanks during its installation. A perched pile cap was thus inevitable.

For steel piles driven in the river, the design level of the pile cap needed to ensure that the piles were not exposed to the atmosphere when river levels were low, in order to minimize corrosion. Steel piles supporting the abutments would require special anti-corrosion protection over part of their length due to the presence of aggressive groundwater in the surface peat layer.

For the largest span scheme with variable depths, two basic forms of river pier were considered. The first was supported on a submerged pile cap, with due regard to the navigation requirements. Alternatively the pile cap would emerge above water level giving direct support to the superstructure.

Deck

A number of options for deck construction were investigated. Following preliminary checks of viable solutions, a short list of four schemes (Figs. 3 and 4) was drawn up as follows:

Scheme 1:

A three-span crossing consisting of twin box girders of varying depth in prestressed concrete construction, with span lengths of 57m, 85m and 57m (slighty modified in the final scheme). This scheme would be built by the balanced cantilever method.

Scheme 2:

A five-span scheme (31m, 45m, 45m, 45m and 31m) containing two prestressed concrete box girders of constant depth, to be built span-by-span, progressing outwards from one river bank.

Schemes 3 and 4:

Both make use of precast prestressed concrete beams acting compositely with an in situ reinforced concrete deck slab. Scheme 4 comprises 10 spans of 16.8m and a central navigation span of 28m, whilst Scheme 3 has seven equal spans of 28m.

A model of the landscape around the site was made to a scale of 1:500 and models of the various schemes were tried on it, with approach embankments.

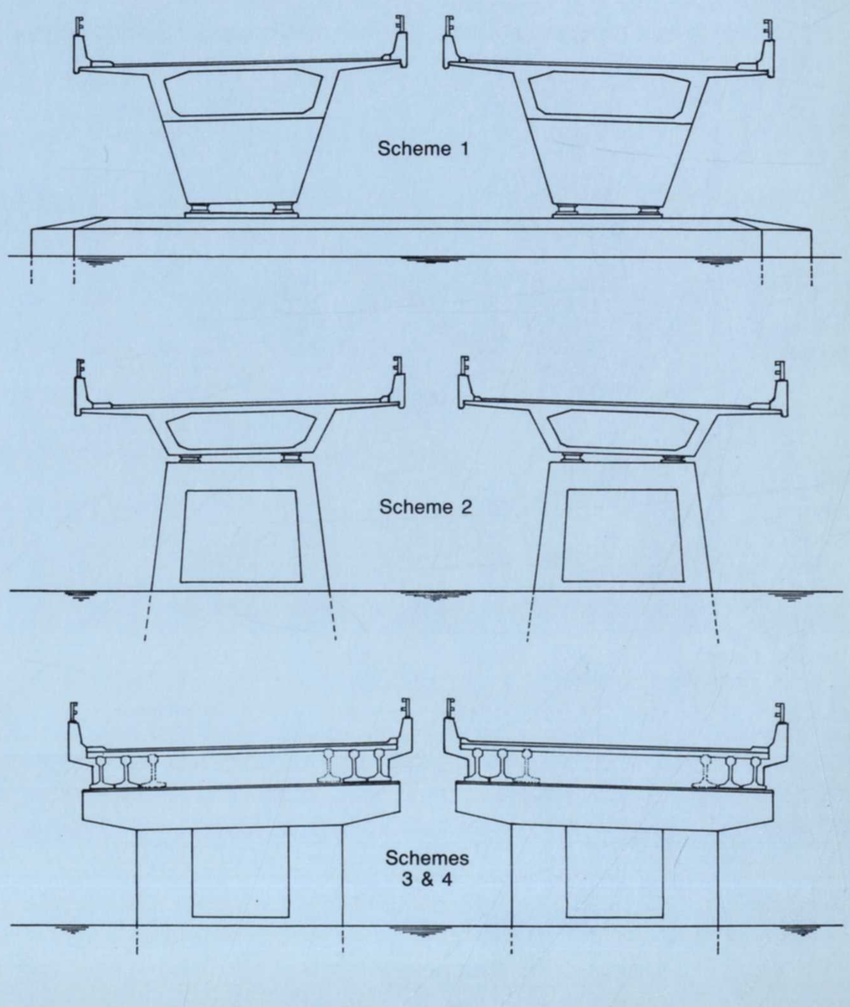
Selection of the final scheme

Cost estimates of the four schemes were carried out, taking into account all aspects of the design and assumed construction process, including temporary works.

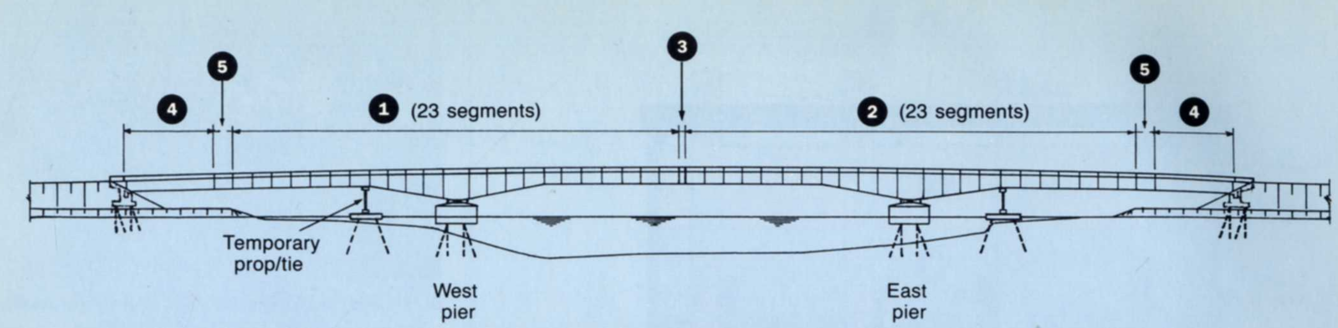
A summary of these costs in relative terms was:

Scheme 1: 1.0; Scheme 2: 1.0;
Scheme 3: 1.17m; Scheme 4: 1.25.

The higher costs of the latter two can be accounted for in part by the fact that the



4. Cross-sections of considered schemes.



5. Sequence of construction of each deck.

method of building the bridge in either case involves considerable amounts of costly construction work in the river, due to the greater number of river piers in these solutions.

It appeared that Schemes 1 and 2 would cost the same within the limits of estimating.

Following detailed consultation with Westmeath County Council and the Department of the Environment, during which aesthetic considerations were discussed and 1:200 models of both schemes studied, the three-span scheme was selected. Variations in the shape of the soffit and slope of the webs were discussed. In the agreed solution, the parallel box girders are supported on a single set of piers and abutments. The carriageway on each box girder consists of two lanes plus a hard shoulder with pedestrian refuges at each side, giving a total width of 12m for the top slab.

The deck, which has a crossfall of 3%, is haunched over a length of 17m on each side of the pile caps with depth varying from 5m to 2.2m. The sloping webs vary in thickness in accordance with the structural requirements. The two reinforced concrete piers are 28m long, 7.5m wide and 4m deep. The chosen foundation solution, at all support points, consists of 356 × 368 × 171 kg/m steel H-piles, driven to the limestone rock. Vertical drains were attached to the piles in order to control porewater pressures in the riverbed soils during driving.

The deck was designed to be constructed by means of balanced cantilevering to positions 41m on each side of the pier, an operation which is in fact a two-stage activity (Fig. 5). During construction of the haunched sections, out-of-balance moments are transferred to the pier pile group by means of torsional action in the pile caps. The deck is stressed down onto temporary piers which carry the loads directly to the pier. The second stage consists of the installation of a temporary prop/tie at the end of the landward haunch to allow completion of the cantilevering process. Once the prop on the landward side is in place the temporary props at the piers are broken out before further cantilever sections are cast.

On completion of two balanced cantilevers for one deck, a central in situ stitch segment is cast, followed by the construction of a closing section to each abutment. The closing sections to the abutments are each 14m long and are cast in a single piece of formwork off the underlying berm of the embankment. Control of line and level is of critical importance throughout, but is especially so in the casting of each of the stitching segments.

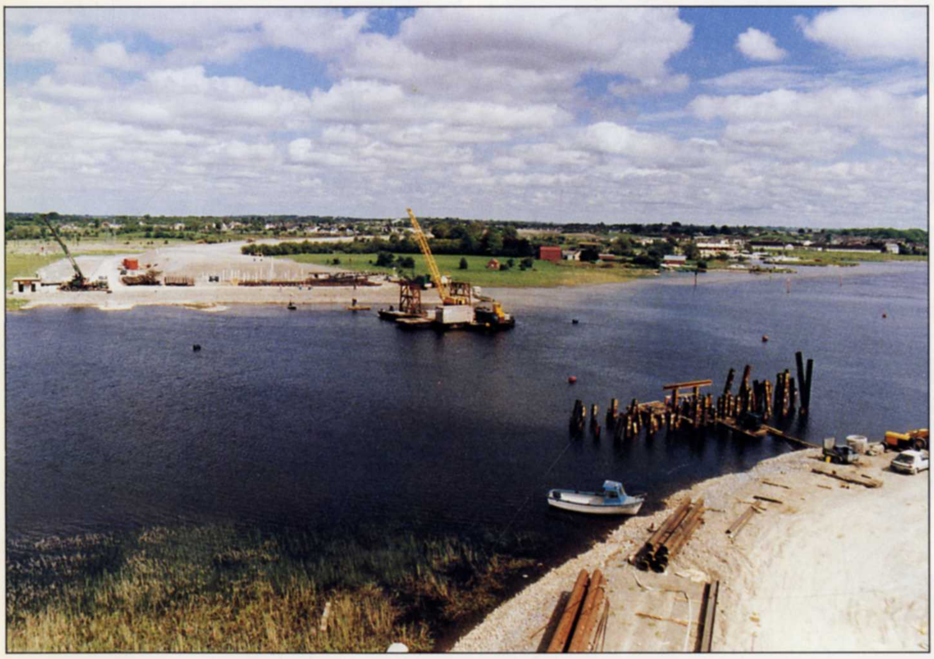
Construction

The bridge went to open tender in mid-1988 and, following interviews with the main contenders, the contract was awarded to the lowest tenderer, Uniform Construction Ltd. Although this firm had built several small bridges in Ireland, none was of the scale or complexity of the Shannon crossing.

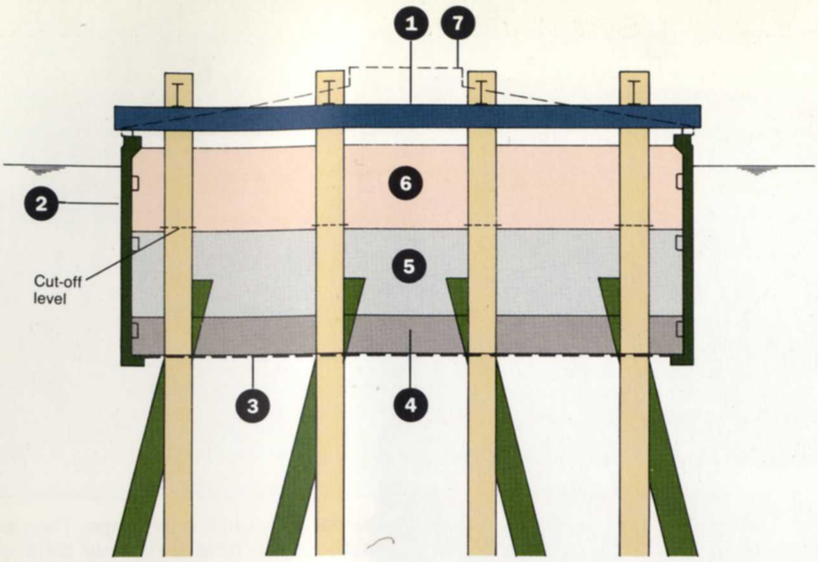
Work started on site in January 1989, commencing with trial piling near the west abutment, followed by piling for the west river pier. Piling in the river was carried out from the horseshoe-shaped well of the contractor's *Uniflote* pontoon, using a specially fabricated driving frame, which allowed pitching of piles including rakers up to 28m in length. Static load tests were required at each of the four principal piling locations, the test piles at the abutments being loaded to 2.5 times design working load, at 450 tonnes. The static load tests on the river pier piles, carried out on a centrally located pile for reasons of practicality and safety, were limited to 1.5 times design working load.

10% of the piles throughout the entire works were tested using CAPWAP (pile driving) analysis, with the CAPWAP results being calibrated against the results of the static load tests. Precast concrete piles up to 14m in length were installed at 3m centres each way on the eastern side to act as bridge approach support piling. Pile caps 1.0m square were cast on these concrete piles and two layers of *Paralink* geomembrane were then laid over the pile caps. The embankment fill could then be placed to the back of the eastern abutment and linking into the previously constructed main approach embankment.

During the piling operations, all piles had vertical drains attached in order to dissipate excess pore pressures generated in the alluvial clays by the pile driving operation. This was necessary to prevent the occurrence of slip failure in the clays.


6. River crossing at start of construction.


7. Pile load test.



A. Fix suspension system (1) to tops of H-piles

B. Install precast concrete lining units (2) and expanded metal formwork (3) on supporting suspended joist grid

C. Place reinforcement; pour layer of *Hydrocrete* concrete (4) (underwater)

D. Dewater; Fix reinforcement, and cast concrete layer (5)

E. Remove suspension system (1), cut H-piles at level shown and concrete layer (6)

F. Cast remainder of pier to required profile (7)

8. Sequence of construction of piers.

9. Installation of bearing plinth, temporary props.

Building the piers

The construction of the piers proved to be one of the most interesting aspects of the project. The use of either a bund or a coffer-dam would be difficult if not impossible. We had assumed at design stage that some form of shutter system could be used, suspended off the tops of permanent piles extending out of the water.

The contractor proposed forming a de-watered concrete 'boat' within which the main body of the pier could be built. The pier had to be redesigned using permanent precast concrete formwork, and so we found ourselves working with Uniform in order to achieve a solution which would best fit our joint requirements. The use of expanded metal and *Hydrocrete* concrete, spread and levelled by divers in stages to ensure no uplift on the piles and to form the bottom shutter proved a good technique and allowed for construction of the reinforcing cages and placing of the main structural concrete in completely dry conditions.

Deck construction

Once the piers were completed, balanced cantilevering could commence. The contractor achieved his required seven-day cycle for a pair of corresponding segments almost immediately, and this, coupled with the fact that a second set of gantries was procured, has meant that completion of the contract will now be three months ahead of the original programme. The Relief Road and bridge are due to open in June 1991.

Postscript

The Athlone bridge and the Liffey Valley bridge are the largest span bridges in the Republic of Ireland and the experience gained by Ove Arup & Partners Ireland in the design and construction supervision of these two very different cantilever bridges has put it in the position of being the leading bridge consultant in Ireland.

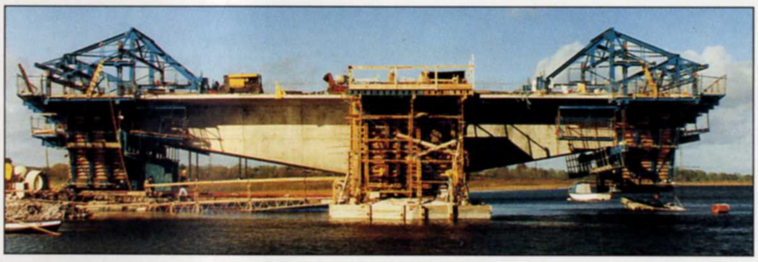
Credits:

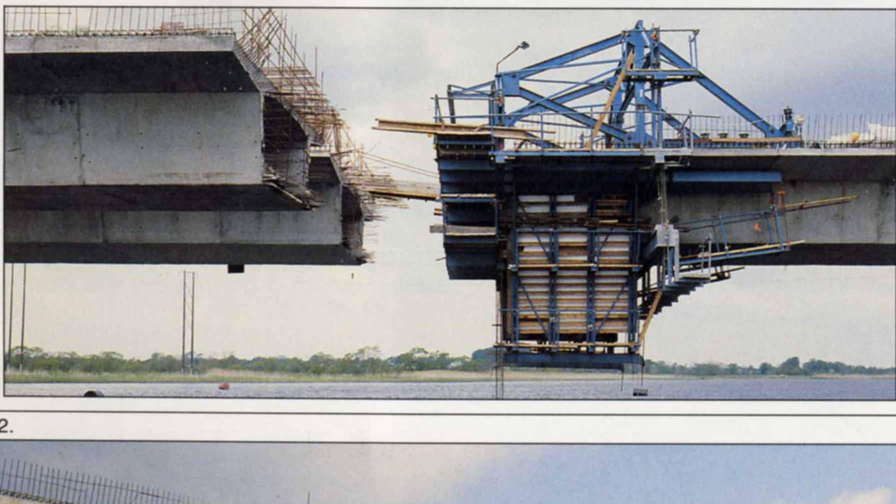
Client:
Westmeath County Council

Designer and engineer:
Ove Arup & Partners Ireland & Civil Engineering Bridges & Civil Engineering Geotechnics

Photos:
9: Michael Scally
10-12: John Kellett

10. & 11. Cantilevering in progress.





12.

University College Dublin, Engineering School

Architect: Scott Tallon Walker

Ian Roberts

Introduction

University College Dublin is one of the three constituent Colleges in the National University of Ireland, founded in 1908. Currently the University is being consolidated on the Belfield Campus in Stillorgan to vacate scattered premises in central Dublin. The move of the Engineering School, first contemplated in 1974, is now in progress with the completion of Phase I for chemical, electrical, electronic and mechanical engineering. The Engineering building follows other Arup buildings on the campus; Science (D60), Library (D498), Restaurant (D185) and the Industry Centre (D637).

Site investigation

Site investigations in 1980 and 1981 revealed topsoil on brown boulder clay above stiff black boulder clay about 3m below ground level. The latter is an excellent founding medium with a capacity of at least 400kN/m^2, ideal for the four storeys over part-basement building proposed.

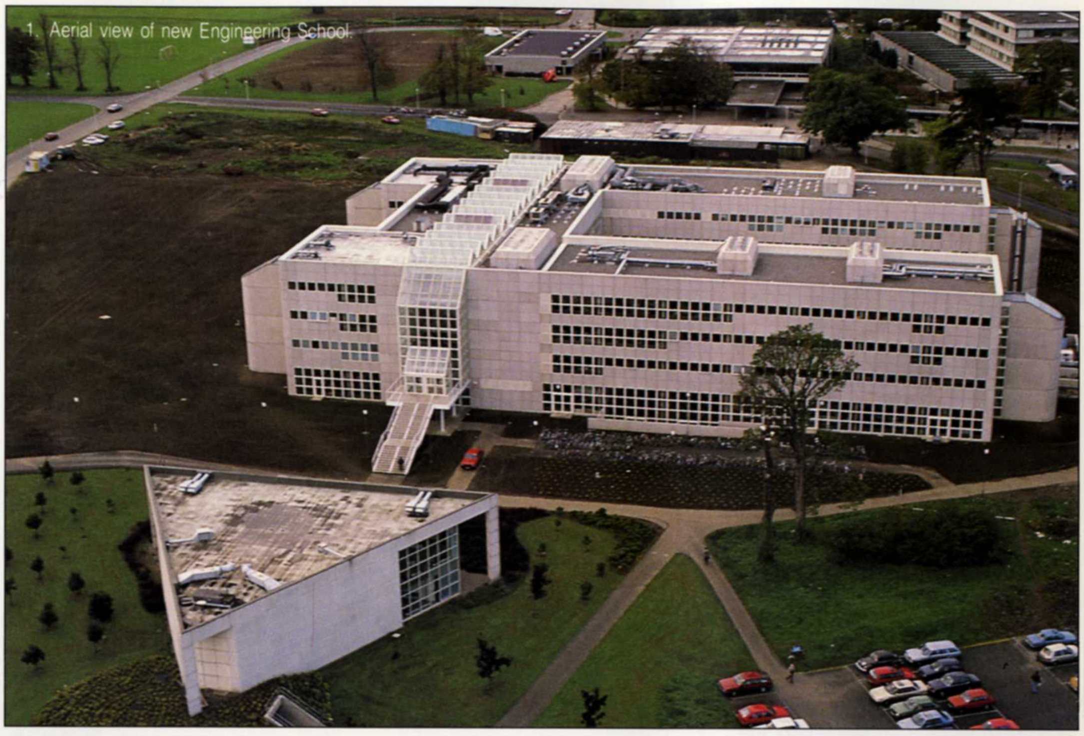
Planning

The form of the building is a U comprising two four-storey laboratory wings with a connecting circulation spine and enclosing a single storey workshop. The general public level is at first floor for lecture rooms, laboratories and offices, with the ground floor containing heavier laboratories and plant areas. A basement is confined to part of the chemical wing and walk-in duct; at roof level there are tank rooms and fume extract housings.

The planning module is 1.2m square with a basic grid of 7.2m × 7.2m. The structural grid is offset by 600mm to resolve details such as shear heads and infill beams. The grid system thus provides 15.6m wings, a 19.8m main workshop and a 3.6m accessway.

Main structure

In view of the presence of groundwater, all substructures were designed to CIRIA *Guide 5* and BS *CP102* with joints provided with water bars and bay sizes controlled. Other substructures are simple pad and strip footings under columns and service ducts. Slabs are all ground-bearing.



1. Aerial view of new Engineering School.

The 7.2m module for the superstructure was chosen after consideration of a large number of structural alternatives and was based largely on its cost-effectiveness. To provide a high quality appearance without false ceilings, a 1.2m coffer slab of 490mm overall depth with 95mm screed was selected, with shear heads and beam strips provided by infilling coffers. The bottom of the rib is notched to form a feature groove and disguise joints. GRP moulds were used as formwork set on table forms to give a high quality fairfaced surface with rapid turnround.

Expansion joints were provided at the junction of the wings with the spine by means of a halved joint with ptfe bearing strips and a permanent steel shutter (Fig. 2).

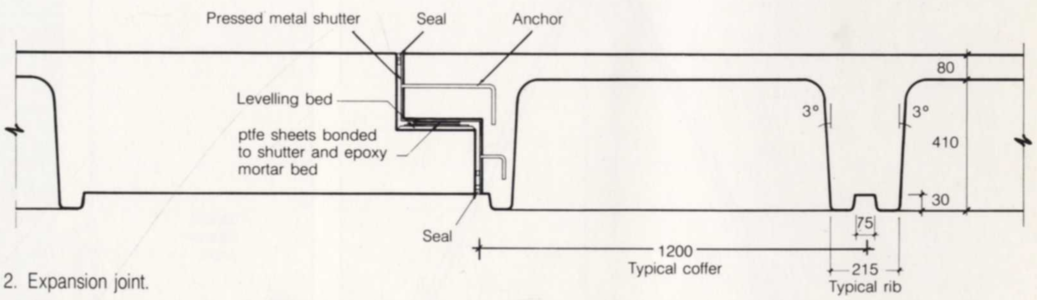
Stability is provided by shear walls, stair cores and service ducts. Exposed concrete walls and columns are finished with a boardmarked surface.

The main access to the building is via a flight of steps to first floor through a fully welded structural hollow section framed porch rising the full height of the building.

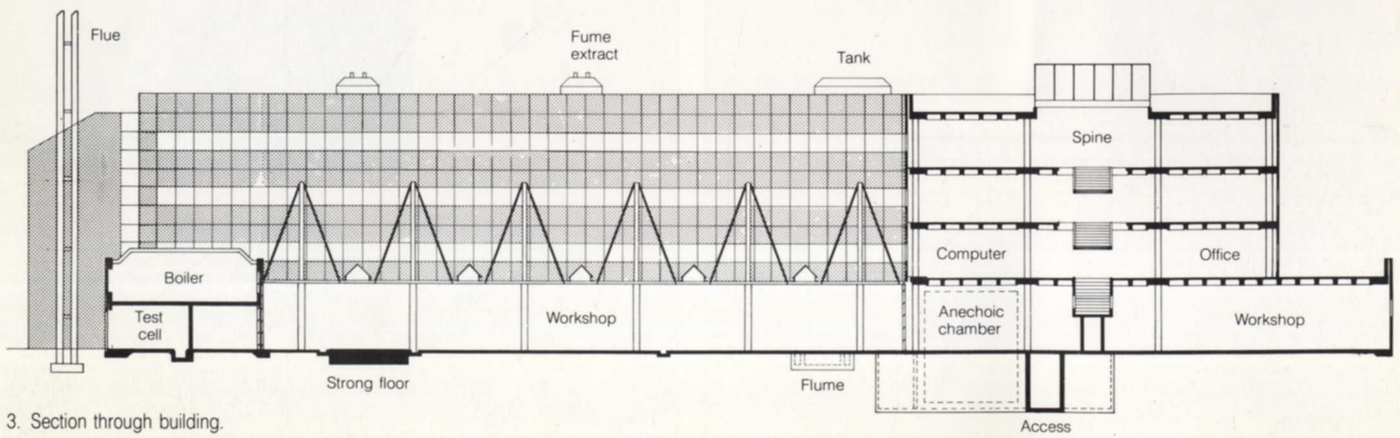
Immediately inside the entrance is a free-standing lift with a welded steel frame and perforated metal cladding.

Stairs are welded steel infilled with concrete and all lightwells are lined with permanent steel framework.

All steel is, where possible, of Irish manufacture to Continental sizes and is fully welded except at articulated junctions such as cross-bracing.



2. Expansion joint.



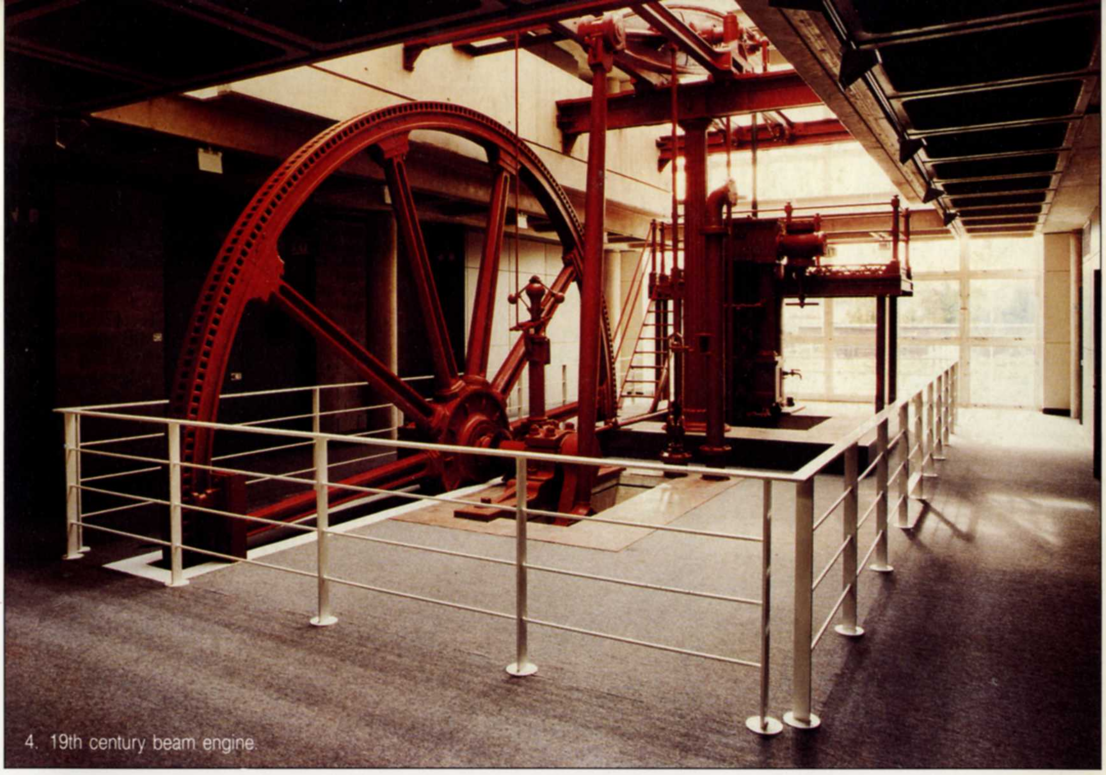
3. Section through building.

At the opposite end of the spine the showpiece is the only Irish-made beam engine in existence. It was built in the mid-19th century for use in a distillery and has been restored by the Electricity Supply Board apprentices and installed in specially constructed mounts in the building. It is electrically operated to turn over at 3 rpm.

GRC cladding

A requirement of the brief was that the exterior of the building be a light grey concrete colour. It was also desirable to minimize the loss of usable floor area, reduce weight and make simple fixings. The architect proposed GRC stud frame, used successfully by him on a project in Belfast.

The panels comprise 10mm fine aggregate concrete, bonded to 8mm of grc fixed to galvanized pressed metal studding. The studding is coated with 250 microns of bituminous paint, insulation is packed between and the inside face is sheeted. A total of 639 panels were manufactured comprising 93 different types. Maximum unit size was confined to 3.6m × 2.4m to limit thermal movements.



4. 19th century beam engine.

To allow for thermal expansion of the grc the panel face is fixed to the studs by 'flex anchors' comprising thin rods which allow lateral and vertical movement. Adjustment of the panel position for line and level is by packs under the support angle and a screw adjustment at the bottom fixing. The close centres of the support system to avoid exposure above or below the slab resulted in a requirement for extra stiffness in the stud frame to prevent unacceptable deflections at the windows.

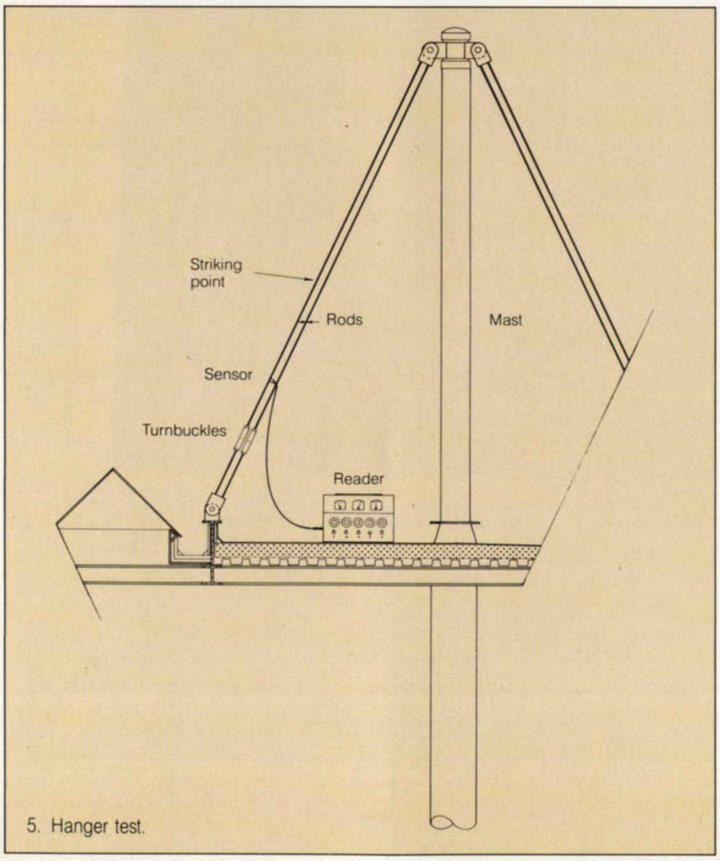
On site, the panels were lined and levelled loosely and then fixed by welding the bolt washer to the support angle. The joints were double mastic-sealed and the exposed aggregate face painted with silicone to reduce the effects of air pollution.

Workshop roof

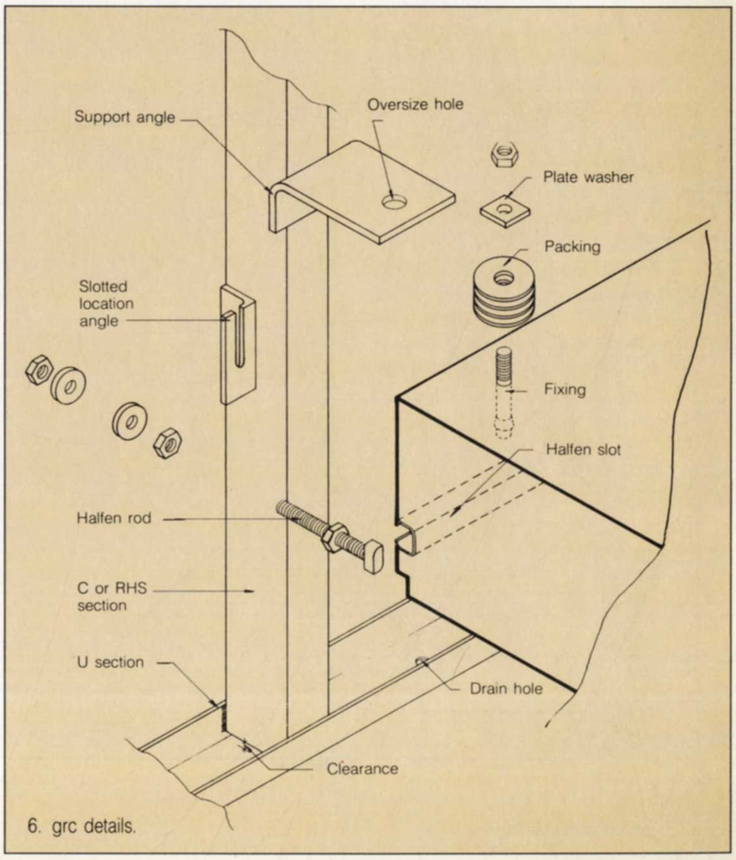
The workshop roof comprises six grillages of 203 × 203 × 46kg universal columns forming plates 21.9m × 5.1m and supported centrally on CHS columns set in pocket bases. Each column is 457mm diameter below roof level and 324mm diameter above, with a fabricated taper connector section. Each grillage is stiffened at the perimeter by T-sections to which are welded support points for six twin hangers taken to the top of the columns. The lower part of each column is filled with super-plasticized concrete to increase stiffness. The roof surface is Plannja perforated acoustic metal deck with membrane, insulation and chippings.

The critical design mode of the roof is that of asymmetrical live loading, both at each side where propping was necessary to avoid excessive deflections, and longitudinally where stiffening was necessary across the continuous rooflights between plates to avoid distortion and distress to the glazing. Perimeter fixings were designed to allow horizontal movement in two directions to leave the roof independent of the main structure. All elements of the roof except hanger connections were full profile fillet or butt-welded to give a continuous profile grillage on the underside.

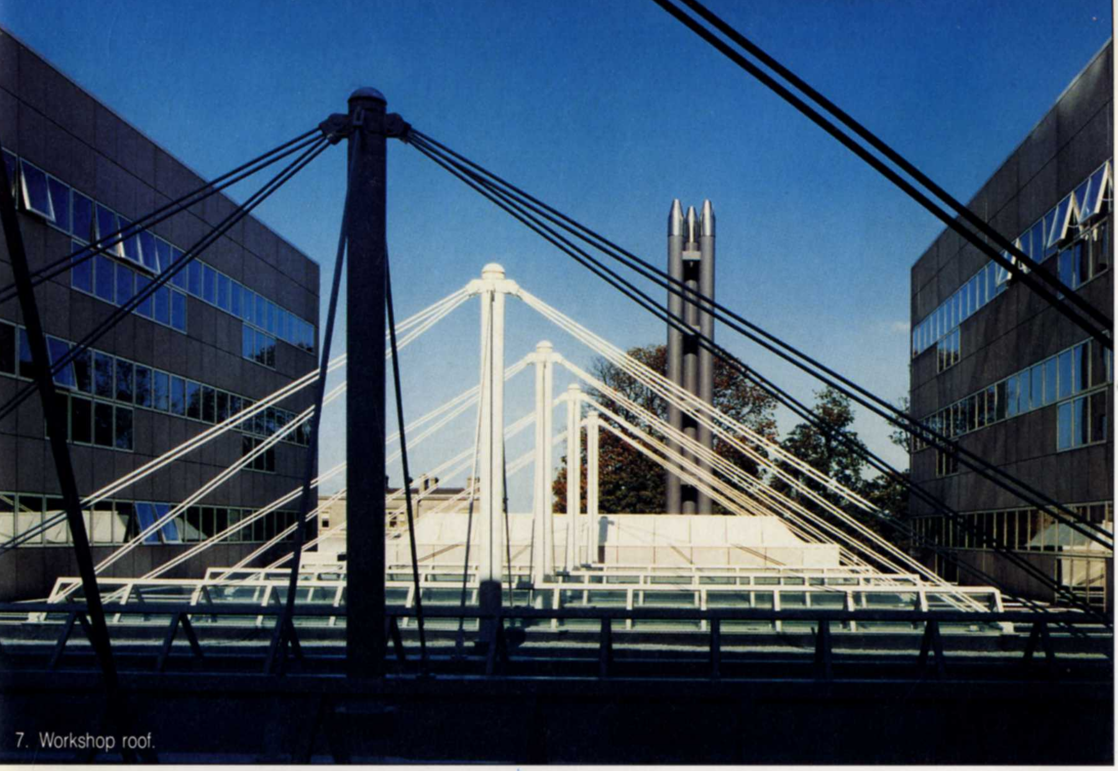
The hanger bars were detailed as pairs of 30mm diameter galvanized mild steel, threaded and lock-welded into forks pinned to the connections at each end. Adjustment is by a turnbuckle on each bar. To ensure equal tension in each hanger and thereby reduce risk of overload, each bar was tested by the tuning fork principal of measuring the frequency of vibration under a blow to the centre of the bar. Matching under dead load conditions ensures reasonably even loading in the live load condition.



5. Hanger test.



6. grc details.



7. Workshop roof.

and emphasize the technical nature of the building. This aspect included some 60 different special precast concrete panels with a hole for each pipe. In the workshop areas a considerable amount of equipment was installed, including that removed from the city centre building. This required a variety of special bases and a complex duct system, particularly for the hydraulic flume, anti-vibration bases and a Westinghouse boiler. A strong floor has also been installed with 30 load points in it, each designed for 100 tonne preload and working loads of 50 tonnes vertically and 35 tonnes horizontally.

Contract

To suit availability of funds the substructures were built in 1986 under a separate contract worth £0.5M. The superstructure contract, worth £11M, was started in March 1987 and completed in June 1989. Total cost was £19.5M, part-funded by a grant of £6M from the structural funds of the European Community. The building was opened to students in September 1989 for the 1989/90 academic year. It has been awarded the 1990 Irish Concrete Society Prize.

8. Workshop in use.

Completion

All internal blockwork is fairfaced and detailed into the ribs by means of inverted T-shaped precast concrete units. In the workshop, restraint at the relatively flexible roof was not viable so reinforced blockwork was used. This technique was also employed in the experimental room in the chemistry wing, both because of the double-storey height and to reduce the effect of small explosions.

The workshops and main laboratories are heavily serviced and include locally air-conditioned areas, clean rooms and two boilers with 22m high flues. The arrangement of services was closely co-ordinated with the architecture to control the discipline

Credits

Client:
University College Dublin with the Department of Education

Architect:
Scott Tallon Walker

Civil and structural engineers:
Ove Arup & Partners Ireland

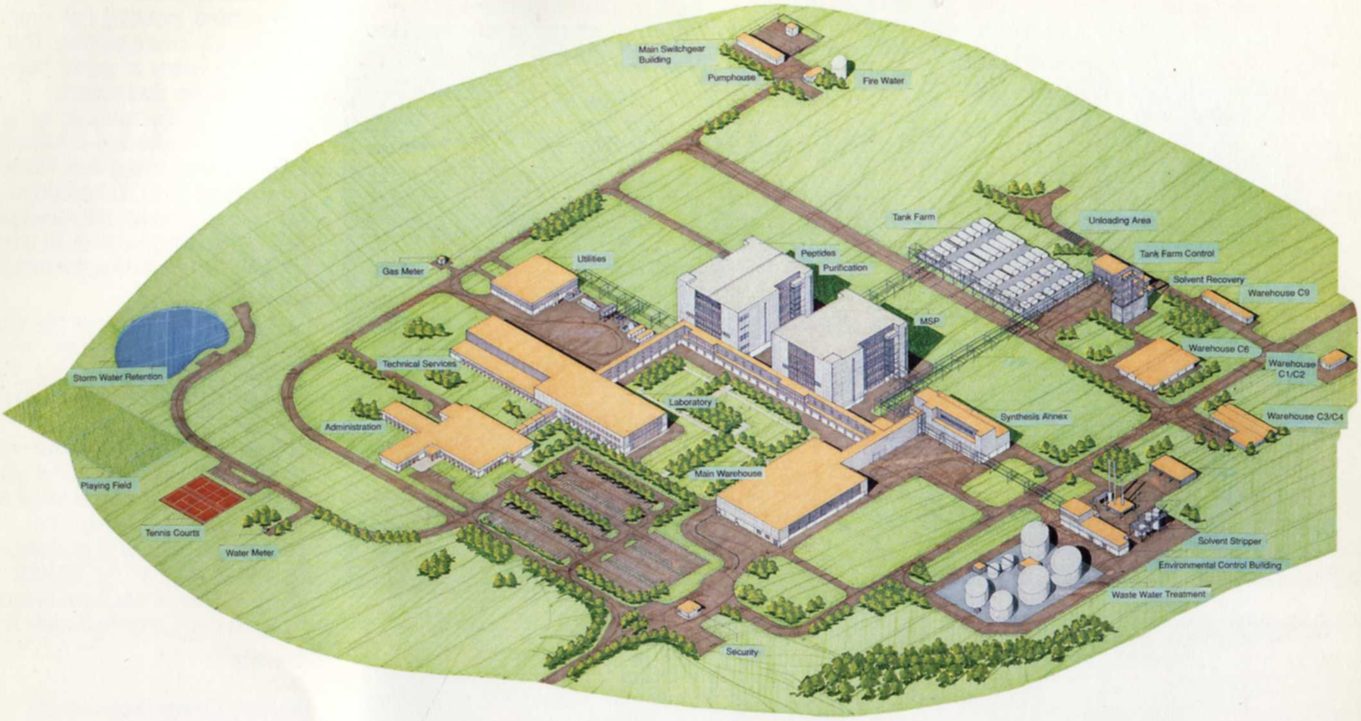
Services consultants:
Varming Mulcahy Reilly Associates

Photos:
1: UCD
4, 7, 9: John Donat
8: John Kellett

9. UCD Engineering School: entrance area.

Sandoz pharmaceutical plant, Cork

Peter Langford Jerry Mehigan



Sandoz, the Swiss chemical company, is currently in the process of establishing a £170M pharmaceutical manufacturing facility in the Ringaskiddy industrial zone near Cork. It is planned to produce the active ingredients for a number of drugs, including Sandimmun which has been responsible for a dramatic increase in the survival rate of patients recovering from organ transplant operations.

Having considered a number of locations in various parts of Ireland, Sandoz interviewed a number of consultants in March 1989 and appointed Ove Arup & Partners to carry out site inspections and a desk study on three sites in the Ringaskiddy area. The parameters to be considered were:

- Ground conditions
- Infrastructure
- Topography and plant layout flexibility
- Visual impact of the development.

A 40ha site was selected subject to confirmation of the assumed ground conditions. This was achieved by means of a preliminary site investigation.

Ove Arup & Partners and the Stearns Catalytic Division of United Engineers and Constructors (UE&C) of Philadelphia were commissioned to prepare the drawings and documents required for the planning and licence applications. UE&C had already been working on the process design for some time.

In preparing the planning drawings, particular care was required in organizing the layout of buildings and facilities on the site. The layout was based on the twin aims of maximizing safety and efficiency on the one hand while designing and siting the plant in a manner which would also minimize the visual impact. To achieve this it was decided that:

- A buffer area, free from development, should be established on the western side of the site to reduce the impact on the immediate neighbours
- The process buildings and the waste-handling facilities should be located on the eastern half of the site, away from any residential development
- The remaining buildings should be located between the buffer area and the process buildings
- The process buildings, being the tallest structures, should be located to the rear of the site, fronted by some of the lower buildings.

Using these principles the most suitable site layout was developed and incorporated in the planning drawings. A comprehensive set of drawings and documents was prepared and submitted with the application for planning permission, effluent discharge licence and atmosphere emission licence in October 1989. A full Environmental Impact Statement, complying with *EC Directive 85/337,* was submitted as part of the planning application. This was prepared by Eolas, an Irish State agency, with assistance from UE&C, Ove Arup & Partners and others.

A feature of the project has been the extensive consultation process required. This was developed to inform all interested parties of the relevant details of the project. At an early stage Sandoz committed themselves to an open door policy in dealing with the public and the appropriate authorities. This led to numerous meetings between personnel from Sandoz, the Industrial Development Authority (IDA), Ove Arup & Partners and concerned groups and individuals.

Interested parties included:

- Politicians
- Community and Residents Associations
- Environmental Groups
- Journalists
- Commercial and Trade Union Groups

Most of the worry and concern resulted from problems which had previously been encountered with a small number of chemical companies in Ireland.

Despite the consultative process, a significant number of objections was lodged with the planning authority prior to the decision to grant permission in mid-December 1989. Cork County Council's decision was the subject of 19 appeals to the Planning Appeals Board. This led to a public oral hearing in March of this year which lasted for three weeks and received considerable publicity in the local and national media. The Planning Appeals Board gave its decision in favour of the project in July, thus allowing Sandoz to commence construction.

While the process design is being carried out by UE&C in Philadelphia, the civil and building design is being undertaken on a cooperative basis by UE&C and Ove Arup & Partners. Construction management is being carried out by Ove Arup & Partners initially and the Arup team will become part of a process-led construction management team as soon as the first mechanical contractor arrives on site.

To help with the time schedule an advance site development contract was let by the IDA in September 1989. This was the subject of a separate planning permission which was granted without an appeal. The £1.2m contract was carried out by the IDA on a risk basis, with Sandoz sharing the risk.

Credits

Client:
Sandoz Ringaskiddy Ltd.

Kilrush Creek Marina

Tim Corcoran
Bob Ames

Introduction
Kilrush is a town with a population of about 3000 and is situated at the head of a tidal creek on the northern bank of the River Shannon on the west coast of Ireland.

Kilrush serves mainly as a shopping centre for the rural and remote countryside of south west County Clare. In the late 19th century and early part of this century it was a flourishing trading centre with a busy harbour and train service which was part of the West Clare railway, made famous by Percy French*. The railway was closed in the 1950s and there has been no commercial and not much pleasure boat activity in the harbour for many years.

Shannon Development Company is a public sector company which has responsibility for all industrial and, since January 1988, tourism development in the mid-west region of Ireland. In March 1988, the company proposed an integrated development in Kilrush and its harbour (Fig. 3). This included the construction of a water-retaining embankment across the mouth of the creek which would impound 20ha of water and create an amenity area for sailing and other water sports, and provide a sheltered location for a marina. Access for boats, in the form of a flap gate or lock gates, would be provided through the embankment. Other essential elements of the proposed development were a marine enterprise centre and marina-related property developments, principally for tourists, the intention being to encourage the town's economy.

The site
Kilrush Creek forms the seaward extension of a valley containing a small river that flows through Kilrush Town. To the north and south of the creek, the ground rises to an elevation of +20m and +30m above chart datum (approximately Lowest Astronomical Tide). The bed of the creek is generally flat or very gently sloping towards its centre. At low tide it is extensively exposed, with gravel flats around the periphery and mud-flats towards the middle. A channel runs diagonally through the creek as a continuation of the small river whose flow it carries at low tide. It has a bed level that slopes very gently from +2.0m at the head of the creek to about +0.5m chart datum at its distal end.

* Percy French (1854-1920) was a travelling drainage engineer in the employ of Cavan County Council at the turn of the century, famous now as a water colourist and also for penning such songs as 'The Mountains of Mourne' and 'Are you right, there, Michael, are you right?', about the West Clare railway.

1.
Kilrush Harbour as it was in the 19th century. (Photo: The Lawrence Collection)

2.
The town of Kilrush and marina site from the air. (Photo: Shannon Photographic Services)

Engineering feasibility study

In May 1988, a feasibility study commenced with an initial examination of the bed levels in the creek, the tide level variations and the associated restrictions on access by boats to the creek. A desk study of ground conditions followed shortly afterwards and site investigation fieldwork commenced in June 1988. The site investigation was undertaken to:

- Assess the bearing capacity and permeability of the soil and rock material under the proposed retaining embankment and access structure
- Obtain information on bed material to be dredged within the impounded area and along the approaches to the embankment.

In addition, two schemes providing access for boats through the embankment were developed. The first, consisting of a lock structure containing two pairs of sector gates, permitted access through the embankment at all states of the tide, and the second, providing a flap gate installed in a cill structure, permitted unrestricted access during neap tides but obstructed access for four hours in a tidal cycle of approximately 12 hours at low water on spring tides. Scheme 1 was adopted despite the lock structure being more expensive as sector gates allowed a higher impounded water level, thus reducing the amount of dredging within the creek. It also provided continuous access for boats, was quick and simple to operate, gave a control point for boats entering and leaving the marina, and provided a measure of flood protection to the creek. The feasibility study was completed in November 1988.

Site investigation

A comprehensive site investigation was undertaken from February to May 1989 to provide additional information to enable the selected lock gate scheme to be designed.

A total of 36 shell and auger boreholes were drilled within and around the creek (Fig. 4). Marine boreholes were sunk along the line of the embankment, under the lock structure, in the approach channel to the latter and inside the creek in areas of proposed dredging. The land-based boreholes were located along the shoreline of the creek to establish the valley profile from the creek head as far as the proposed embankment line and Skagh Point.

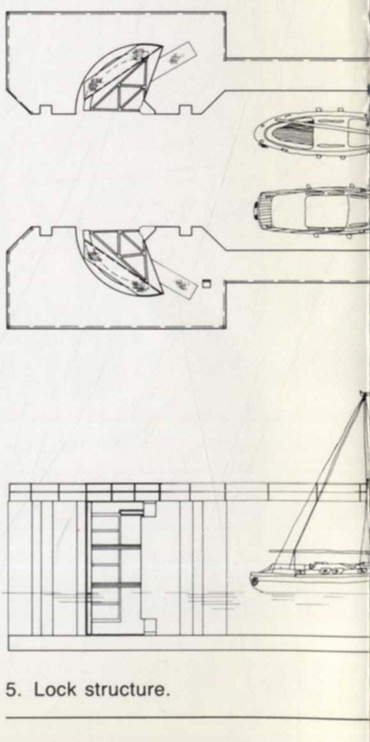
In order to confirm the permeability of the gravel stratum underlying the proposed embankment line, two wells were installed for field pumping tests. As pumping tests over water were not practical, the wells were located on the southern and northern shores on the line of the proposed embankment.

4. Kilrush Greek: feasibility study boreholes (showing water at MHWS).

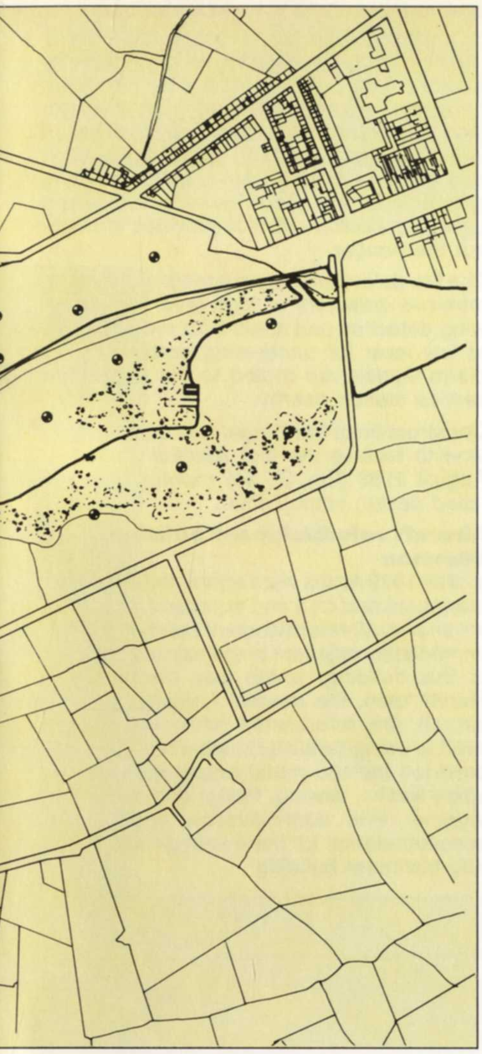
Water-retaining embankment

A wide range of materials and construction techniques was considered for the water-retaining embankment. Dredged material the bed of the creek, glacial material exposed around its banks, bedrock shales south of the creek and locally available crushed rock fill were all investigated. Techniques considered which would render the embankment impermeable included slurry trenching, grouting and installation of an impermeable membrane. Clay, suitable for an impermeable core, is not available locally. A scheme was selected which maximized the use of locally available material,

3. Model of development.
(Photo: Miguel Photolab)

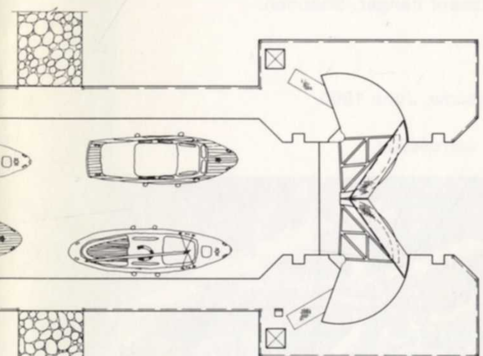


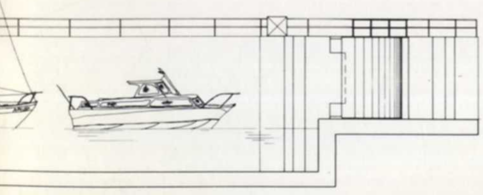
5. Lock structure.



provided a technically satisfactory solution, and also minimized cost. It consists of a crushed stone core protected by rock armour on its seaward face, an impermeable membrane, and glacial fill material, excavated from the amenity area, to protect the lining and maintain the overall stability of the embankment.

The impermeable membrane is sandwiched between two layers of filter fabric to improve its puncture resistance, and is returned on the bed of the creek below the core material to lengthen the seepage path at bed level, thus reducing water loss. It appears from discussions with membrane manufacturers that this is a unique application for their product.





Lock gates and structure

The lock structure controls boat access through the embankment and the flow of water into and out of the impounded water area (Fig. 5).

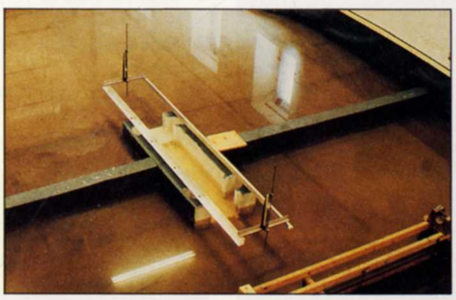
The gates provide a clear width of 9m and are hydraulically operated, with power packs on each side of the lock structure. The lock barrel is 11m wide and 23.3m long giving a locking capacity of four 10m yachts in any one operation. Stop logs are provided to allow in situ maintenance of the lock gates. A lock control building houses electrical boards, a standby power unit and the facilities for the lock operator while on duty.

The lock structure is being constructed within an open excavation in the mouth of the creek, protected by temporary water-retaining bunds. These bunds also enable the creek to be dewatered, allowing what might otherwise have been expensive tidal dredging work to be carried out by land-based excavation and haulage plant. The lock structure consists of reinforced concrete walls and base and is a gravity structure.

As it is intended to allow the tidal flow of water through the lock structure at high stages of the tide, an assessment of flow velocities was made by computer. A 1:30 scale model of the lock was tested in University College, Cork, to check the calculations and to observe the behaviour of the water in the lock structure (Fig. 6). As a result of the model tests, modifications were carried out on the lock gates to reduce turbulence which could cause difficulties in navigation.

Water quality

Once the marina is in operation, both sets of lock gates will be opened for a period of two to three hours in each tidal cycle on each high tide to allow tidal exchange of the impounded water. The embankment will restrict the exchange of water to a maximum of 30% of the impounded volume. To study the effects of the impoundment, an investigation was undertaken into the amount of pollution contained in the incoming tide and the amount carried in the small river flowing through Kilrush and into the creek.



This looked at:

- The physiochemical state of the water
- The nutrient content
- Microbiological pollution.

A report was prepared assessing the effects of impoundment and compliance with bathing water quality standards. The conclusions anticipate that, with appropriate water catchment and marina basin management, the water quality will be satisfactory.

Project implementation

Ascon Ltd., the successful tenderer, commenced construction in mid-January 1990. The contractor sealed off the mouth of the creek by constructing a bund across its full width in March 1990 (Fig. 7), consisting partly of the rockfill element of the permanent embankment, the remaining section being a temporary embankment in the area of the lock structure. An impermeable membrane was placed on the óuter face of the bund to prevent tidal water ingress into the dewatered creek.

Excavation for the lock structure foundation commenced following construction of the bund and was completed by mid-May 1990 when construction of the foundations commenced.

Lock gate manufacture, by NEI Thompson Ltd. Sir William Arrol, started in May 1990 and installation, taking two months, began in October 1990. It is intended initially to install pontoons for 100 yacht berths and these will be in position for the 1991 sailing and tourist season. Construction of onshore facilities including a marina centre, housing and a boatyard are due to commence later in 1990 but these land-based facilities are not within the Arup brief.

The promotion, operation and further development of the overall project is now being undertaken by Shannon Maritime Developments Ltd., a subsidiary of Shannon Development, which was established specifically to undertake the first project of this type in Ireland. It is hoped that the construction of the Kilrush Creek Marina will stimulate the growth of similar facilities along the south west and west coats of Ireland. Marinas and associated developments at regular intervals along the coast would open up relatively unexplored waters with unspoilt scenery to overseas yachtsmen and tourists.

Credits

Client:
Shannon Development Company
Project planning and design:
Ove Arup & Partners Ireland/Civil Engineering Maritime Group, London.

6. Model test, University College, Cork. (Photo: The College)
7. Bund construction, March 1990. (Photo: Senan Rush)

Hangars for Aeroflot

Tim Corcoran
Peter Samain

Introduction

Aeroflot, the Soviet airline, has been using Shannon Airport as a refuelling stop on the Moscow-Havana route for over 10 years. Soviet aviation fuel is imported by ship and discharged at a dedicated oil terminal adjacent to the airport. The airline, considered to be the largest in the world, is now Shannon's second most important user and several flights daily in each direction pick up and set down passengers.

Economic feasibility study

In late 1987 Arups, in association with construction managers Tierney and Associates, were commissioned by Aer Rianta, the Irish Airports Authority, to undertake an economic feasibility study on the stripping and painting of aircraft at Shannon. At that time, Aer Rianta were negotiating a contract with Aeroflot to carry out this work on Soviet aircraft at Shannon in a dedicated painting hangar. It was thought that there might be spare capacity in the hangar. Although the study confirmed that a potential and profitable market existed, the market has not been exploited due to the size of the contract subsequently negotiated with Aeroflot.

Painting hangar, Shannon

In April 1988, Tierney and Associates were awarded a contract for the design and construction of a painting hangar at Shannon. The brief required that the hangar was to be large enough to accommodate all aircraft flying for Aeroflot at that time, including Ilyushin IL62 and IL86 and Tupolev TU154 passenger aircraft and the IL76 cargo aircraft. To comply with the brief, the building has a clear span of 52m and is 67m long. The clear heights to truss soffit are 14m and 17.5m in the fuselage and tail sections of the hangar respectively.

Arups were appointed by Tierney and Associates to provide the complete engineering design for the project. Detailed design commenced in April 1988 and site clearance began immediately. A site investigation, undertaken previously, indicated that the overburden consisted of 6-8m of soft silt on limestone rock. A total of 400 augered piles, rock socketed into the limestone, were installed to support the reinforced concrete hangar floor and the steel superstructure (Figs. 1 & 2), which consists of universal beam columns and lattice trusses at 6.6m centres. An insulated sandwich panel cladding system was used on the sidewalls and roof. Six mechanically-operated door leaves provide a 52m wide × 17.5m high clear opening into the hangar.

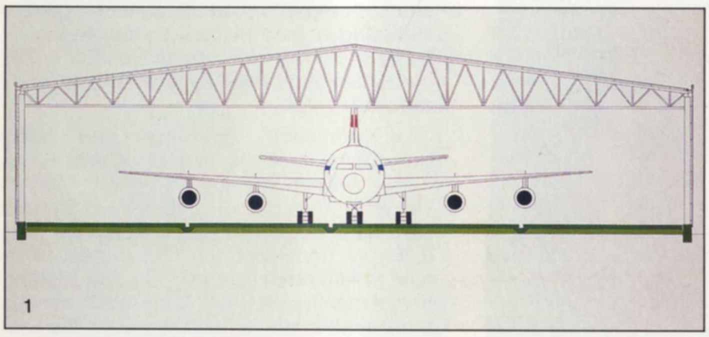
A high temperature, high velocity (HTHV) heating system was installed. Air is extracted through two underfloor ducts which are sized to accommodate air exhaust rates associated with the installation of high capacity (approximately 5-6 air changes per hour) heating and extraction equipment at a later date. High pressure sodium and metal halide luminaires provide both good illumination and colour rendering suitable for painting aircraft. Compressed air, water services and power distribution are also provided throughout the hangar.

The fire detection system consists of rotating infra-red detectors at high level for above-wing detection and static infra red detectors at low level for under-wing detection. Fire alarm signals are routed to the airport fire service station nearby.

Construction of the hangar was completed in time to receive the first Aeroflot aircraft in August 1988 (Fig. 3), 4½ months after detailed design commenced.

Aircraft refurbishment building, Shannon

In May 1989 Arups were appointed as project managers and civil and structural engineers for an aircraft refurbishment building (Fig. 4) immediately adjacent to the painting hangar. In this building, which was completed in March 1990, the internal furnishings of an aircraft are refurbished while the aircraft itself is being repainted next door. Facilities provided include metal preparation rooms, spray rooms, sewing, fitting, and trim areas together with administration and welfare accommodation for the painting hangar and refurbishment building.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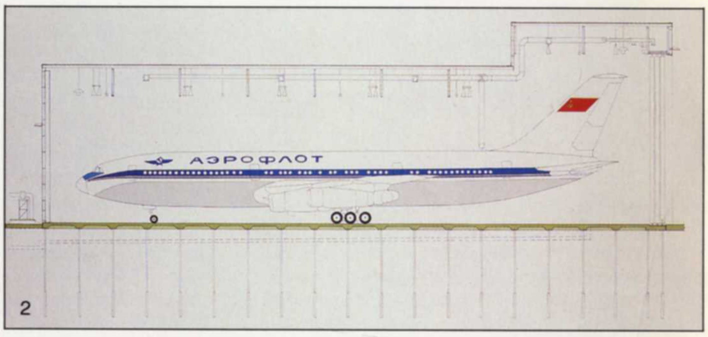

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1. Cross section and 2. longitudinal section through painting hangar, Shannon.

3. Opening of painting hangar, Shannon, August 1988.

4. Internal view of refurbishment hangar, Shannon.

5. Site filling, Moscow.

6-7. Steelwork erection, Moscow, June 1990.

8. Moscow hangar nearing completion.

4

Maintenance hangar, Moscow

Aeroflot expect to receive the first of their new Ilyushin IL96 aircraft off the assembly lines in 1990. However, there is currently no hangar large enough to accommodate this aircraft at the international airport at Sheremetievo, Moscow. Tierney and Associates were awarded a design and construct contract for the provision of an IL96/B747 size hangar at Sheremetievo in summer 1989. A requirement of the contract was that the construction be completed by the end of 1990.

Arups are providing a complete engineering design of the building.

The hangar is 67m wide, 72m long with clear heights of 21m and 12m at the tail and fuselage sections of the hangar respectively. In addition there are two plantrooms and a small ancillary building.

A site investigation of the ground conditions consisted of trial pits, six rotary percussion boreholes, ten static cone penetration tests and laboratory testing. As a result of the investigation it was decided that 2m deep of frost-susceptible material would be excavated and replaced by suitable compacted fill (sand) over the whole area of the building footprint. Most of this work was undertaken by a Soviet subcontractor employed by Tierney and Associates in 1989, before cold weather terminated construction. Filling was completed in early 1990 (Fig. 5), and foundation construction, also by the Soviet subcontractor, commenced in April 1990.

All above-ground structure, cladding, hangar doors and mechanical and electrical equipment are being imported from western Europe, mainly from Ireland. 550 tonnes of structural steel, including 67m long trusses, was fabricated in Dublin. All connections are bolted to minimize transport costs. A trial assembly of a truss at the workshop checked the accuracy of fabrication (Fig. 6).

Services provided in the hangar include a medium temperature hot water primary heating system with an oil-fired standby system. Both are medium velocity and when run together provide a maximum of two-hour temperature recovery from −26°C to 16°C as required by the client's brief. The design internal and external temperatures are 16°C (8°C) and −26°C (−42°C) respectively. Lighting is similar to the painting hangar in Shannon but consists of high pressure sodium high bay fittings only.

A full system of multiple pressure compressed air outlets, ground power and three-phase power supplies are provided within heavy grade service pits in the floor along the main axis of the hangar. In addition, power and water distribution is provided around the perimeter.

Fire detection and alarming are similar to the Shannon hangar. In addition, telephones, public address and basic security systems will also be installed.

In mid-June 1990 construction of the hangar was on schedule for completion by November 1990 (Fig. 8).

Credits

Client:
Aer Rianta/Tierney & Associates

Photos:
3: Rob Evison
4, 6, 7: Tim Corcoran
5: Nash Radosevic
8: Shannon Photographic Services

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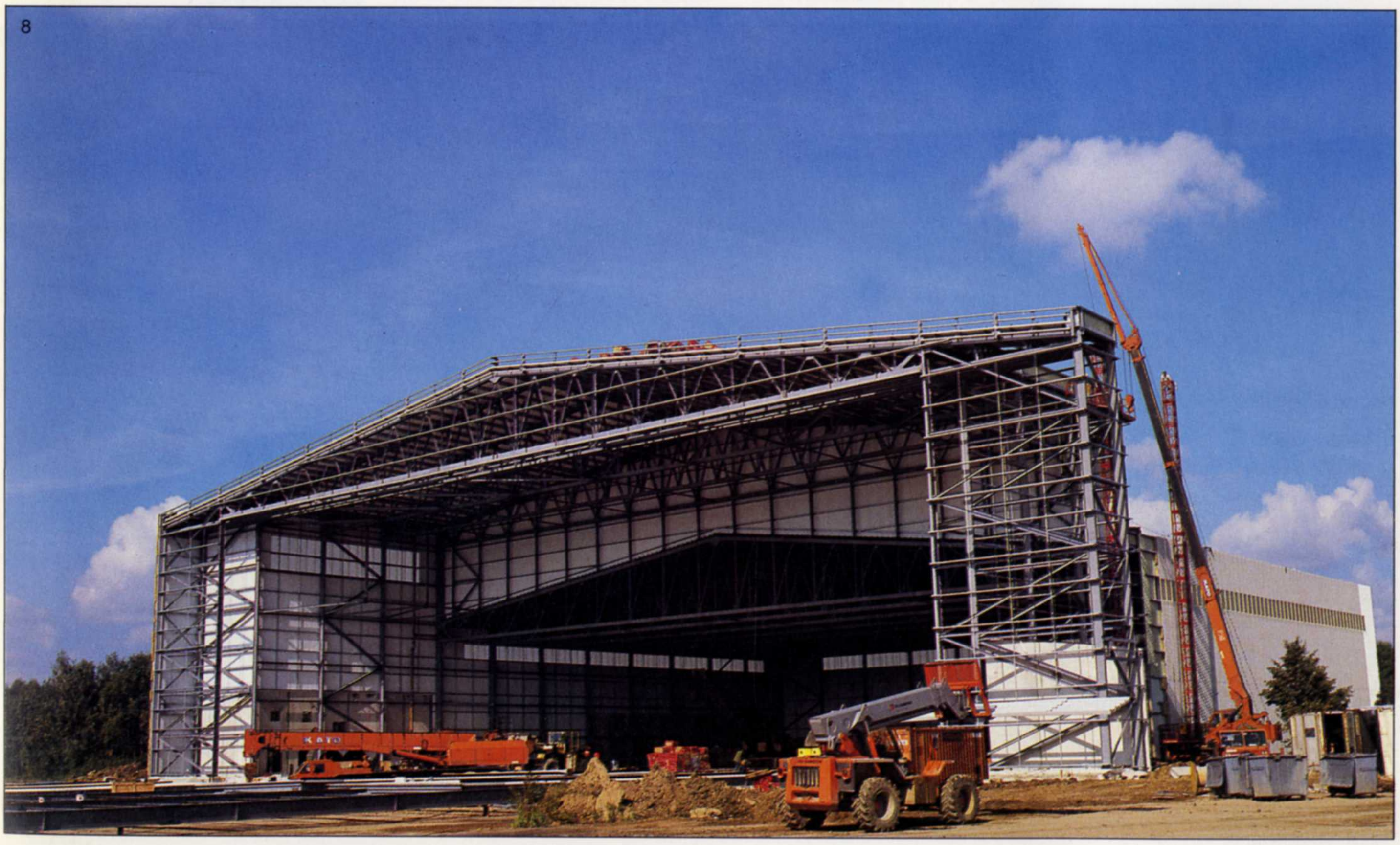

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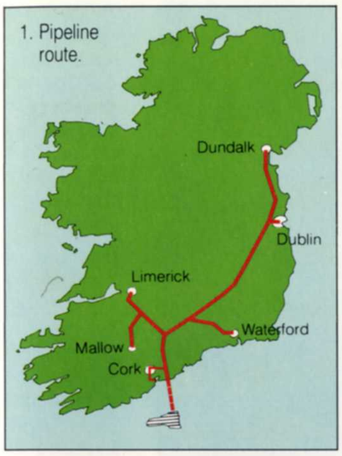
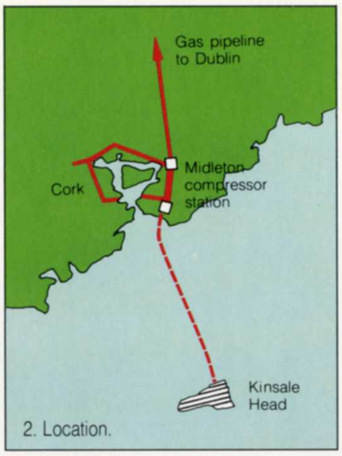
Natural gas compressor station, Cork

Peter Langford   Gerry Donnelly



1. Pipeline route.



2. Location.

Background

Bord Gais Eireann (Irish Gas Board) or (BGE) is responsible for the distribution and sale of natural gas in Ireland. The gas comes from the Kinsale Head gasfield which is located about 50km offshore from the southern part of Ireland. The field is operated by Marathon Petroleum who supply the gas to BGE at their onshore terminal at Inch in County Cork. From there the gas is piped at high pressure to various centres throughout Ireland. The principal marketplace is in Dublin.

As the Kinsale Head field has depleted, the gas pressure in the field has declined in the usual manner. In accordance with BGE's contract with Marathon Petroleum, a minimum delivery pressure of 24 bar must be maintained at the landfall terminal. While this pressure is sufficient for the distribution of gas in the Cork area, the fall-off in pressure has had the effect of reducing the capacity of the Cork-Dublin pipeline.

The yearly reduction in capacity did not affect BGE commitments until the 1987/1988 winter. However, since then the capacity of the pipeline, utilizing the natural field pressure only, has not been sufficient to meet the demands for gas in the Dublin area. The installation of gas compressors was necessary to boost the gas pressure up to the maximum pipeline design pressure of 70 bar and thereby maintain the capacity of the pipeline.

BGE began detailed in-house studies of compression requirements in 1983. The potential timing and cost of a compressor station was evaluated and it was decided in 1985 to begin project work with a target operational date of late 1987.

Appointment of consultant

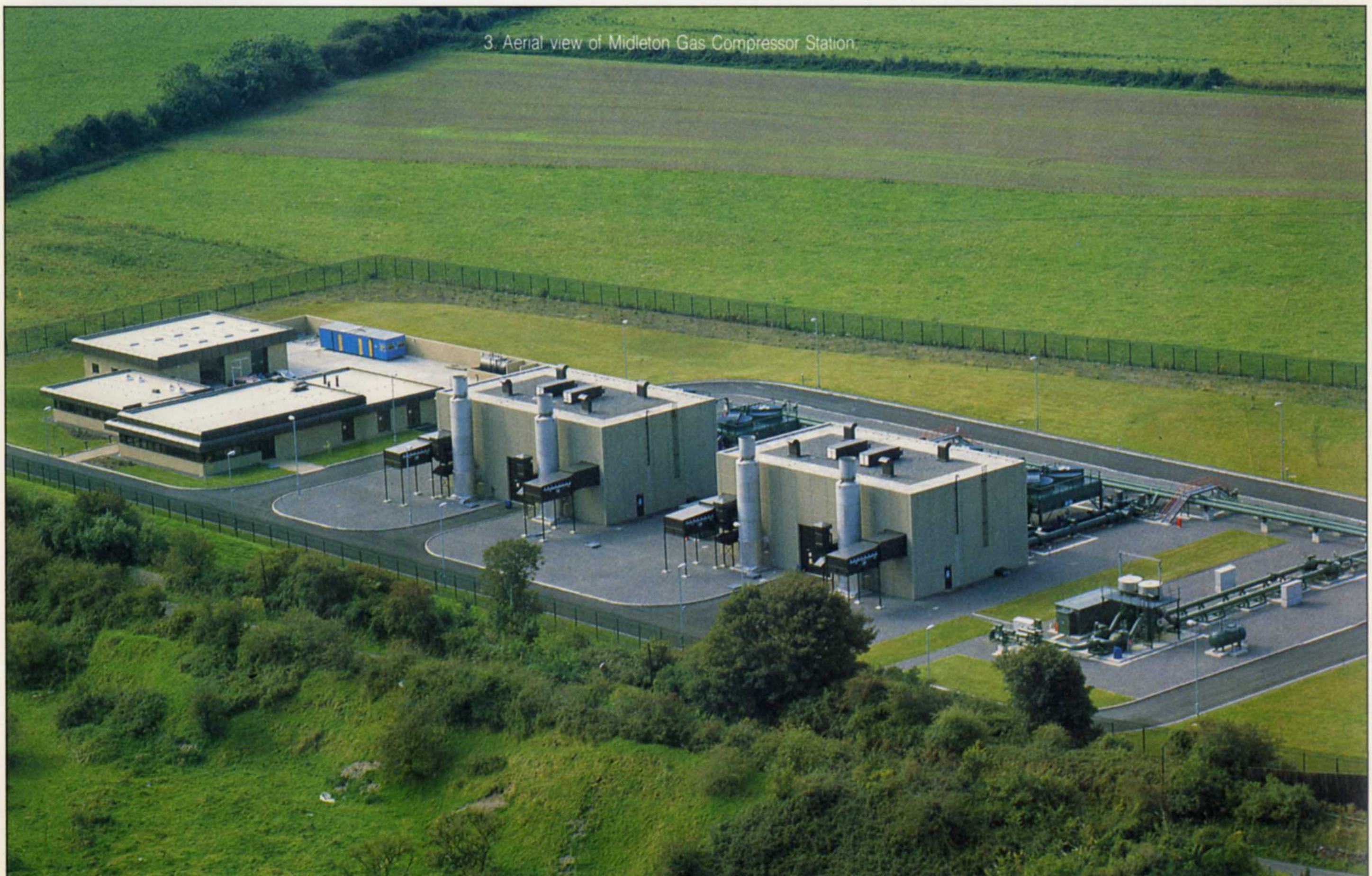
In February 1985 invitations were issued to selected engineering companies with appropriate background and experience, to submit proposals for the design and project management. 10 West European-based consulting companies were identified as meeting BGE's general requirements — eight of these firms submitted proposals. An essential requirement of the brief was the inclusion of a significant Irish participation in the consultancy team. Four consultants were shortlisted and requested to make presentations in their home offices to BGE. This allowed detailed discussions on the proposals, an assessment of the key people in the proposed team and an inspection of the office systems and general organizational set-up of each company. Pipeline Engineering GmbH (PLE) in association with Ove Arup & Partners Ireland were selected as consulting engineers for the project. PLE is a subsidiary of Ruhrgas, the West German natural gas transmission company, which is one of the largest gas companies of its kind in Europe.

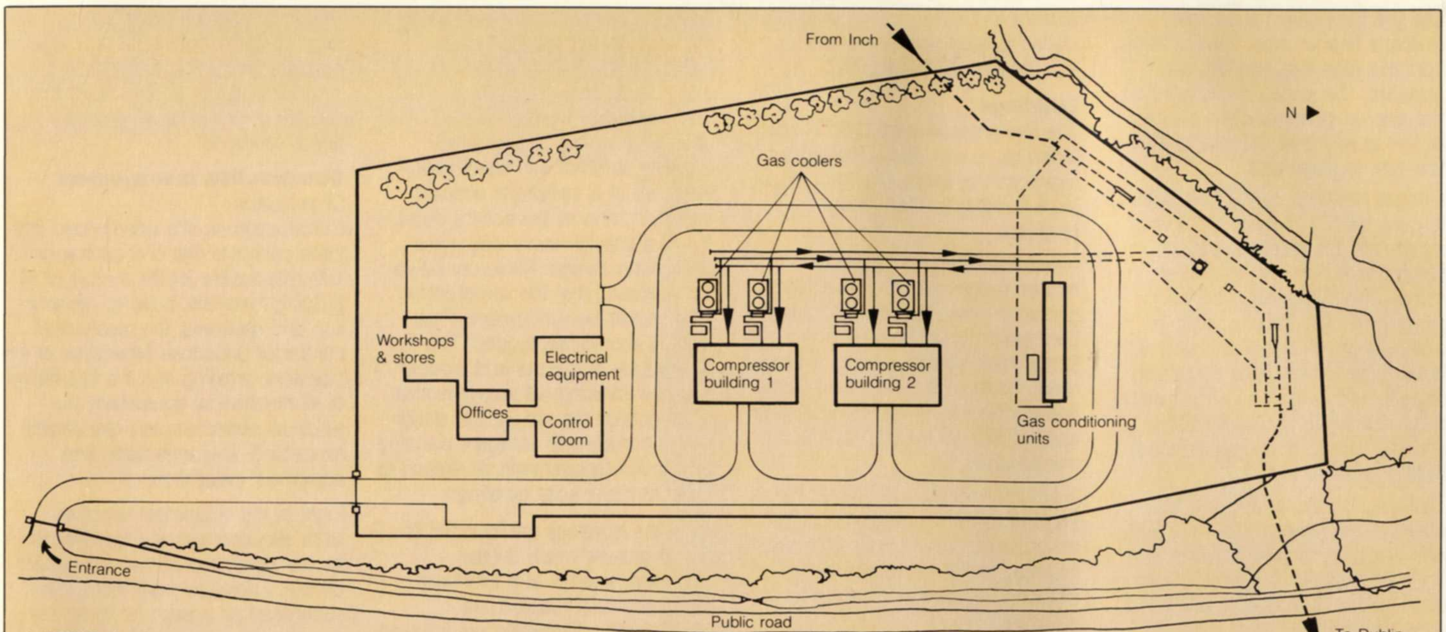
The work split was such that we should be responsible for site selection, obtaining all statutory approvals and designing and letting contracts for all civil and building work. PLE were responsible for all process and equipment-related aspects of the project as well as the team leadership. Construction management was to be carried out by a combined team, based on site under the overall management of PLE.

Basic design

Immediately on appointment PLE/Arup commenced work on all aspects of the preliminary design to meet the loads on the BGE network. In accordance with BGE requirements, sufficient engineering work had to be completed in this phase to enable a cost estimate for the project to be prepared to an accuracy of ±10%. Specifications for all the principal equipment packages were drawn up and budget quotations were requested from potential suppliers for cost estimating purposes. Discussions were also held between PLE/Arup and BGE to establish in detail every aspect of the project management. At the end of October 1985 the Basic Design Report was submitted. This report, which was divided into seven volumes, established in full the scope of the project. The matters dealt with included:

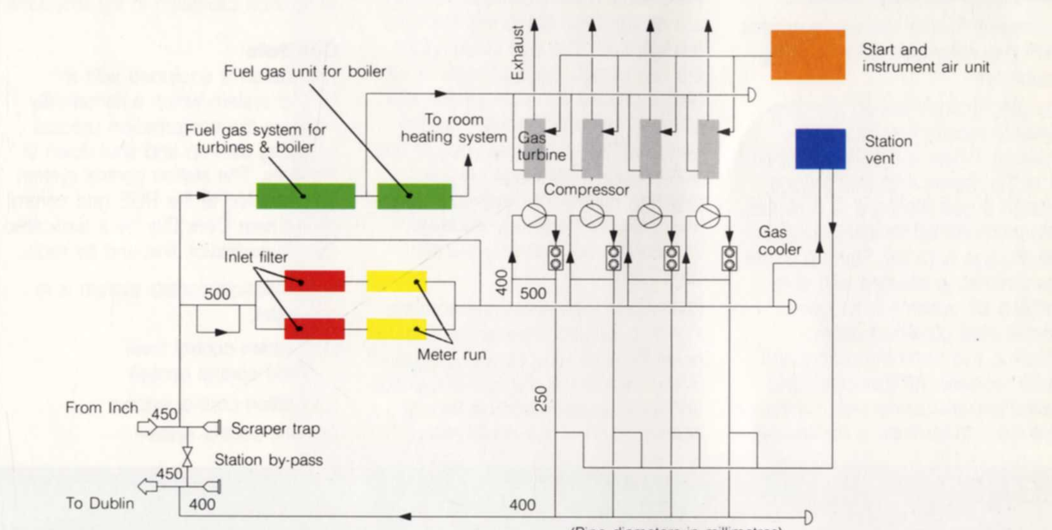
- Design data
- Project limits
- Time schedule
- Site selection
- Compressor selection
- Project procedures
- Specifications, drawings and description of work
- Project budget.


3. Aerial view of Midleton Gas Compressor Station.



4. BGE Station layout.

The compressor station was designed to meet the loads on the Cork-Dublin pipeline. It was planned to have the station operational by the 1987/1988 winter, although the maximum load on the station would not occur before 1991.



5. BGE Station schematic.

Site selection

A detailed study was carried out which identified four potential sites.

These were fully examined in terms of systems design, site area and topography, availability of electrical power, water supply, access, ground conditions and environmental considerations. All of the sites were within easy reach of the main transmission line and reasonably close to the junction of the Cork and Dublin supply lines.

For each site a photo-geological interpretation was carried out and the implications for design and construction were assessed. The infrastructure requirements were also established and the different systems configurations were developed for each case. The true cost of each site was calculated and a comparison was made between the sites on both technical and cost grounds. A 3.4ha site 4km from Midleton was finally selected.

Compressor selection

From a performance viewpoint the compressor station had to meet two requirements, flow rate and compression ratio. All technical solutions to meet these requirements were considered and meetings were held with the different equipment manufacturers to consider suitable designs.

It was concluded that the optimum technical solution was to have two reciprocating units or three centrifugal units. The additional centrifugal unit is because of the narrower operating envelope of centrifugal compressors. An additional unit is required for standby duty, irrespective of whether centrifugal or reciprocating compressors are used.

A detailed economic analysis was carried out on the cost of centrifugal versus reciprocating machines. This was based on budget prices received from the various manufacturers. An operating cost analysis considering fuel and other maintenance costs showed the reciprocating units to be cheaper to run. However discounted operating cost savings did not justify the extra capital costs involved. It was decided therefore to base the station design on four centrifugal gas-turbine driven compressor units.

Project procedures

Every aspect of the management of the project including procurement, financial controls, reporting, site organization and management, was discussed and agreed between BGE and PLE/Arup. The agreed procedures were formally written up as a Project Procedures Manual. The Procedures Manual was divided into three sections:

(1) BGE Internal Procedures

(2) Coordination between BGE and PLE/Arup

(3) Coordination between PLE/Arup and contractors.

The first section, as the title implies, covered the internal BGE management and financial controls as applied to the project.

The second section established all procedural rules between BGE and PLE/Arup. This document defined responsibilities for correspondence, meetings, monthly reports, procurement and materials control, cost control, planning, approvals, quality control and completion documentation. The final section summarized the rules applying to each contractor for the project, and related to items such as reporting relationships, correspondence, meetings and materials control. This section was later incorporated in the manufacturing and construction contracts for the project.

Project budget

Engineering in this phase was sufficiently detailed to enable an estimate to an accuracy of ±10% to be prepared.

Specifications and drawings (P + IDs, General Arrangements) for each item of equipment and of the station were prepared. Budget quotations were obtained from suppliers for all the required equipment. Material lists were prepared for items such as valves, fittings, pipes, and again budget quotations obtained. The construction work on site was measured from the drawings and a cost plan was prepared.

The project budget was estimated at Ir£18.4M ±10%. An analysis which was carried out independently by BGE showed that this budget price compared very favourably with the cost of other compressor stations internationally.

Project timetable

PLE/Arup set up a project schedule using the computer program PROJACS; this used procedure diagramming methods. The minimum duration for the project was estimated at 22.5 months from the issue of tenders for the compressors.

Station design and details

Flow description

Figs. 4-5 show the station layout and schematic. Incoming gas is initially filtered. While the gas in the pipeline system is very clean and dry, any impurities, including any drops of water, could seriously damage the compressor blades.

The gas then passes through meter runs which stabilize and measure the gas flow. Measurement of the gas is required for control purposes in running the station. There are two filter/meter streams installed in parallel, one operational and one standby.

The gas then enters a 500mm diameter header pipe. Four offtakes from this pipe feed the four compressors. The station is designed so that one or more compressors may be run at any time depending on the flow rate requirements.

The gas heats up during compression to over 100°C. This is too hot and would melt the pipeline coating downstream of the station. After compression therefore the gas is passed through fin-fan coolers in which air driven by electric fans is blown over finned pipes containing the gas, which cools to 45°C, and is than returned to an outlet header and discharged back into the Cork-Dublin pipeline.

The gas turbines driving the compressors are Dresser Clark DC 990s and are skid-mounted together with the compressors. The rated output of each turbine is 4.5MW at ISO conditions. The turbines burn a gas-air mixture, the necessary air being drawn in through air inlet filters. The turbines are fitted with airtight enclosures for fire isolation purposes. Each has automatic halon flooding equipment.

The gas turbines driving the compressors require fuel gas at low pressure, which is therefore tapped off at the station inlet and passed through a gas filtering and pressure reduction unit before being routed to fuel the gas turbines. Start-up of the gas turbines is effected with compressed air, which has its own independent pipeline system, including two air compressors and an air receiver. All gas pipes and equipment are connected to a station vent stack to facilitate quick depressurization in case of emergency. A station bypass operates when compression is not required.

Buildings

The compressors are housed in two buildings, two in each. There is an overhead five tonne gantry crane in each building for maintenance purposes.

A separate administration block houses a control room, emergency generator, low tension switchgear and motor control centres, transformer room, battery room, inverter room, boiler room, ventilation plant and the necessary offices, workshop and stores area for the daytime maintenance staff.

A fibreglass enclosure houses the pressure reduction equipment. The air compressors are housed in skid-mounted metal enclosures. Other incidental equipment is located outdoors.

Great attention was paid from the outset to environmental aspects of the station. The layout and buildings are designed to blend into the rural background. The wall cladding for the compressor halls consists of full height precast concrete panels with a honey coloured exposed aggregate finish. The external walls of the administration buildings have a matching *Forticrete* blockwork outer leaf. External pipework, ductwork and equipment is mostly painted green or brown.

Control of noise emissions from the station is of vital importance. The noise from all sources was calculated at the design stage and the selection and location of equipment included a consideration of the noise effects. Silencers are built into the exhaust stacks of the turbines. The compressor halls have concrete roofs with internal sound absorbers. The end walls have internal sound-absorbing panels. The precast cladding external wall panels are made up of a composite acoustic sandwich, and all the access doors are of a special heavy duty noise-attenuating design. Noise considerations dictated that the compressor halls should be windowless. Pipework is acoustically lagged. The topography of the site and existing and new planting will also minimize noise outside the site, as the station has to comply with stringent planning permission requirements in relation to noise at the nearest dwellings.

All of the buildings are founded on glacial gravels which overlie limestone bedrock at a minimum depth of 3m. A detailed site investigation was carried out followed by probing of the formation during construction to ensure the absence of solution cavitation in the limestone.

Controls

The station is equipped with a control system which automatically monitors the compression process including start-up and shut-down of the units. The station control system is connected to the BGE grid control centre near Cork City by a dedicated data transmission line and by radio.

A hierarchical control system is in operation:

(1) System control level (grid control centre)

(2) Station control system

(3) Unit control system.

The station control system only requires the remote input of a flow or pressure setpoint in order to start up the station automatically, select the number of required compressors and run all functions.

Construction management

Organization

Construction on site was divided into three contracts: the civil contractor was responsible for the supply of all building materials, building construction and siteworks; the mechanical contractor undertook fabrication of all pipework, welding and the installation of all mechanical equipment; the electrical contractor was responsible for cabling, instrumentation and equipment installation.

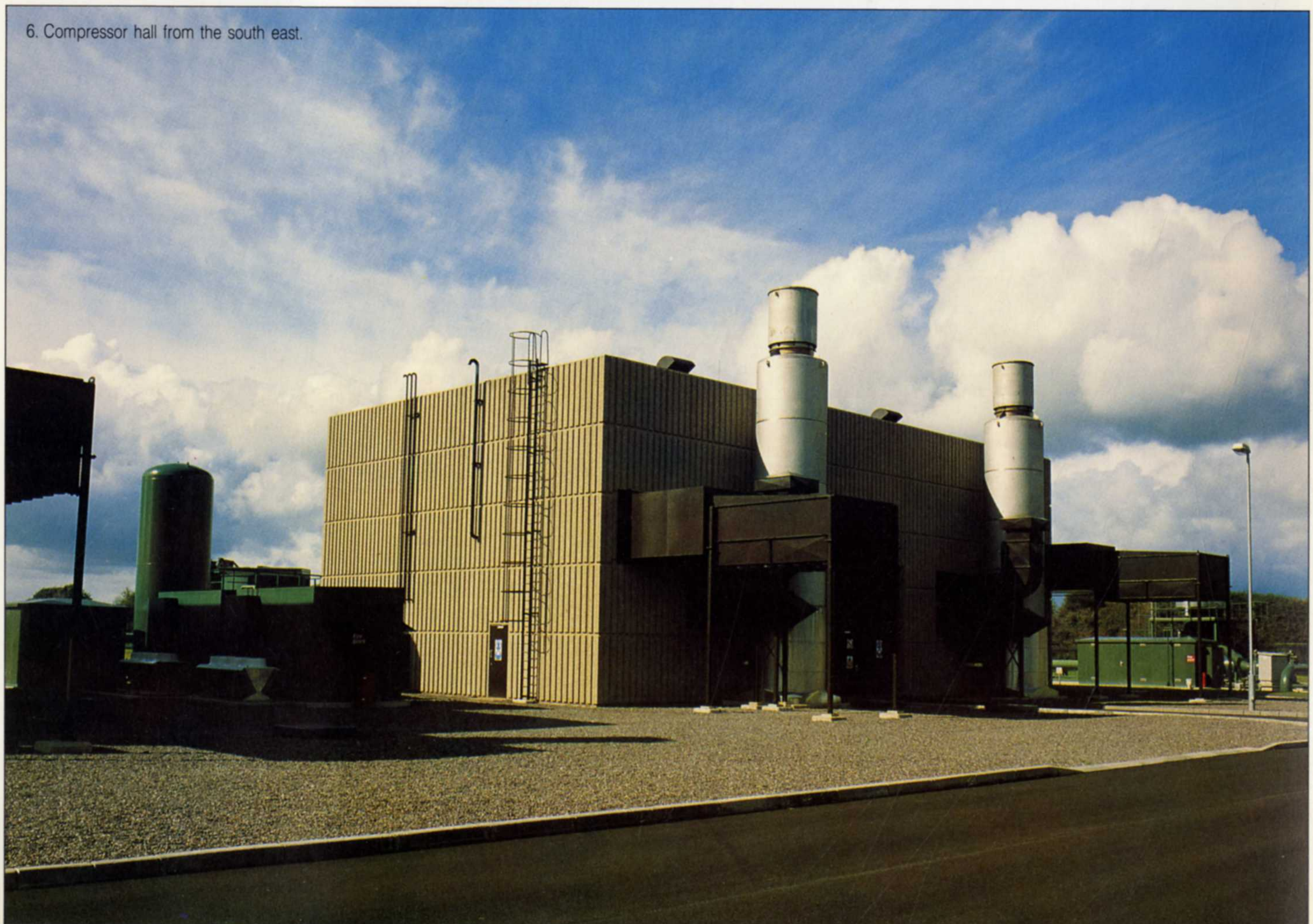
Eight of the equipment suppliers were also contractually responsible for the installation of their equipment on site. Engineers from these firms supervised all aspects of installation and commissioning of their equipment, with the three site contractors providing the necessary manpower to complete the installation and commissioning work.

When the project was planned several features were included which helped its success on site:

(1) Overlap in the scope of work of the different contractors was minimized.

(2) Each of the contractors was provided with a separate compound. When the civil contractor started on site one of his first functions was to provide these for the other contractors, so that fenced areas with electrical and telephone services were available for them when they came on site.

6. Compressor hall from the south east.



7. Control room.

8. Compressor.

(3) The roads on site were completed to a base course level early in construction and hard standing areas were also installed on site. This provided easy mobility, minimizing wet time delays and keeping the whole area clean for equipment set-down.

Contracts
The conditions of contract were identical and were based on a modified version of the IEI Third Edition 1980. Two of the modifications gave PLE/Arup control of the site in the role of construction manager.

- The civil contract was started first so that all buildings were weather-tight and bases completed before the arrival of heavy equipment.
- Possession of the site was not given to any contractor but was retained by BGE.
- PLE/Arup had the right to change the order of any contractor's work if necessary.

Contracts were again on a fixed price, lump sum basis. An indicative bill of quantities was included in each contract, for measurement of interim payments and valuation of any changes. Contractors had to provide bonds in accordance with the format in the IEI conditions.

Scheduling
Project progress was constantly monitored using the output from the PROJACS programme. The progress was updated on a monthly basis which enabled any slippage to be immediately identified and corrected. Delivery of equipment on site was phased so as to enable timely unloading and installation.

Quality control
All manufacture and construction was subject to rigorous testing and inspection. This included:

- 100% x-ray of all gas containing welds
- Hydrostatic testing of pressure containing components
- Factory performance testing of equipment before it was released to site. The final factory tests simulated, as closely as possible, actual working conditions on site.
- One compressor-turbine package was string-tested. The entire package, including the unit control panel, was assembled and run in the factory in the USA under simulated operating conditions to ensure that all the integral components performed satisfactorily as a combined unit.
- All equipment was performance tested on site before it was certified for take-over by BGE.

Cost control
Particular emphasis was placed on project cost control. A tight control system was implemented whereby all costs were evaluated by BGE and PLE/Arup on a monthly basis. This included a forecast final cost which was updated each month. The project was completed within budget.

Commissioning and operation
Commissioning of the station started in September 1987. At this stage all construction work was completed except for some siteworks and landscaping. All pipework had been successfully hydrotested.

Extensive precommissioning activities took place before the introduction of gas to the station. The station was gassed up in accordance with a planned written procedure. The pipework was nitrogen-purged and then the gas introduced on a phased basis.

Very tight safety procedures were enforced. All work was carried out in accordance with a written work permit system. Any work on equipment was allowed only after its complete isolation.

The station commenced operation in February 1988. At that time the capacity of the Cork-Dublin pipeline, based on the inlet pressure from the Kinsale Head field, was no longer capable of meeting the demand for gas in the Dublin area.

9. View from north west showing main headers and fin-fan coolers.

Credits

Client:
BGE — Irish Gas Board

Photos:
6-9: Richard Mills

Dublin Castle restoration

Ralph McGuckin

1. Marginal sketch from Charles Brooking's map of Dublin 1728: Dublin Castle in transition.

2. The Great Courtyard in 1792: James Malton *del et fecit*.

Historical background

The Normans came to Ireland in 1169, captured Dublin the following year and in 1204 came King John's mandate '. . . to erect a castle there . . . as strong as you can with good ditches and strong walls'. The site chosen could scarcely have been bettered: on a hill in the south-east corner of the old Viking town, protected to the south and east by the River Poddle. The castle was completed by 1220 and a deep ditch or moat dug to encircle the two remaining sides. The walls formed a rough rectangle 100m × 60m with a circular tower at each corner and within were all the paraphernalia of justice and government with comings and goings controlled by a drawbridge. And so it was until a serious fire broke out in 1624 when many of the buildings were destroyed or blown up to keep the flames from the gunpowder store and the State Records.

Thus ended Dublin Castle as a mediaeval fortress and in the 18th century the buildings round the Great Courtyard were rebuilt much as we see today; the marginal sketch from Thomas Brooking's map of 1728 (Fig. 1) shows the new buildings emerging from their mediaeval chrysalis and James Malton's print of 1792 is of the completed work (Fig. 2). An attic storey was added in the 19th century and sundry buildings at the rear, including George's Hall as a supper room for the visit of George V in 1911.

But all was not well. On the northern side of the Great Courtyard the buildings, apart from the courtyard facades, had been built over the filled-in moat which had probably been used as a town dumping place from quite early on. So it was not surprising that settlement over the years had resulted in many of the buildings being vacated.

In 1984 came news that facilities for Ireland's Presidency of the European Community in 1990 would be provided at the Castle and the architectural planning immediately commenced. The site is L-shaped and includes all the buildings depicted by Malton: the nondescript old kitchens, stores and so forth would be cleared away from behind and new accommodation provided for delegates, catering, media coverage and the great entourage that a major conference now generates.

Archaeology

Prior to building, it was decided that an archaeological excavation (Fig. 3) would be carried out and this was done while the design was evolving; our involvement was in determining how extensive the excavations could be without jeopardizing the buildings to be retained.

Over 100 000 finds were recovered from the moat area, mostly mediaeval but some Viking, and analysis and recording are still in progress. The foundations of old castle walls and towers were also revealed. This necessitated some re-planning and structural amendment, and by the Powder Tower an archaeological exhibition area has been incorporated wherein the public may view the ancient walls and part of the Viking town defences. Two of the buildings facing the Great Courtyard were conserved — the West Range and the old Genealogical Office, now part of Castle Hall.

Foundations

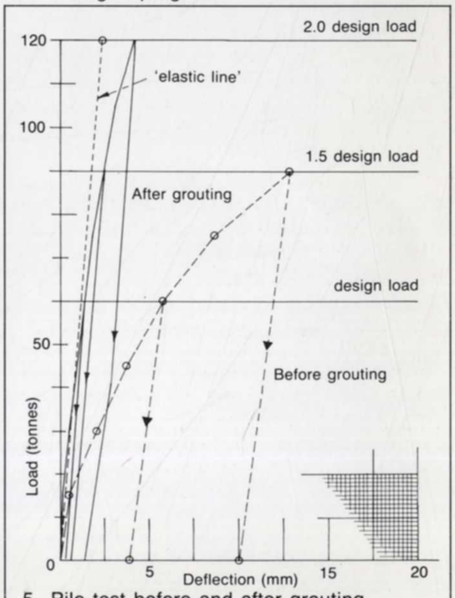
Site investigation, not unnaturally, indicated filled material in the moat, in places right down to the underlying calp limestone, and piled foundations were the obvious choice (Fig. 4). Rock coring showed thin bands of mudstone in the upper layers of rock and, by casting in a 75mm diameter pipe vertically in each pile, provision was made for subsequent drilling and grouting the rock at the pile bases. The effectiveness of the grouting is shown in Fig. 5 where a pile tested to 1.5 × design load before grouting gave a residual deflection of 10.2mm; this reduced to 1.3mm after grouting, when a second test load of 2.0 × design load had been applied and released. And, lest the first test loading had in itself contributed significantly to the improvement, further piles were first grouted and then test-loaded — satisfyingly small deflections were again recorded.

The scheme

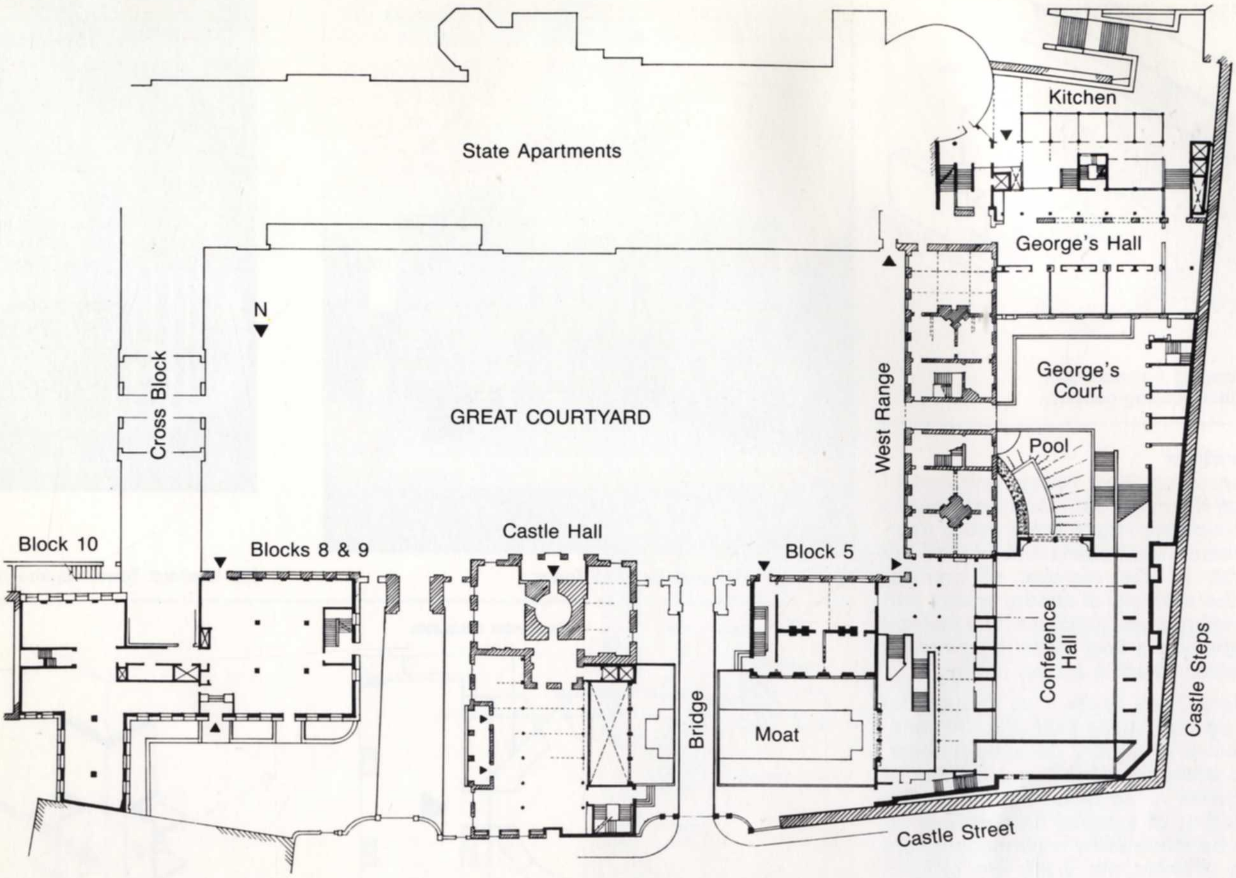
The general layout of the scheme is shown in Figs. 6 & 7. The Kitchen Building and George's Hall are for press use, as well as for food preparation; Castle Hall also serves as the public entrance to the Castle and Blocks 8, 9 and 10 are offices for Government Departments. The Conference Hall fits snugly into the north-east corner of the site.

△ 4. Piling in progress.

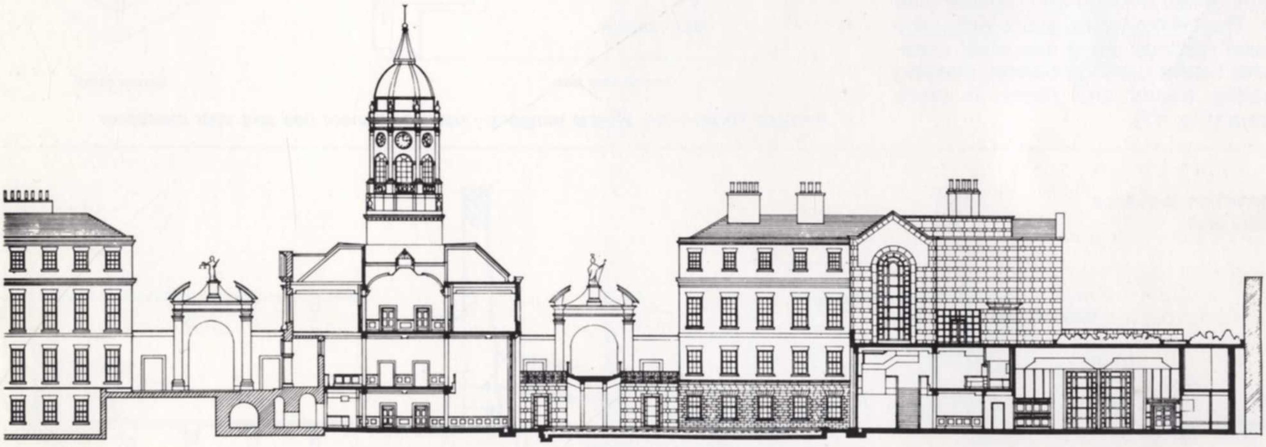
3. Archaeological exhumation of the old Powder Tower, with the Record Tower in the background. ▷



5. Pile test before and after grouting.

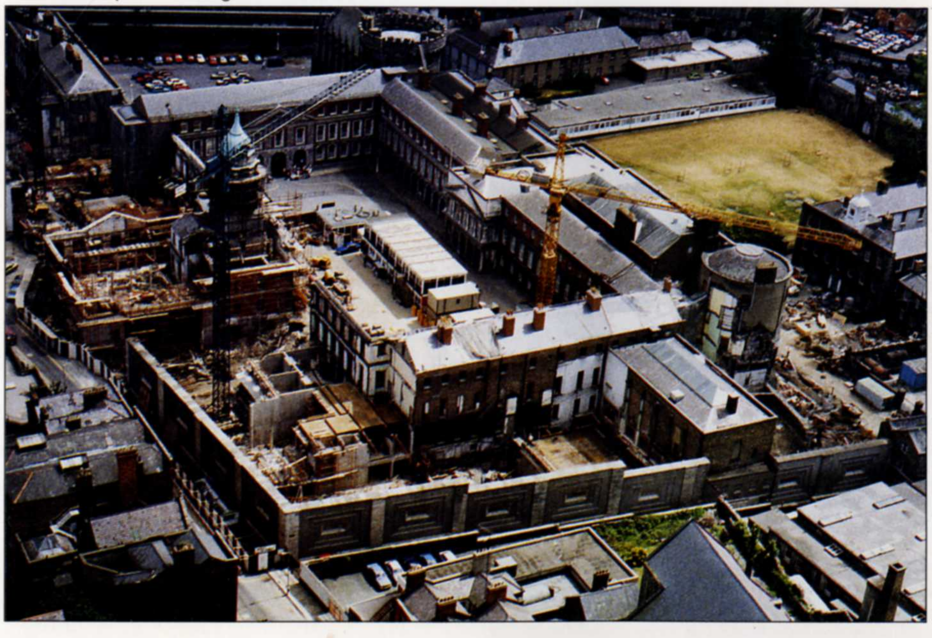


6. Plan.



7. East-west section.

▽ 8. Aerial photo during construction.

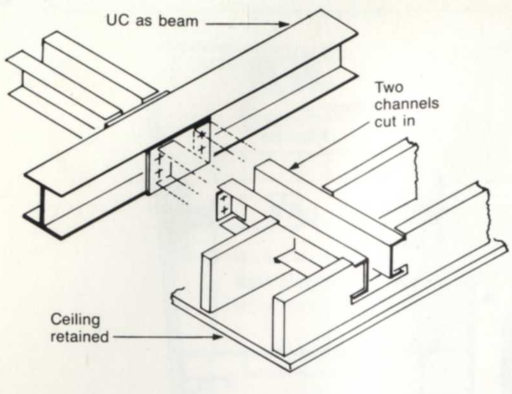


The engineering design had many facets. Block 5 and Blocks 8 and 9 had so much settled into the filled-in moat that only their facade walls were retained — shored and propped until the new buildings, generally of conventional reinforced concrete, had been built behind.

In the Great Courtyard the Gate of Fortitude, hitherto a dummy gate, was made into a real gate with an arched bridge linking to a new entrance from Castle Street.

Under George's Hall

The interior of George's Hall was not part of the contract and the fine panelled room was kept locked throughout. It was, however, necessary to lower the level of the floor below (part 'ex-met' reinforced concrete of 1910 vintage) and to construct a new basement throughout. Fortunately the original drawing was available and the old foundations turned out to be below the new basement level — strengthening for the increased column loads was by extending the footing area and taking the new suspended floor loading on a new brickwork encasement of the existing steel columns.



9. Strengthening a timber floor whilst retaining ceiling beneath.

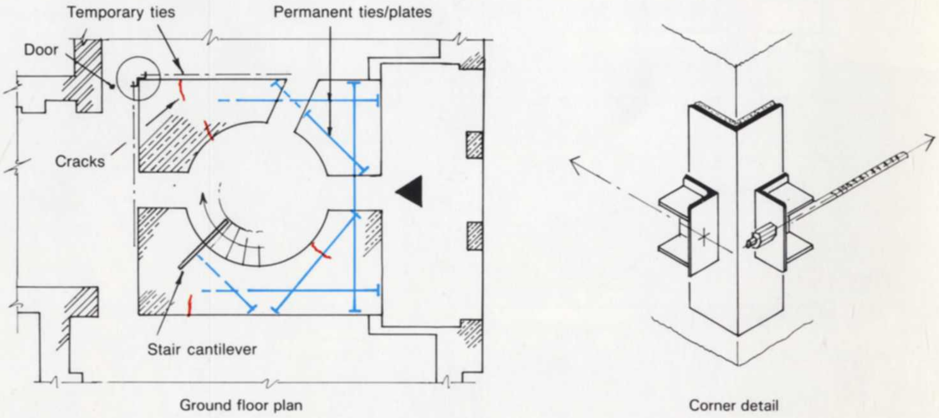
10. Castle Hall and Bedford Tower.

12. Bedford Tower: central stairs.

Conservation

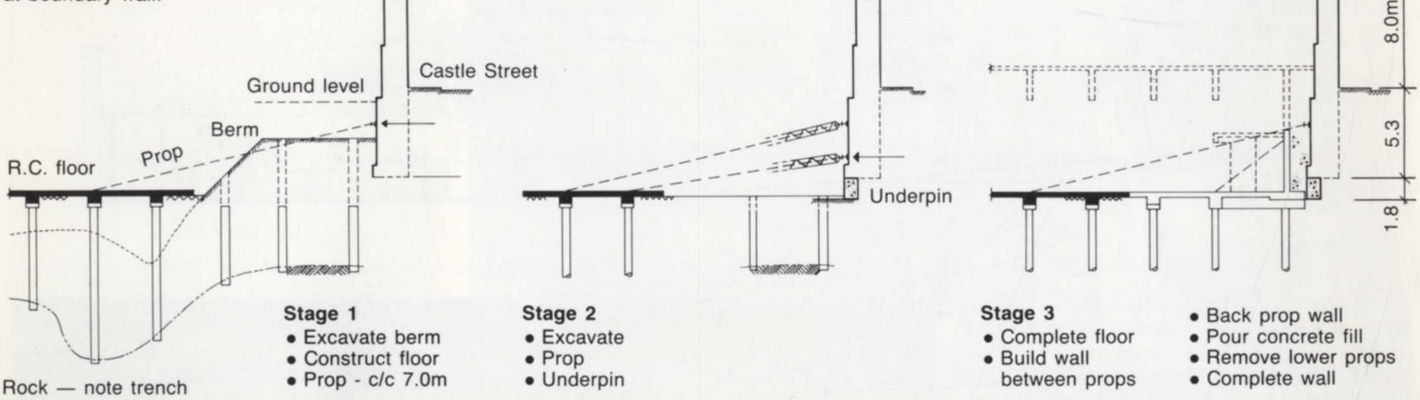
In the conserved West Range and part of Castle Hall the major structural restorations were the strengthening of timber floors, overhauling timber roof trusses and work to the walls such as the removal of bonding timbers, the stitching of sundry cracks and the re-bonding of wall junctions. Our method of strengthening a floor whilst keeping the plaster ceiling intact is shown in Fig. 9.

The Bedford Clock Tower rises through the restored part of Castle Hall (Fig. 10) and, upon removal of sundry decayed timbers, displayed active movement of a number of vertical cracks — so much so that a temporary binding of external tie bars was installed to be followed by a permanent consolidation wherein the walls are grouted (requiring some 12.5% of their volume to be filled with grout) and permanent threadbars and plates drilled through and grouted (see Fig. 11). The central spiral stairs within the tower were restored using new steel cantilevers and timber carriage beams, keeping the existing treads and risers in place throughout (Fig. 12).



11. Bedford Tower Plan: typical temporary ties, permanent ties and stair cantilever.

13. Construction sequence at boundary wall.



14.

The Conference Hall

The Conference Hall is located in the northwest corner of the site, at low level and hard against the 19th century brick and stone boundary wall. This rises about 8.0m above the street outside and its foundation was about 1.8m above the Conference Hall formation level within.

The construction method was to leave a berm along the wall and construct as much of the piled floor slab as possible; then to prop the wall off the floor slab and, in staged sequence, excavate, underpin and complete the floor and new wall (see Fig. 13). The Hall is spanned by deep reinforced concrete portal beams with services between and a total of 10 interpreters' booths are ranged along two sides; in the lobby the main stairs are dog-legged over two storeys, some 2m wide with a 'cantilever' length of 7m (Fig. 15).

15.

The bridge

The bridge making a new link between the Great Courtyard and Castle Street was designed for highway loading type HA and 25 units of type HB loading and spans 12m across a now-symbolic moat. The structure takes the form of a 460mm thick circular arch of reinforced concrete with two shallow arch-ribs on the soffit; the rise is 750mm. Its light appearance derives from its thin edging and the upward splayed soffit — the kerbs and parapet edges are of Wicklow granite as is the carriageway of mortar-bedded stone sets on a waterproof membrane. The bridge and moat form a pleasant adjunct to the Conference Hall and Castle Hall.

The project took 27 months to build and was completed in November 1988, leaving one year for furnishing before the European Community presidency commenced in January 1990. The work was at once diverse, exciting and demanding and has brought a new dimension to a major public building of national and international importance.

14. Inside Conference Hall.
15. Conference Hall lobby: Main stairs.
16. Bridge Moat and Castle Hall.
17. Mrs Thatcher, Charles Haughey, *et al*.

Photos:
3: Con Brogan OPW
4: Gerry Duffy
8: Ronnie Norton
10: Roger Kemp
12, 14, 15: Bill Hastings
16: Hugh MacConville
17: Derek Spiers/Report

Credits

Architects:
Office of Public Works
New Works 1, New Works 2

Structural and civil engineers:
Ove Arup & Partners Ireland

Service engineers:
Varming Mulcahy Reilly Associates and
Robert Jacob & Partners

Main contractors:
Mahon and McPhillips Ltd.
John Paul Construction Ltd.

Covers:
Front: Dublin Castle
(Photo: Hugh MacConville)
Back: Athlone Bridge
(Photo: John Kellet)

Printed in England by Reedprint Limited, Windsor, Berkshire