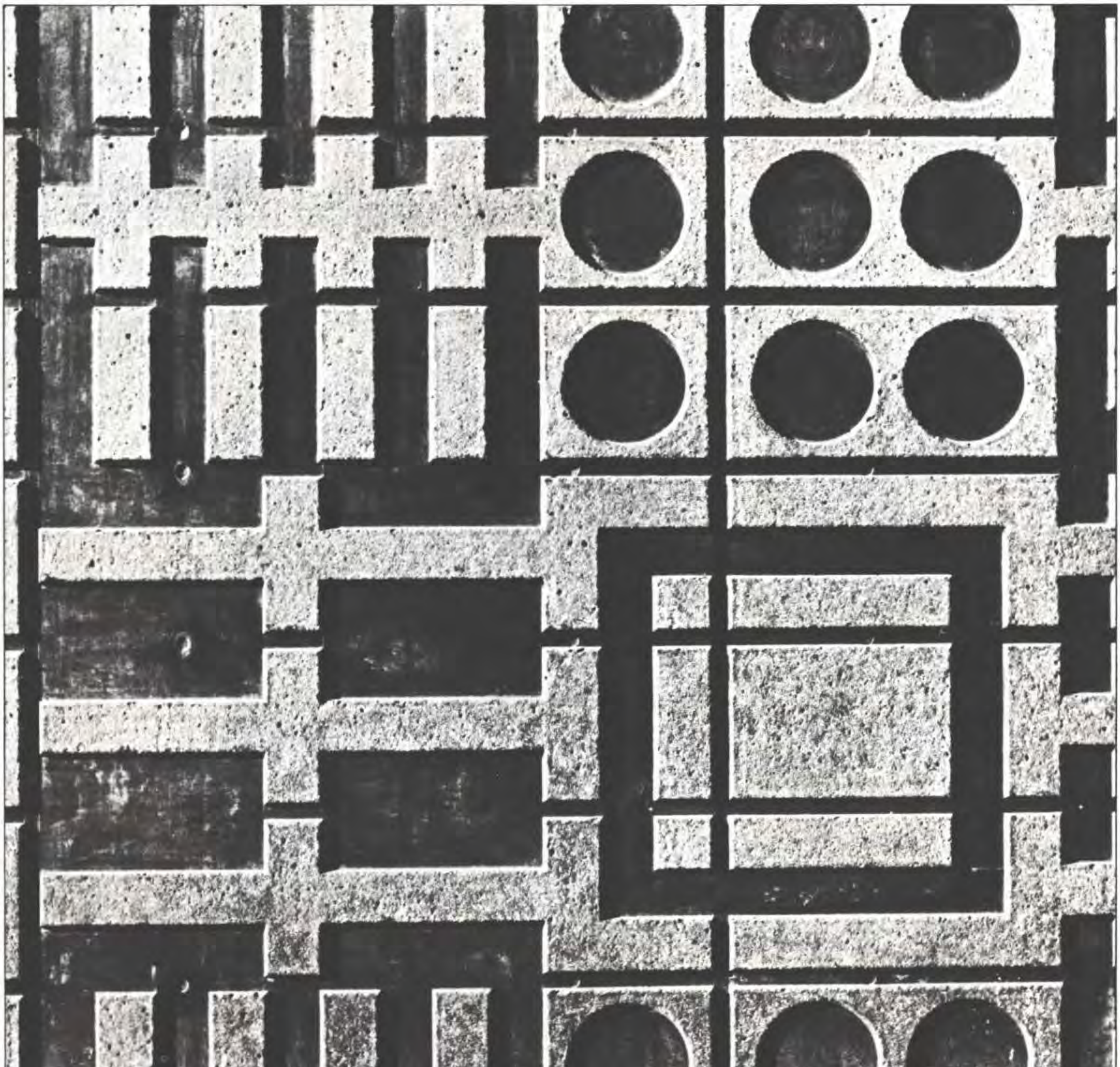
THE ARUP JOURNAL

SEPTEMBER 1978



THE ARUP JOURNAL

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Back cover: Detail of window walling units, Danish Embassy (Photo: Harry Sowden)

Royal Danish Embassy, London

Colin Wade

PROJECT DEVELOPMENT

The history of this job goes back to early 1968, when we were asked by the Embassy to advise them on negotiations they were making with their landlords, Cadogan Estates, for the buildings they were occupying at that time in Pont Street and Cadogan Square, S.W.1.

As the leases on these buildings were due to expire, they wished to bring all their staff together in one building which would also include the Ambassador's residence.

It was intended that the Embassy would occupy a six-storey building along Sloane Street, which was to have been a speculative-type office block built on behalf of Cadogan Estates but incorporating the requirements of the Embassy. Due to the economic situation at that time and new government legislation brought in for building development, Cadogan were unable to continue with this proposal but instead offered the site to the Embassy on a 99-year lease, provided they demolish the existing houses and erect a new building to suit their own requirements, subject to it being approved by Cadogan themselves. This was agreed to and we were appointed as structural and services consultants, coupled with providing quantity surveying and cost control services. Professor Arne Jacobsen of Copenhagen was appointed as architect by the Danish Ministry of Foreign Affairs in late 1969.

We prepared tender documents for a demolition contract, which began in August 1970 and was completed in February 1971. The site was left with much of the old basement walls, foundations and vaults in place and with much rubble material filling the old rooms up to street level. A site investigation was also carried out and four boreholes were sunk in March 1971.

Also in March 1971, about the time the preliminary design was complete, Arne Jacobsen died, but his practice carried on under the leadership of Hans Dissing and Otto Weitling.

Design work continued until November 1971 when the Danish Government decided for economic reasons to postpone the project for a minimum of three and a maximum of five years with the agreement of Cadogan Estates to keep their option on the site open. The site was now a rather sorry-looking gap in a prominent position opposite the landscaped square of Cadogan Place Gardens and, to make some financial advantage, it was decided to lease the site to National Car Parks Ltd. and until March 1975, behind a rather dull hoarding, the site was used as a car park.

Although rumours of a revived scheme came and went and various requests for revised cost estimates and design programmes were dealt with, nothing happened until early 1973, when the project was revived and we began negotiations with the client and architect to up-date cost estimates and to consider how best to tackle the job contractually. The outcome of this was to adopt a two-stage tendering procedure which is discussed under Quantity Surveying and Cost Control aspects.

Construction work began in April 1975; the structure was completed in July 1976 and the building was handed over in September 1977.

DESCRIPTION OF THE BUILDING

The Embassy is situated in Sloane Street and is bounded to the south by Hans Street, to the west by Pavilion Road and to the north is abutted by the party wall of no. 53 Sloane Street.

The building covers the entire site, which measures 44.4 m by 39.5 m and the gross building area is 6340 m². Fig. 1 shows a general isometric at Level 2 (first floor).

The main block fronting Sloane Street is six storeys high and contains at ground floor level, the visa and information department situated directly off the main entrance foyer, a lecture/exhibition hall, Ambassador's entrance and other ancillary rooms. The first, second and third floors contain the Chancellery proper, which basically comprises the Ambassador's office and all other offices for the diplomatic and consular staff, conference rooms, library, etc. These rooms are arranged on either side of a central corridor running the length of the building on each floor and are reached from a glass-enclosed metal staircase entered from the entrance foyer.

The fourth floor is the Ambassador's official residence and provides large reception and dining areas for diplomatic functions, plus kitchen and support facilities to cope with official occasions. Running the entire length of the building on the Sloane Street elevation is a balcony that leads directly from the reception rooms. A similar, but smaller balcony adjoins the Ambassador's library at the rear.

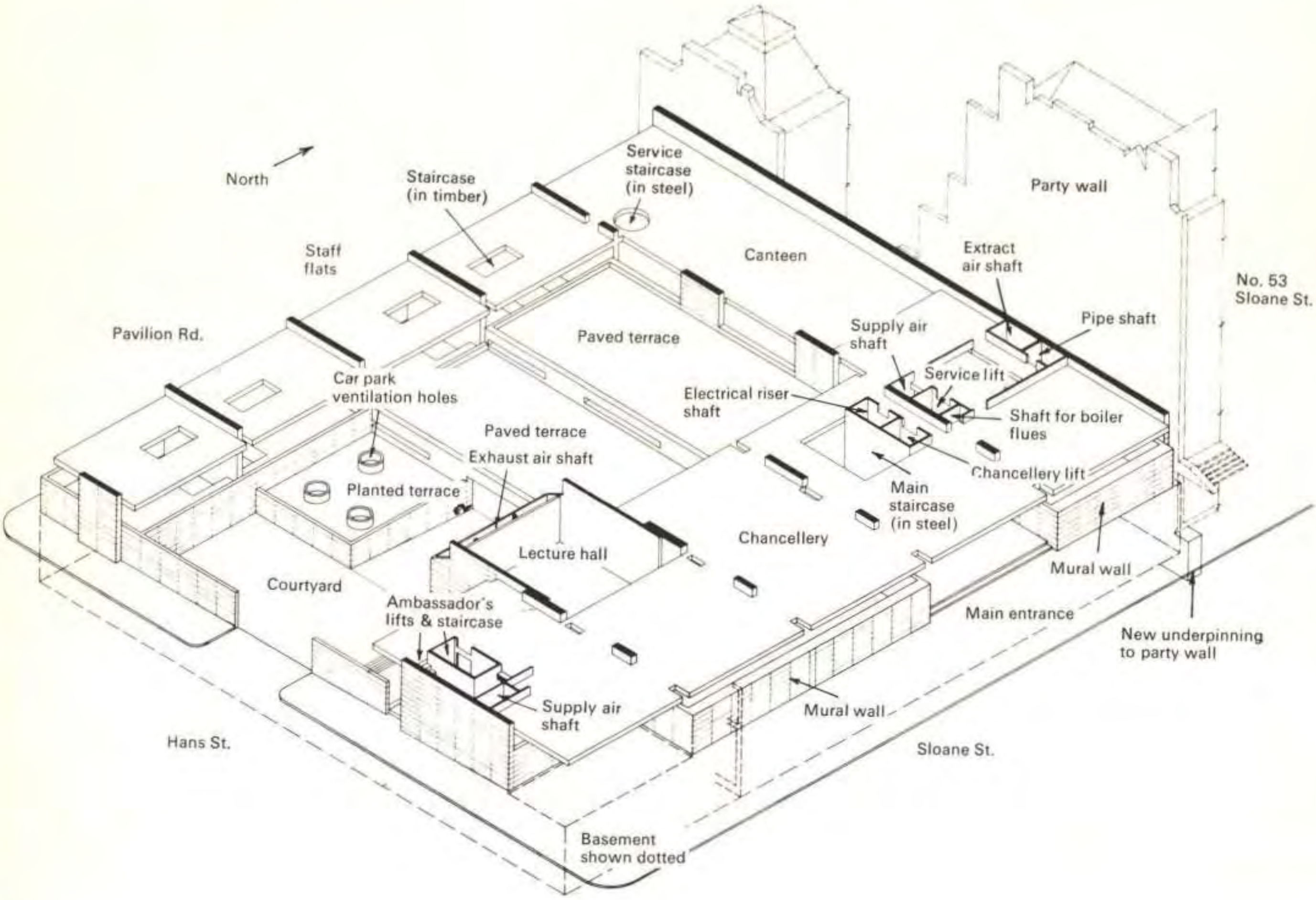


Fig. 1
Isometric at Level 2 showing structure

The sixth floor contains the Ambassador's private residence, with guest rooms, maids' rooms and all supporting facilities.

A plant room structure on the roof houses two lift motor rooms, air handling plant for the Ambassador's residence, a standby diesel generator set and cooling towers. Access to this level is via a spiral staircase in a glass enclosure on the rear elevation (Fig. 2). Two window-cleaning cradles on separate tracks are situated on the roof to clean each elevation, one being on the main roof, the other on top of the plant room roof.

Along Pavilion Road is a two-storey block containing four self-contained staff flats. Each flat has its own entrance onto the street and is large enough for a family with children. The flats house the Embassy 'support' personnel – caretaker, chauffeur, etc.

The area between the two buildings forms a courtyard. At the northern end, this is enclosed by a canteen at first floor level, which connects the two buildings, forming a 'U' shape in the overall plan arrangement.

From the canteen there is access onto a split level terrace, which covers half of the remaining courtyard and provides covered parking underneath at ground level.

A basement covers the entire site and contains car parking, laundry archive and store rooms, plant rooms, fuel storage tank and switchroom. Vehicle access is via a straight ramp behind the staff flats.

Fig. 2
Rear elevation from courtyard
(Photo: Harry Sowden)

Overall architectural concept

The site was previously occupied by a terrace of houses and, to reflect this, Jacobsen divided both buildings into five equal bays with the structural cross walls retaining the general pattern of the old party walls. The building line of the Chancellery along Sloane Street follows its neighbours but, at the Ambassador's residence level, the façade is set back to respect the parapet height of the adjacent buildings; this set-back naturally formed the balcony fronting the reception rooms. The massing of the overall building takes into account the bulk of its neighbours and the previous houses, in that the rear elevation steps down to the courtyard and then rises very slightly in the form of the staff flats; this a traditional pattern of buildings in the area, where large terraced houses to the main street have a mews to the rear. The courtyard between the two buildings also forms a perfect foil to a similar garden space in the existing buildings to the south of Hans Street. Fig. 3 shows the relationship with surrounding property.

Cladding materials

Where visible above ground, the structural walls have been cast using black concrete poured against extremely well detailed and constructed shutters, to give a rectangular pattern of grooves. The whole subject of the black concrete, its evolvement and history is far too detailed to explain in this article but briefly, the decision to use it came after investigations into many alternatives and black was chosen to help blend in with the dark colour of buildings in the vicinity. A rigorous specification was drawn up after a lengthy period of experimentation, the required shade being obtained by using pulverized fuel ash, black oxide powder pigment, dark grey basalt coarse aggregate and brown fine aggregate.

For security reasons, the ground floor is enclosed by a concrete wall on all three elevations, being pierced only at entrances. As Ove Arup's contribution to the June issue of *The Arup Journal* has already mentioned, the client was conscious that a long blank wall in any material along Sloane Street could be dull and to remain coherent with the visible structural walls, this surface had to be in black concrete. It was therefore decided to incorporate a mural, and a Danish artist, Professor Ole Schwalbe, was commissioned by the client to carry this out. Schwalbe's concept was to reflect the decorative effects visible in the older building details which he saw in the neighbourhood. He made a number of visits and took photographs from which to work. The outcome was a 'flat relief' within the architect's basic planning module and Schwalbe designed a series of circles, crosses, rectangles and squares all reflecting the effects that tend to occur in the local buildings (Fig. 4).

The three upper Chancellery floors and the upper floor of the staff flats are enclosed by box-type window wall units made up from extruded aluminium hollow sections around a steel skeleton structure. Each window unit is storey height and covers the complete 8.4 m between the lines of the cross walls (Fig. 6). The windows have light brown tinted glazing, and external sliding blinds are provided to help reduce heat gain from direct sunlight. When not in use, the blinds are parked behind a central fixed aluminium panel.

The box units at the Hans Street gable wall end are made up from an insulated steel framework clad in the curved aluminium sheets that match the window units (Fig. 5). All the aluminium is painted a brown/yellow colour.

The Ambassador's residence is clad in a plain curtain walling, again with brown tinted glass windows and non-translucent glass

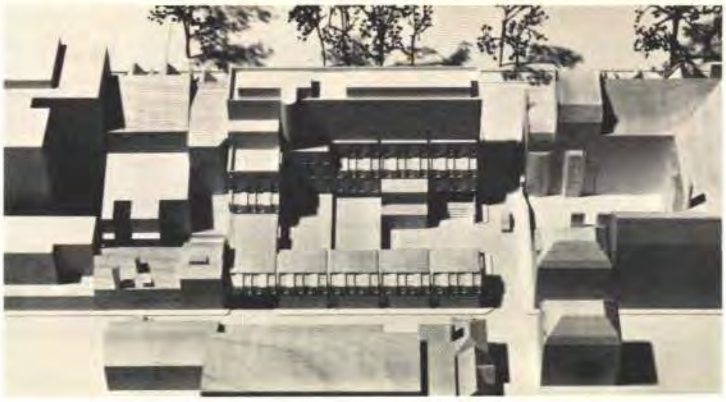


Fig. 3
Rear view of model (Photo: Mydtskov and Rønne, Copenhagen)

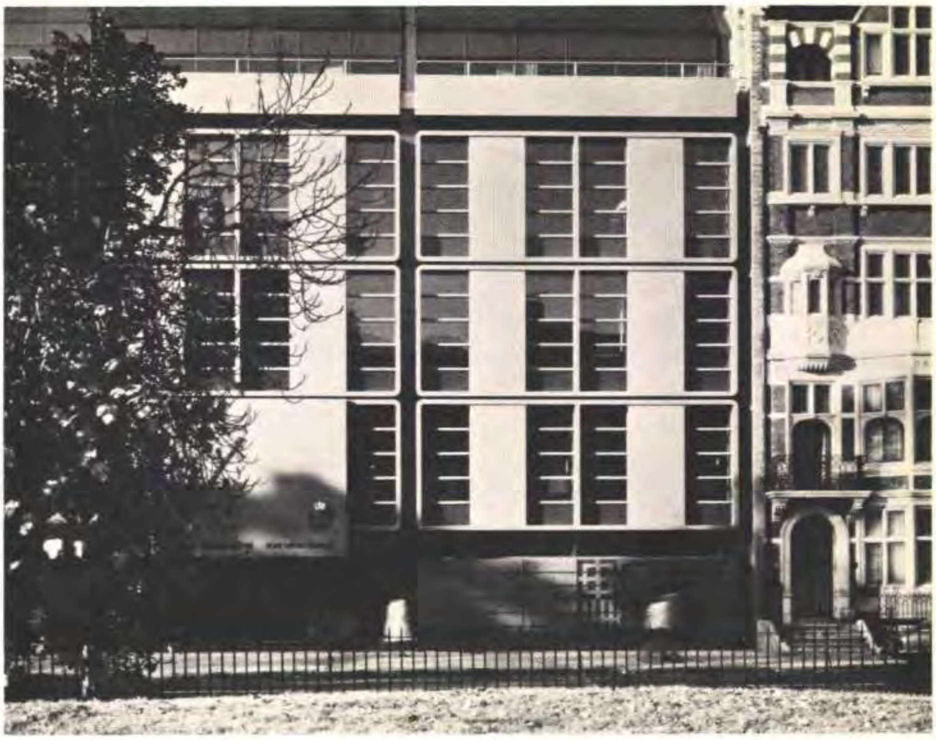
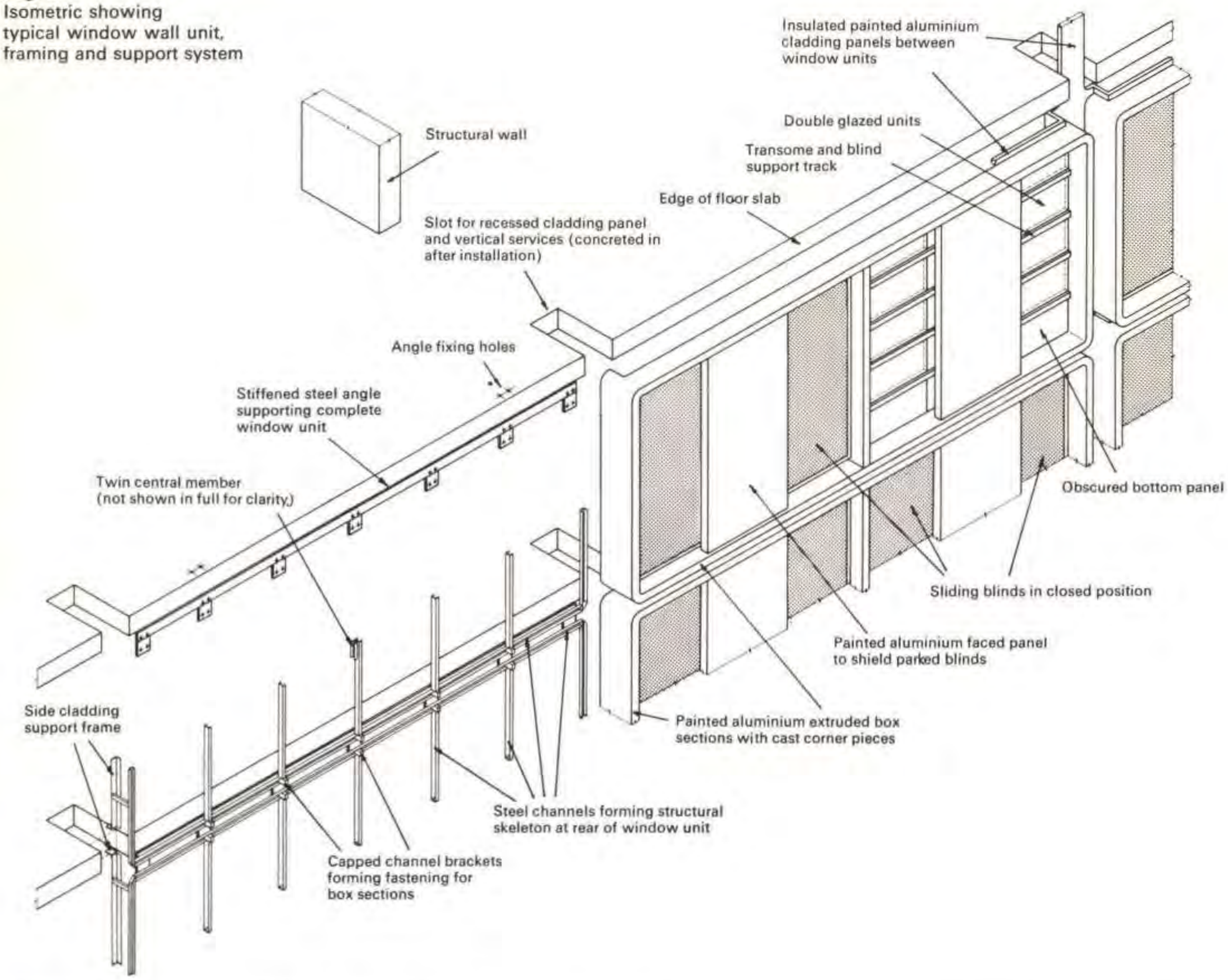


Fig. 4 above
Part of Sloane Street elevation (Photo: Harry Sowden)

Fig. 5
Hans Street/ Sloane Street corner (Photo: Colin Wade)

Fig. 6
Isometric showing typical window wall unit, framing and support system



panels. The curtain wall reflects the changes in the sky during the day and is one sheer plane, the mullions and transoms being on the inside face to make this face as unobtrusive as possible. Except for the staircase tower at the rear and some small conservatory projections on the Sloane Street face, these walls are a plane face divided into clearly defined bays at the cross wall positions.

STRUCTURAL ASPECTS

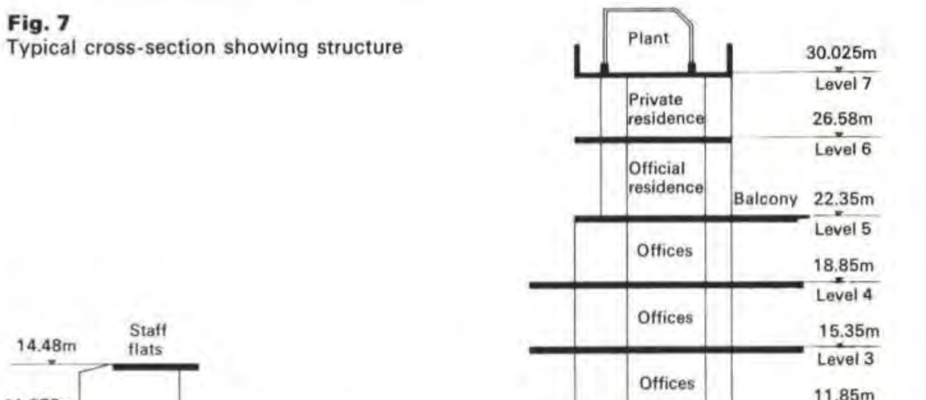
Substructure

The site investigation revealed 5 to 7 m of medium dense sandy gravel overlying stiff fissured London clay. The water table was approximately 8 m below street level. As the cross walls became longer at lower levels, the most sensible foundation was to provide strip footings. To limit differential settlement between the six-storey and two-storey blocks, different bearing pressures of 300 and 200 kN/m² respectively were recommended.

As no part of the substructure went below the highest recorded water table level, no trouble was envisaged, or indeed encountered, during construction. We did, however, design and specify the entire basement as a water-tight construction with rearguard waterbars in every construction joint, which we pre-determined and detailed in conjunction with the contractor during the second stage tender period.

Two other associated problems were under-pinning the entire length of the adjacent party wall to no. 53 Sloane Street and re-propping the high part of this wall by a suitable new steel shore until such time as the new building re-stabilized it.

Fig. 7
Typical cross-section showing structure

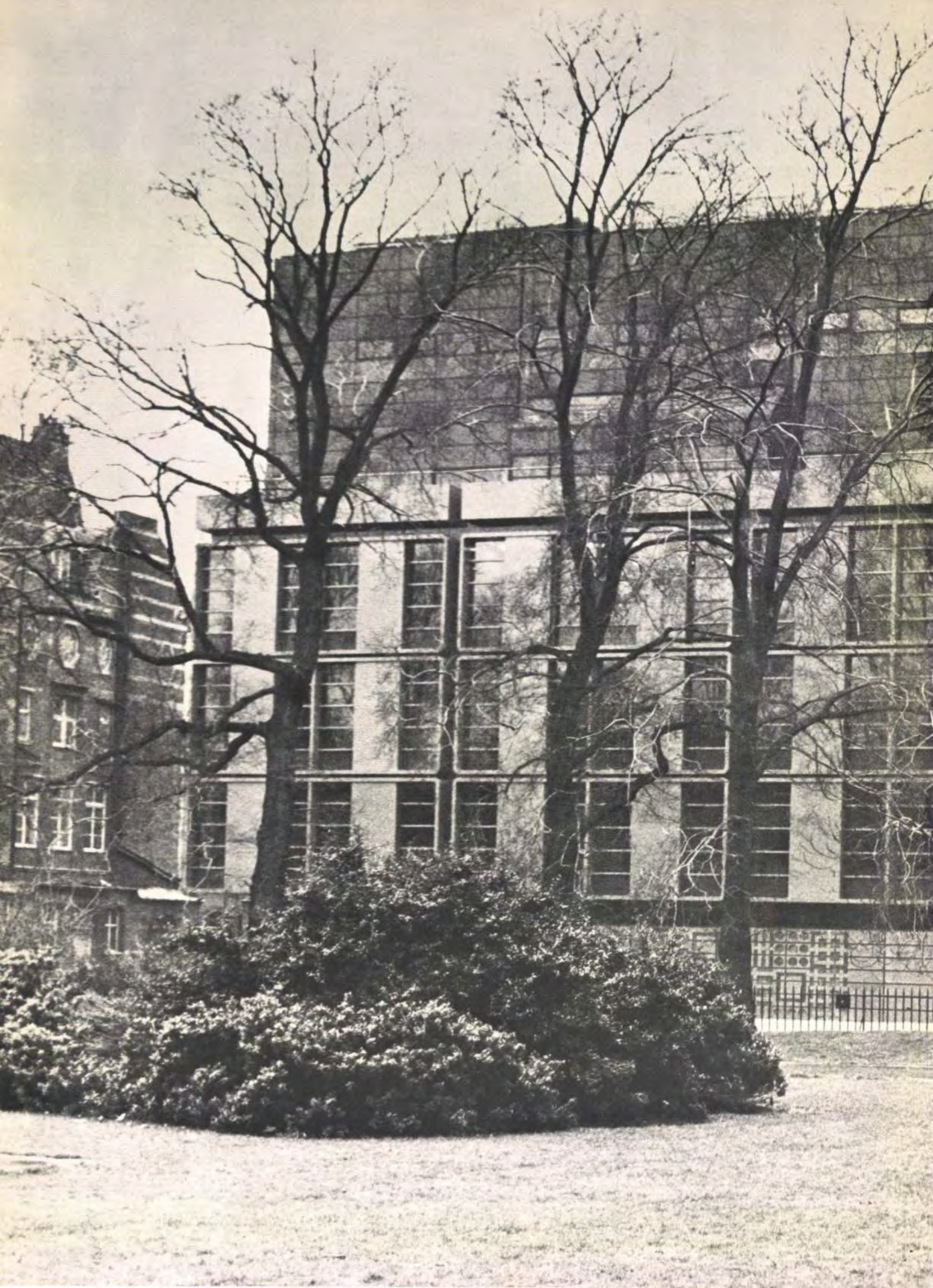


Superstructure

The basic structure of the building is very simple and strictly speaking comprises two elements – namely walls and slabs, i.e. no columns and (very nearly) no beams – and, apart from the steel framed plant room on the main roof, the structure is entirely of in situ reinforced concrete.

As mentioned, the bay size of 8.4 m stemmed from the wish to reflect the party walls of the original houses and this led to the basic vertical structure as a series of cross walls for all three areas – Chancellery, canteen/courtyard and staff flats; these are 400 mm thick at 8.8 m centres. Fig. 7 shows a cross-section through the building indicating this arrangement. Although the walls take vertical load and give lateral stability, there are two core areas, one at each end, for lifts, boiler flues, air shafts and service risers, which also take much of the wind load and give all the longitudinal stability.

Photo: Colin Wade



Except for the basement floor, terraces and Chancellery roof, all slabs are solid and 325 mm thick. Structurally, the floors were the most interesting aspect due to the configuration of the supports, holes, openings for stairs and the cantilevers occurring in the upper levels of the Chancellery and staff flats. The largest cantilevers occur on the Sloane Street elevation where the four upper floors project 3.8 m past the ends of the cross walls to carry the window wall units. Fig. 8 shows a plan of the structural arrangement at Level 3 (fourth floor).

It was appropriate to feed services from the basement plant rooms via vertical shafts then distribute horizontally within the suspended ceilings along the corridors and into the offices. Due to this requirement and to planning restrictions on building height, the headrooms were limited, so it was felt undesirable to have a downstand beam solution; therefore a flat slab was considered the favourite.

The decision to cantilever the floors was brought about mainly by the planning consent given by Kensington & Chelsea Borough Council, which required, within the Sloane Street building line, a minimum 4.5 m x 4.5 m pavement on the Sloane Street/Hans Street corner. The architect also wished to have a continuous glazing strip along the top of the mural wall to Sloane Street.

Early investigations were made to try to avoid cantilevering the slabs, but all had planning, architectural or structural problems, so, having decided to cantilever the slabs with a heavy line load from the window wall units on the extreme edge, we began checking the actual form of the slab.

Five types were considered: solid normal weight prestressed with unbonded tendons, solid or coffered normal weight reinforced, and solid or coffered lightweight reinforced.

The unbonded tendon solution looked extremely interesting and some work was done in consultation with C. C. L. Ltd. However, it was rejected partly due to cost and partly for practical reasons, these being an inability to easily accommodate holes, staircases and changes of level.

Lightweight schemes were also rejected, more on pratical grounds than on economics, especially for the cantilevers where shear stresses and deflections were high.

It therefore became a straight choice between solid or coffered reinforced concrete and, on a weight basis, a coffered scheme was adopted in early 1971.

Solid versus coffered scheme

When the project resumed, we kept our options open about the coffered scheme, but as details were developed we were not entirely convinced about the solution and decided to look again at various schemes whilst acknowledging what had been done previously. Again the choice narrowed to solid versus coffered and, after more investigation, we chose, for practical reasons, a solid slab.

The most complex part of the design proved to be the cantilever slabs, as we were naturally very concerned about the deflections. Our biggest worry was the final visual aspect of the window walling units being out of line due to differential deflections on different floors. As well as dissimilar support conditions of the slab panels at each end of the building, i.e. the party wall end being continuously supported on one edge whilst the Hans Street panel had no edge support at all, the presence of cut-outs at the edge of the slab between each window wall unit gave a discontinuity and did not help our ideas of ironing out deflections. To avoid distortions due to any slab deflections, each 8.4 m long window unit is supported at only two points by bolt fixings through the slab; the window unit itself spans between these points on a large stiffened angle member. Each unit is supported by the slab it sits upon, the top fixing being purely a lateral restraint which allows for vertical movement due to differential deflections.

Numerous desk computer runs were made with varying load patterns and reinforcement configurations to check moments and deflections whilst a finite element elastic analysis was carried out for the most irregular floor, Level 2 (i.e. first floor) of the Chancellery.

The computer analysis was done with the PAFEC finite element program and good correlations were obtained between this output and the hand calculations on deflections along the free edge of the cantilevers. Reinforcement patterns were kept as simple as possible with banded arrangements over the support lines in the direction of the cantilevers. The only complication was the need for shear steel at some of the supports to the large cantilevers on the Sloane Street side.

Although the two stage tendering procedure allowed us to agree many problems with the appointed contractor in advance of site work, we pointed out in the First Stage Contract Documents the special attention that would be needed for the cantilevers, particularly to propping and cambers. As the design continued and the slab analysis became final, we produced a series of floor drawings showing cambering levels for all slab panels together with the special lines of propping which we considered necessary. The contractor, in close liaison with the resident engineer, followed our proposals

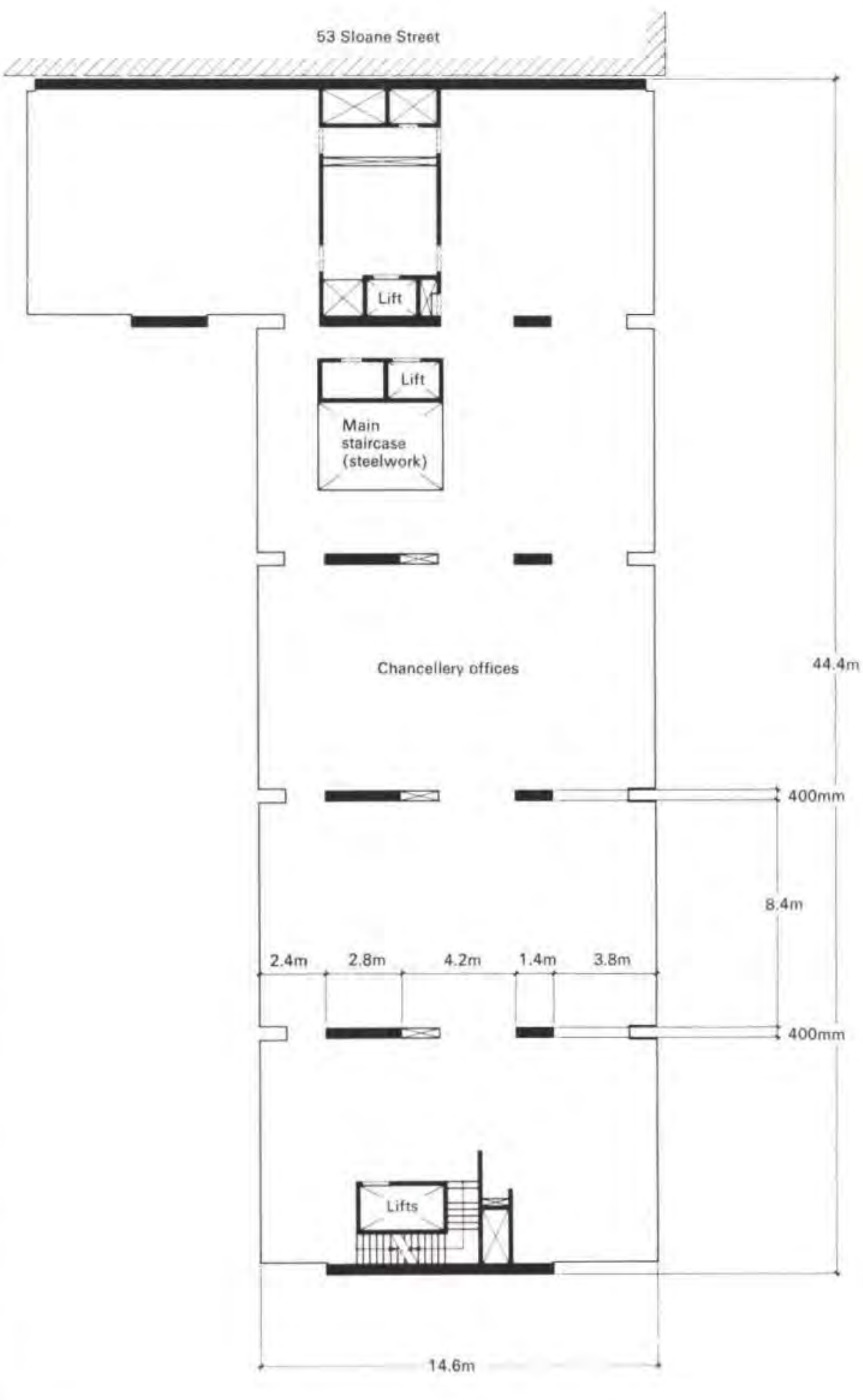


Fig. 8
Plan at Level 3 showing structure of Chancellery block

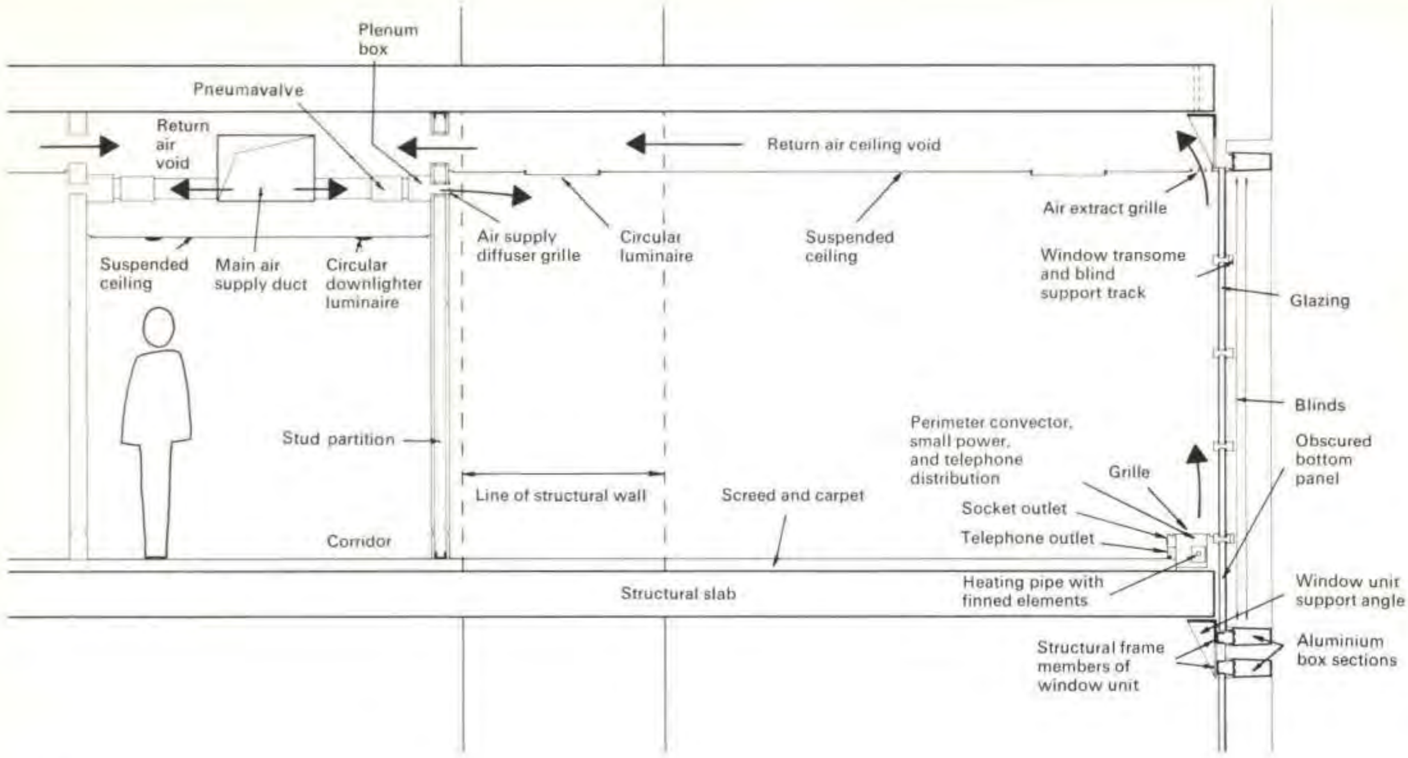


Fig. 9
Cross-section through typical office

very carefully and the actual deflections of the de-propped cantilevers were recorded. Apart from some odd readings, the dead load deflections were quite close to the calculated values. Due to sight lines and access problems, it was not possible to check when all the other dead loads were applied, particularly by the window units, but it was quite gratifying to know that what seemed at the outset to be over-large cambers would one day be nearly level when long-term effects were taken into account.

MECHANICAL SERVICES

Sloane Street is a heavily trafficked thoroughfare, linking Knightsbridge with Chelsea, and after surveys were carried out during the early design stages it became obvious that noise and, to a lesser degree, air pollution, would be major factors in the design of the internal environment of the building.

The Chancellery was therefore to be fully air-conditioned and only a small percentage of windows in the Ambassador's floors are openable. The staff flats, being remote and sheltered from Sloane Street, are not air-conditioned and have opening windows.

Air-conditioning

There are three separate air handling systems serving the Sloane Street block. The first caters for the Lecture Hall on the ground floor, the second serves the remainder of the ground floor, the canteen and the upper office floors, and the third, the Ambassador's official and private residence.

Lecture Hall

The Lecture Hall has an individual ducted supply served from a multi-zone air handling unit situated directly below it in the basement plant room. The air is discharged into the Hall via high level horizontal linear grilles set in the wall panelling. Return air is either discharged via a shaft in the courtyard which forms the end of the Lecture Hall or is re-circulated, depending on the room conditions. Fresh air is drawn into the plant from the same shaft that supplies the offices. Temperature and humidity are controlled to pre-determined levels by thermostats and humidistats located in the return ductwork. The thermostats are arranged to modulate dampers on the plant to ensure correct mixing of the discharge air to maintain the desired temperature.

Offices

The air-conditioning system to the three office floors is of a single duct, variable air volume type and works in conjunction with a perimeter heating arrangement. High velocity air is drawn in at roof level via a shaft to the air handling plant in the basement, treated, distributed vertically in a single shaft to each floor then horizontally along the corridors to terminal volume controllers serving each room. The air is discharged through the walls via horizontal linear grilles just below ceiling level. Exhaust air is taken through a linear grille in the suspended ceiling adjacent to the window wall units. Fig. 9 shows a typical cross-section through an office and corridor.

Although demountable, the ceiling is sealed and the entire void above the offices between ceiling and floor slab acts as a return air plenum. The ceiling void above the corridors serves as a collecting return air plenum for each room. This air is taken back via a shaft to the basement for re-circulation/mixing or is expelled via the Lecture Hall exhaust system as necessary.

The office room temperatures are maintained by thermostats designed to vary the quantity of air being emitted, depending on the room requirements. A control limiter maintains a minimum air rate to ensure that a sufficient amount for ventilation is achieved when the heat loads in the room diminish.

The static pressure of the system is maintained at a pre-determined constant on each floor by pressure control valves whilst the fan static discharge pressure is maintained at a constant by varying the pitch angle of the blades on the supply fans located in the plant room.

The system will limit the average relative humidity of the office and circulation spaces between the summer maximum and the winter minimum conditions by the operation of a spray coil, initiated by a humidistat located in the return air duct.

The perimeter convector heater is designed to off-set the fabric heat loss and limit the down draught effect associated with the glazing. This is situated at floor level against the window walling and is continuous across each room. Incorporated in the side of the casing is a twin compartment trunking containing small power and telephone cables with integrated socket outlets. (Fig. 10).

Ambassador's levels

The Ambassador's air-conditioning system operates as seven individually controlled zones, five on the official residence level and two on the private residence level.

A common exhaust duct takes air back to the roof plant room for re-circulation/mixing or to be exhausted as required. Temperatures are controlled to pre-determined set points by thermostats located in each room. The thermostats are arranged to modulate dampers on the multi-zone air handling discharge unit which mixes varying quantities of hot and cold air to maintain the correct room temperature.

In the private residence, individual temperature control is achieved by room thermostats controlling heater batteries located in the false ceiling above each bedroom.

Fig. 10
Typical perimeter convector heater casing in offices, showing socket outlets (Photo: Colin Wade)

Plant

As well as the majority of the air handling plant, the basement plant room contains the boilers, refrigeration plant and all associated pressurization, pumping and control equipment.

There are two boilers, one being the main heating boiler, the other a smaller hot water service boiler. They are of cast iron construction and are rated at 698 and 296 kilowatts respectively. Both serve a pressurized system, operate on natural gas having a calorific value of 38 Megajoules/m^3 and produce hot water with a temperature of 103 C. (Fig. 11).

The water chilling plant comprises an electrically-driven, screw-type compressor with shell and tube-type condensers and evaporators. The chiller has a cooling capacity equivalent to 588 kilowatts and is designed to produce water with a temperature range between 5.6 and 12.6°C.

Heat from the condenser is passed into the condenser water system which dissipates the heat through the cooling tower on the roof. The cooling tower is a forced draught-type fitted with centrifugal fans; the temperature of the condenser water is controlled by the operation of a mixing valve in the water circuit.

PUBLIC HEALTH AND FIRE FIGHTING SERVICES

All hot and cold water services are softened before distribution by a water softener located in the main plant room together with the water storage tanks and associated boosting pumps.

All sanitary ware has been installed with *Vola* fittings which were originally designed by Arne Jacobsen.

For fire fighting, the office floors are provided with 'concealed' hosereels at strategic points and are supplied by a boosted installation from mains supply with a standby pump set and a 2000l tank in the basement plant room. The basement car park is protected by a sprinkler system which is supplied from duplicate mains.

ELECTRICAL SERVICES

Two 400 amp services from the London Electricity Board supply the maximum demand load of 400 kilovolt ampères. Each is terminated onto a switchboard adjacent to the basement plant room. One service is for non-essential lighting and power circuits to the whole building, the other, via sectioned bus bars caters for:

(a) Non-essential supplies to domestic areas

(b) Essential supplies to selected lighting circuits of the whole building, the Ambassador's lifts and services associated with the Ambassador's residence.

An automatic standby diesel generator set, rated at 187.5 kVA feeds onto the essential section of the second switchboard in the event of electricity supply failure. Dual feeds to the mechanical services main control switchboard, located in the basement plant room, also enable standby supplies to be provided for a proportion of the total connected HVAC load sufficient for essential requirements to be maintained. The generator set, located on the roof, is supplied from a local

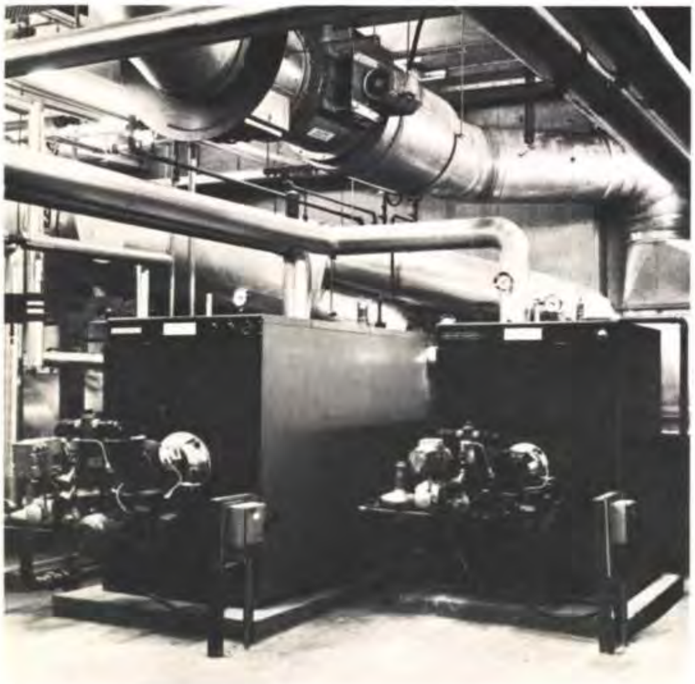


Fig. 11
Boilers in basement plant room
(Photo: Colin Wade)

Fig. 12
Lecture hall at ground floor: detail at main doors
(Photo: Colin Wade)

Fig. 13
Corridor on typical office floor and main staircase enclosure
(Photo: Harry Sowden)

Fig. 14 right
Spiral staircase adjacent to Pavilion Road entrance gate
(Photo: Colin Wade)

day tank fed from a main storage tank located under the access ramp in the basement.

Electrical supplies are generally distributed vertically via two 250 amp triple pole and neutral rising bus bar systems (for essential and non-essential supplies); final sub-circuits are taken through fused switch and distribution gear and wired with pvc-insulated single core cables in concealed conduits and trunking. Separate supplies are taken from the basement switchboard via pvc-insulated multi-core cables to the staff flats.

The connected lighting load for the whole building is nearly 130 kVA, a large proportion being tungsten filament sources. Both recessed and ceiling-mounted surface luminaires have been used. Generally, circular recessed downlighter-type fittings are used in the circulation spaces, staircases and Ambassador's reception rooms. The offices are lit by circular, surface-mounted, Munkegaard fittings which were originally designed by Arne Jacobsen many years ago for a school in Denmark. The Lecture Hall is lit by recessed and tubetrack fittings. Dimming and projection facilities are provided for film shows, lectures, etc., with the projection room situated at first floor level.

Telephone requirements are provided by linked PMBX and PABX systems, the former giving a more personal service to the Ambassador and the latter an automatic service for internal and external communications generally. These systems are supplemented by four telex machines for the various departments in the Chancellery. Private lines are provided to the staff flats and a coin operated telephone for the use of visitors is located in the visa waiting area.

Strict security of the entire building is maintained at all times with the aid of remotely controlled doors and by visual coverage of certain areas by a closed-circuit television monitoring system.

Fire prevention is aided by a combined fire alarm system operated from manual break-glass points and automatic smoke detectors with provision for the shutting down of all plant and for alerting the fire brigade.

Four lifts are installed: one accessible directly from the entrance foyer serves the office floors, one serves as a personal and service lift for the Ambassador's domestic staff, whilst the remaining two serve the demands of functions in the Ambassador's official residence. The latter also serve the private residence.

A receiving aerial and cable system distributes amplified broadcast television signals to a number of locations in both the domestic and office areas.

QUANTITY SURVEYING AND COST CONTROL

First estimates

Early in 1968, we provided an analysis of the cost data available at that time for a standard office block, fully fitted out and with limited areas of high quality finishes and partial air-conditioning. Due to the unknown factors, the site being uncertain and no architect having been appointed, our figure was suitably qualified. In November 1968 this was followed up by a brief cost study based on area requirements given by the client. Again, no design information was available and heavily qualified high and low costing limits were given.

In early 1969 the initial brief was re-defined and we began working from a detailed area requirement analysis provided by the client, together with a single sketch of a proposed ground floor plan and east/west section showing a building roughly following the shape of those already on the site. By April 1969 we had drawn up an envelope cost for a building of 6200 m² with a fairly basic specification.

After Jacobsen's appointment we began preparing estimates based on approximate quantities from his outline sketches and these, with reports, went to the client at frequent intervals between September 1969 and May 1971. During this time it became apparent that the original cost comparison with a speculative office block no longer held good, the quality of the building now envisaged being considerably higher than we had first allowed for. Estimates were getting progressively higher as the design proceeded, and significant concessions had to be made by the architect until by May 1971 we had achieved a figure which formed the basis for a new budget accepted by the Danish Ministry of Finance, shortly before the scheme was postponed.

Fig. 15
Visa and Information Department on ground floor
(Photo: Harry Sowden)

Fig. 16
Detail at Ambassador's entrance
(Photo: Colin Wade)

Fig. 17 right
Black concrete side wall to lecture hall
(Photo: Colin Wade)

Fig. 18
Sloane Street elevation
(Photo: Colin Wade)

Revived scheme

When the client was considering reviving the scheme in March 1973, we were asked to give an idea of the scale of inflationary movement since May 1971. Our initial reaction was to update the budget using the index of building costs published by the Building Cost Information Services (BCIS) of the Royal Institution of Chartered Surveyors, which we had been using prior to 1971 to apply inflation increases to the estimates. However, on pricing the May 1971 approximate quantities estimate it was evident that the BCIS index was not reflecting the 'market' increases in tender prices but little more than the basic rise in labour and material prices. During the early '70s the building industry was experiencing enormous increases in tender prices. These were caused by a combination of an upsurge in demand which the industry was not geared to meet, and the oil price increases. It became clear that the Department of Environment tender index introduced in 1972 was the more accurate indicator to use in these circumstances and this was accepted by the client.

Two-stage tendering

Construction was due to start in 1975, and we recommended to the client that a two-stage tendering procedure be adopted. The main reason for considering this is to enable the design team to bring in a contractor at an earlier stage than usual. His expertise, knowledge and facilities can be used to firm up design and contractual points, to assist in selecting and obtaining quotations from sub-contractors and to advise on construction methods, in order to obtain an accurate cost before construction work begins. In our case we also felt that an overseas architect, not familiar with UK practice and conditions, would be able to make good use of the second stage period in firming up his requirements, particularly with regard to UK supplies, fittings, etc.

The first stage tender based on a bill of approximate quantities was returned in May 1974 and the lowest bid was £2,254,178. However, the budget was fixed at £2,133,000 which was established by updating the May 1971 budget using the DOE index. We made full use of the second-stage period to effect the necessary savings, and by December 1974 had established the cost at the budget figure. During this time the substructure was remeasured and 17 sub-contract tenders were obtained; the total value of sub-contracts being approximately 50% of the contract. Authorized additional expenditure for improved health and safety requirements by the Statutory Authorities, increased security measures, and inflation have raised the contract sum. We now anticipate the final account to be in the region of £3,450,000, 35% of which is increased costs.

Credits

Client:
Danish Foreign Ministry

Architect:
Arne Jacobsen/Dissing + Weitling

Main contractor:
Harry Neal Ltd.

Sub-contractor for concrete structure:
Caxton Reinforced Concrete Ltd.

Services sub-contractor:
Matthew Hall Mechanical Services Ltd.

Oil related developments in Scotland: 1971-78

Tom Ridley
George Pease

Introduction

The fortunes of the oil and gas industry appear to be as fluid and volatile as the minerals themselves, and the impact of their development in Scotland has been equally unpredictable. Differing timescales of development, field characteristics and land-base requirements have caused wide variations in the types of facility required and the engineering expertise needed to provide them.

1971–75 saw a rapid rise and an equally rapid decline in projects and proposals devised to meet these requirements of the exploration and development phases of the oilfields. In 1974, perhaps the peak year of activity there were over 100 projects in hand or proposed around the shores of Scotland–the impact has been almost exclusively on the coastline–and these projects were widely distributed as the map (Fig. 1) shows, related more to the suitability of the sites or locations for the purpose required, rather than to the location either of the fields or of the markets to be served.

Whether the oil developments will prove in the long run to be a benefit or a cause for regret is as yet unclear, but the cushioning effect of oil on the unemployment situation, the reversal of population decline and the difficulties faced particularly by remote and sparsely populated areas in dealing with the arrival of large-scale industries are well known.

The initial administrative responses to the pressures created were often slow and ill-timed but despite the downturn in investment which has characterized the last two-three years, investment in infrastructure has been continuing, notably with road and rail improvements.

The production phase began with the landing of the first oil from the Forties Field in 1975 and further exploration and development, together with the growing requirements of platform and sub-sea maintenance, has provided a continuing demand for skills and materials particularly through service bases on the east coast. The fate of platform and module fabrication yards has been much more uncertain. Many of the yards proposed in 1974 failed to materialize and several of those that did are now closed or in difficulties.

This chequered history has been imposed on different parts of the country in different ways but the recent period of recession has allowed the communities affected to meet the problems created and has seen the establishment of a more settled pattern of activity. Problems still remain in several areas—notably the West Coast—but the country has now largely come to terms with the offshore oil industry.

Onshore oil-related industrial activity has fallen into three broad categories:

(1) Platform and other fabrication yards

(2) Service bases and back-up supply industries

(3) Terminals, storage areas and pipeline systems.

Fig. 1 shows the distribution of projects of these three kinds. Of the 17 areas shown, Ove Arup and Partners have been involved in projects in six—Shetland, Orkney, Caithness, the North East, the Tay and Forth Estuaries.

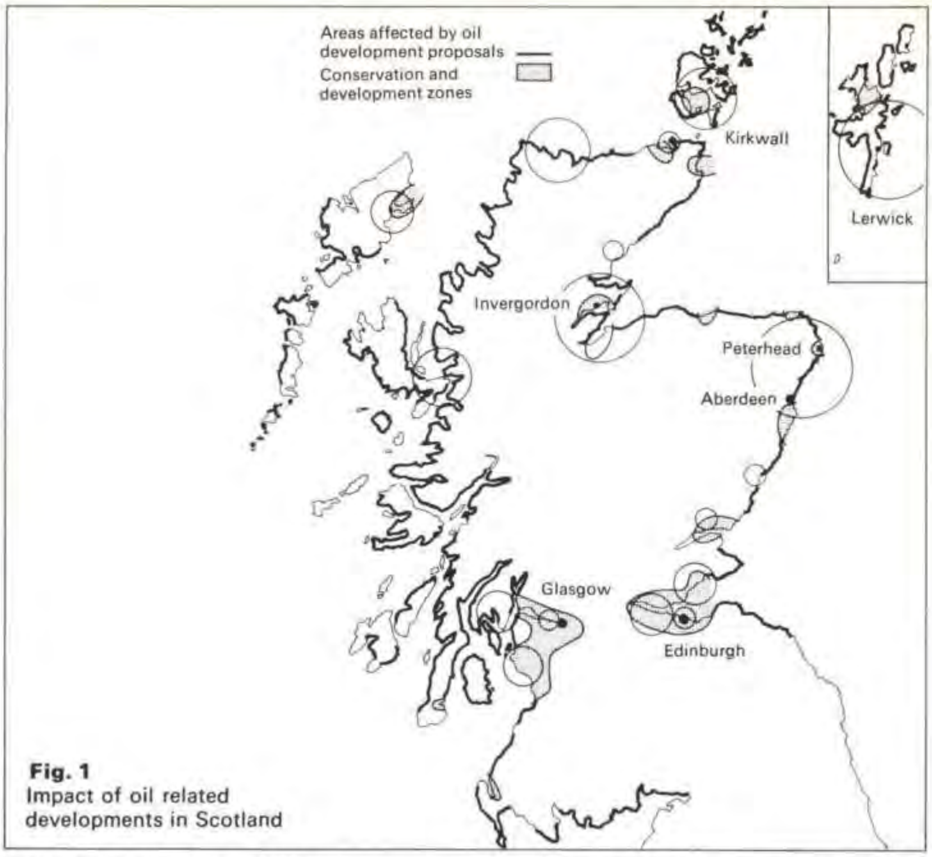


Fig. 1
Impact of oil related developments in Scotland

Offshore production platform structures industry

Our first awareness of the engineering challenge being faced by the development of oil and gas reserves in the North Sea was the sight in 1971 of the BP Forties field steel structures design on the drawing boards of Brown & Root in Houston, Texas. These structures are higher than the tallest buildings in the UK and were clearly stretching the design technology of US engineers due to the severity of environmental conditions and 100–150 m depth of water. This not only limited the construction 'weather window' for a piled steel structure, but made the overall economics of oil or gas field development in the Northern North Sea very questionable. Why not consider the obvious advantages of an offshore concrete structure, with only its own weight on the seabed to provide a fixed platform for production operations without the need for piling? During late 1971 and early 1972 this possibility was discussed with a number of civil engineering contractor friends. It was given much encouragement by the confidence being placed in the construction of the large concrete oil storage tank for the Ekofisk oilfield by Phillips Petroleum. Several UK contractors were then forming joint ventures with French, Dutch and Norwegian partners to win a place for concrete structures in future North Sea developments. All were considering Scotland as the natural location of their UK construction activity.

The success of this idea is illustrated in Table 1 which gives details of the 13 concrete

Table 1: Concrete structures in the North Sea

Type	Name	Operator	Year	Water Depth: m	Foundation Soil
Doris	Ekofisk	Phillips	1973	70	Dense fine sand
Condeep	Beryl A	Mobil	1975	120	Dense fine sand over clay
Condeep	Brent B	Shell	1975	140	Stiff clay with sand layers
Doris	Frigg CDP1	Elf	1976	96	Dense fine sand
Sea Tank	Frigg TP1	Elf	1976	104	Dense fine sand over clay
Doris	Frigg MCPO1	Total	1976	94	Dense fine sand
Condeep	Brent D	Shell	1976	140	Stiff clay with sand layers
Condeep	Statfjord A	Mobil	1977	145	Stiff clay
Andoc	Dunlin	Shell	1977	153	Stiff clay with sand layers
Condeep	Frigg TCP2	Elf	1977	102	Dense fine sand over clay
Doris	Ninian	Chevron	1978	136	Stiff clay with sand layers
Sea Tank	Brent C	Shell	1978	140	Stiff clay with sand layers
Sea Tank	Cormorant	Shell	1978	150	Stiff clay with sand layers

platforms installed by the different contractor consortia up to 1978. We helped two consortia who were unsuccessful in their efforts to win a place on this list so missing the final reward of being involved with one of these installed structures.

During this period the designers of offshore steel platforms have carried out intensive development work to refine their longstanding technology on the design, fabrication and performance of this type of structure. Fabrication yards in the North of Scotland have been established with the leadership of major USA offshore contractors and in the Firth of Forth by the nationalized British Steel Corporation, and these have successfully maintained their competitiveness in answer to the challenge from concrete structures. At the present moment, there is a balance in favour of steel structures for use on the currently located new offshore developments where piling into the seabed soils encountered can be carried out without difficulty. There are future locations where very stiff clays and dense sand seabed soils will make the concrete structure an attractive solution, and we consider further developments in design will attract future orders for more of these to be built in Scotland.

Onshore service bases

During the period when our engineering skills were being excited by the rapid development of design technology to deal with the offshore concrete platform structures, we became aware of the increasing impact the new marine activity was having on the existing harbours along the east coast of Scotland. This activity had been in progress since 1968 when the first offshore exploration drilling rigs had needed supplies from onshore during their short summer season period of drilling operations.

As the number of rigs increased, and successful oil and gas discoveries were made, the demand for onshore services became so great that existing ports like Aberdeen could no longer cope with the needs for quayside space and warehousing to meet the oilmen's requirements. This led to a number of traditional Scottish firms looking for new opportunities to venture into the onshore supply industry for these exploration rigs as their first step into the oil scene.

At once it was discovered that new marine developments on the scale envisaged were totally against the tradition of our history of slow growth of port facilities. This kind of development is wholly entrusted to long-established port authorities, whose chief problem is to balance new developments against the post-war trend of diminishing cargo traffic. The 'short-term' nature of the oilmen's activity with the peak months only extending from April to September, made this traffic a welcome but difficult one to entertain.

Our interest became involved in 1972 with the prospect of large new onshore service bases being provided in locations best suited to deal with the shortest sailing times between the exploration rigs and their supplies of pipes, drilling muds, cement, water, fuel, etc. The drilling crews were transported by helicopters from the nearest main airport, and this led to Aberdeen becoming the key location of personnel for the expanding population of oil-related labour force.

Shetland Islands: Sullom Voe oil terminal development

The combination of a knitwear manufacturer, quantity surveyor and amateur geologist was our first introduction to the oil scene in the Shetland Islands. They formed the local organization of the Nordport Company Ltd. who had found a development project for a £100m oil port in the Sullom Voe. This was to be the landfall terminal for the offshore oil from the most northerly oilfields in the North Sea. We were to work in association with another consulting engineer, Bernard Clark of London, whose preliminary ideas for the terminal were already with the Zetland County Council for approval.

The private venture aspects of this proposal were seen to be contrary to the best public interests by the Council. They promoted a successful Bill in the House of Commons to give them powers to take on the development of Sullom Voe as part of the overall oil-related infrastructure which they realized was urgently needed to exploit the oil reserves. After a certain amount of skirmishing between the opposing interests, which involved us in foot slogging surveys over this windswept, treeless and barren part of Scotland, we were advised that the Nordport interest in this development had lapsed.

As a more fortunate by-product of this activity we subsequently became involved in the Shetland Schools programme which catered for the rapid expansion of population arising from the influx of new workers on oil-related projects (see *Newsletter 105* Nov./Dec. 1977). Novel building methods had to be devised to overcome the serious shortage of manpower and materials for building construction.

Orkney Islands: Carness, Kirkwall

During 1972 we were approached by a marine civil engineering contractor named Termco Offshore to assist with proposals for a marine supply base at Carness near Kirkwall. This was at a time before the Occidental Oil Company had decided to locate its onshore terminal from the Piper and Claymore oilfields in the island of Flotta in Scapa Flow. The Carness project was possibly the first sign that the Orkney Islands were to be part of the rapidly expanding oil scene, and it was soon obvious that the approach to development was much more receptive to private enterprise.

Our investigations involved the usual data search on weather conditions, hydrographic information, navigational routes, land use appraisal and infrastructure support services before we concluded that the development of a marine supply base was feasible (see Fig. 2). Bearing in mind the need for rapid construction to allow servicing of the offshore exploration rigs to begin as soon as possible, the main feature of our proposals was to utilize the GEM Hersent jack-up barge to handle a totally prefabricated harbour scheme. This consisted of large concrete cylinders placed on a rockfilled prepared seabed foundation in 15m water depths from which the pre-

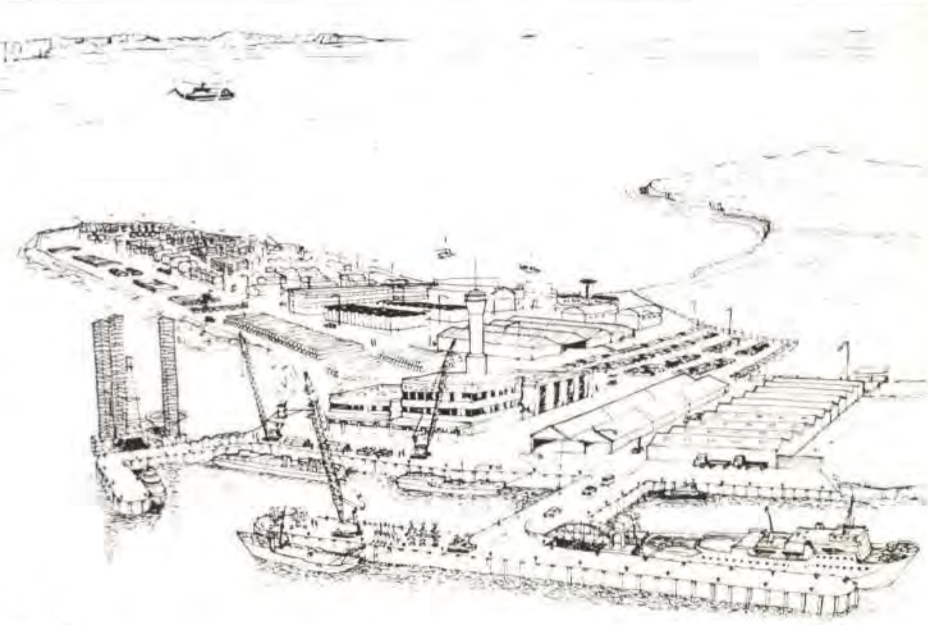


Fig. 2
Drawing of Carness supply base

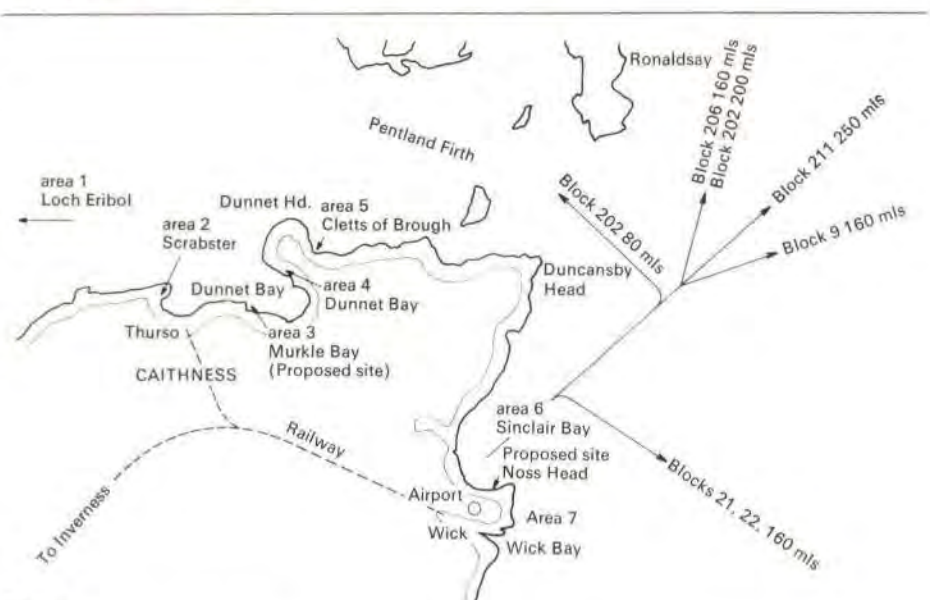


Fig. 3
Location of sites in Caithness

fabricated concrete deck structure could be erected very quickly.

While this development work was proceeding the potential operator company for the marine base, Hudsons Offshore Ltd., were investigating the economics and logistics of material supply routes to and from the Orkney Islands with regard to the location of exploration rigs in the North Sea. Their conclusions were that the majority of supply boat services would need to be located much nearer to the Shetland Islands or Aberdeen to give satisfactory commercial viability to a supply base venture.

Caithness: Supply base site evaluations

This project involved the evaluation of seven sites on the coast of Sutherland and Caithness, between Loch Eriboil and Wick, for possible development as service bases (see Fig. 3).

We had to investigate the ideal specification for a service base to supply both the exploration and construction phases of typical offshore oil and gas developments. This meant visits to existing bases in England and Norway where previous onshore services had been offered from adapted existing harbour facilities. The specification we derived from this investigation gave us the following items:

(a) Berthing facilities for six supply vessels of 5/6m draft

(b) Berthing facilities for one ocean going vessel of 10m draft

(c) A quay area with a working depth of at least 15m

(d) Mobile craneage at quayside with a minimum lifting capacity of 30 tonnes

(e) Facilities for bunkering and watering vessels

(f) Transit warehouses of at least 5000m² alongside quays

(g) Bulk storage tanks for mud, chemicals, cement located on quayside

(h) Open storage areas for tubular drill pipes of 40,000m²

(i) Heliport for three helicopters

(j) Offices, catering, communications, carparks for 100 personnel.

We were therefore looking for an onshore site of at least 4 hectares with scope for expansion and easy provision for:

(1) All-weather access from the sea

(2) Deep water near shore

(3) Good road access

(4) Flat storage areas

(5) Nearby labour pool

(6) Good transportation links.

In this remote part of Scotland we were not surprised to find that very little information was readily available to give data on which possible sites could be examined. Marine conditions were generally uncharted for those locations where suitable land areas were to be found, and a high degree of exposure to storm conditions was a difficulty along all of the coastline being studied.

Of the seven sites we studied we were able to recommend one at Murkle Bay which offered good access by sea and land with close proximity to road, rail and air transportation. This site was chosen for a more detailed feasibility study.

Murkle Bay, Caithness

The location of Murkle Bay relative to the Northern North Sea offshore oil and gas developments is illustrated in Fig. 4, and it is clearly well placed to deal with activity to the west of the Shetland Islands. It is situated inside a projecting headland near to the well-known Dunnett Bay, and consists of a treeless area with steep coastline and rocky foreshore. At the time of this detailed study in 1973, we were acting for the Aberdeen Service Company who were offering to operate supply base services to a number of offshore contractors already working in the North Sea.

The scheme proposed consisted essentially of about 12 hectares of reclaimed land behind 400m of quay wall, thus providing a site for the construction of transit sheds, warehousing, offices and storage yards and making available all weather berthing for six supply vessels. A second phase, to be planned after the base was in use, consisted of a piled quay to provide deep water berthing for ocean-going vessels.

Reclamation of land from the sea would be carried out by hydraulically placing sand on the shelving rock of Murkle Bay. At the same time a sheet-piled retaining wall would be constructed into the sand as it was deposited, to form the quay wall. The surplus sand on the seaward side of the quay wall would subsequently be removed by dredging. The whole construction operation was planned to be achieved as rapidly as possible so that the supply services could be offered soon after site acquisition.

During this study several non-engineering factors emerged which were to have a serious influence on this scheme, and others in Scotland of the same kind. The most significant one was that the bonanza of oil-related activity did not breed sufficient confidence in financial circles to warrant the outlay of large capital investment in schemes for future supply base services. Furthermore, there was little help forthcoming from Government finance, as the highly speculative ventures for oil-related services were not large-scale, labour-intensive projects. Then the world oil scene for the first time in its history saw a downturn in demand for its products, which left the difficult North Sea developments in a state of quandary over future confidence in progress to realization. As a nett result of this change of scene, which coincided with our work, the Murkle Bay scheme was postponed until offshore exploration became active west of the Shetland Islands.

Peterhead harbour of refuge

This project involved the reclamation of about 10 hectares of land within the existing Peterhead harbour of refuge and thereafter the construction of warehousing, storage areas, fuel tanks, office accommodation, and the necessary roads and drainage (Fig. 5).

The reclamation was carried out by others, and involved the placing of hydraulic fill

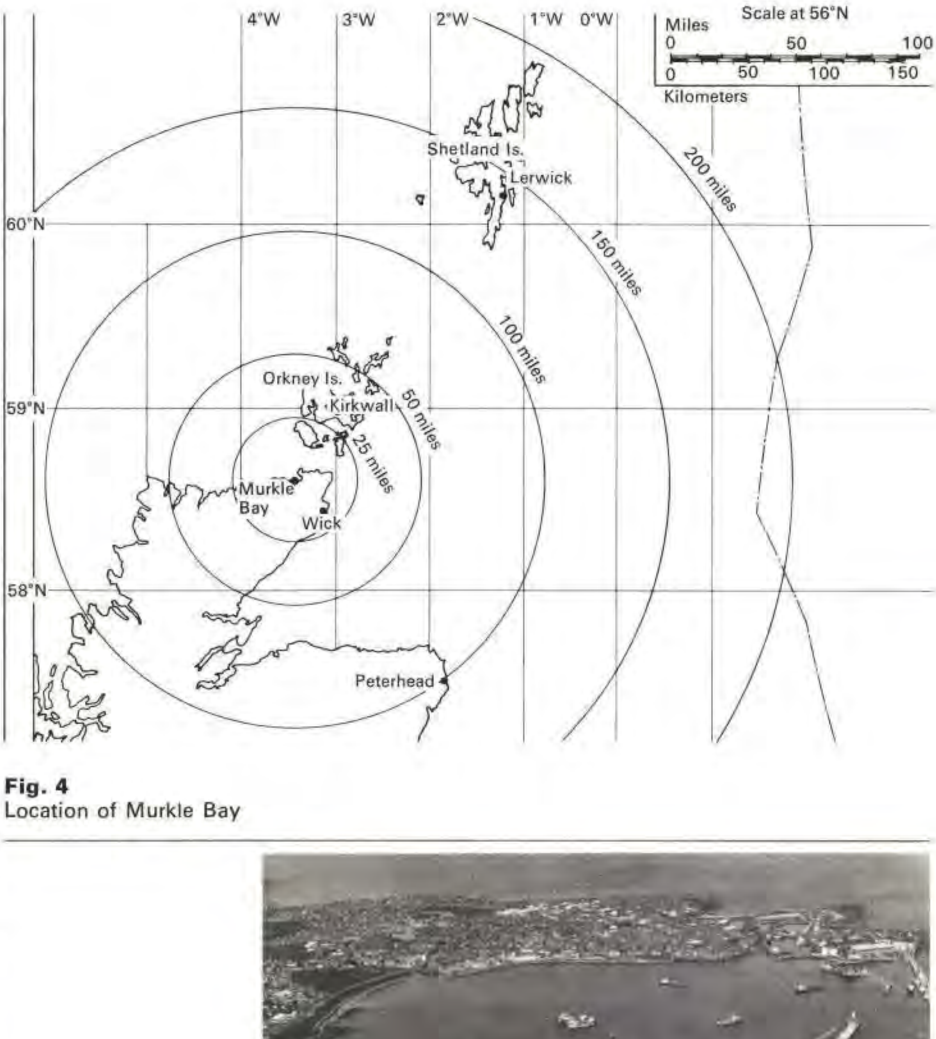


Fig. 4
Location of Murkle Bay

Fig. 5
ASCO Base, Peterhead
(Photo: Charles Fraser, Peterhead)

to form the working area together with a concrete diaphragm wall to form the quay. We were appointed to advise on the bearing capacity of the fill and to design subsequent foundations for all the structures of the base.

The base is backed by cliffs, and proposals to cut into them to form oil tanks and storage areas required careful investigation. The cliffs were found to be unstable, and the tank siting and foundations were planned accordingly.

Foundations for Goliath crane tracks have had to be carefully assessed for spread and settlement of the fill. Problems have been influenced by the speed at which the fill had been placed and the necessity to have the base operational as quickly as possible.

Peterhead harbour development: General purpose quay

This project was a feasibility study for a general purpose quay at Peterhead Harbour together with a quay to service and supply oil exploration rigs. The new jetty had to be integrated with future berthing facilities for oil tankers.

A berthing water depth of 12 m at *MLWS* tide, together with ease of access and security of mooring, was required. Craneage for servicing purposes in the form of a 200 tonne track-mounted mobile crane was to be provided with access.

To avoid wave reflection across the harbour an open-piled jetty structure with no solid walls was designed, L-shaped in plan. The head provided 4800 m² of area and the approach was 20m wide and 230m long (see Fig. 6).

The design applied precast concrete construction methods to meet the tight construction programme. No lift greater than 20 tonnes was required during construction. Raking piles, normally difficulty to drive from floating plant, were planned to be driven from the partially completed deck after vertical piling was complete. This project is still under consideration by the Aberdeen Service Company Ltd.

Quarry products for offshore engineering

The use of various stone materials for such offshore engineering purposes as scour protection to concrete platforms, pipeline protection, ballast weight, etc., led to Aberdeen Service Company considering using their base at Peterhead for a supply service using quarry materials in the Banff and Buchan areas. We were asked to study three main items:

(1) An assessment of offshore requirements for quarry products in the northern North Sea to be shipped via Peterhead.

(2) An assessment of onshore requirements for quarry products shipped via Peterhead.

(3) An assessment of active, disused and potential quarries in the Peterhead area.

Our conclusions were that there was not a great demand for quarry products in offshore engineering in terms of normal quarry annual output figures. Most of the material needed was to deal with production platforms (see Fig. 7) and pipelines and could not be seen to exceed 300,000 tonnes per annum.

The shorter haul distances from Norwegian ports also make it difficult to compete from Peterhead for this trade. It was considered that there could be a more attractive market for quarry products in Europe, as roadstone consumption is increasing and Scotland is currently only exporting a 4% share of this 1m tonnes per annum demand.

Tayside region: Offshore maintenance and repair study

A point has now been reached where seven offshore oilfields have commenced their production operations, and 14 will be producing by 1980 (see Fig. 8). The operating companies have now much more at stake in terms of their own organizations, as the whole success of the long-term production life-span is under their own management. This commitment is unlike the short-term exploration requirements, and every support service needed has to be examined in the light of long-term efficiency and economy for continuous work throughout the year.

Against this background the Tayside Region study was to consider the potential of the Tay Estuary, and in particular, the Dundee area, to service this production phase of the offshore industrial opportunity. This phase really only started in 1975 in the UK sector when production commenced on the Argyll and Forties oilfields. In the Norwegian sector, production had commenced even earlier on the Ekofisk oilfield, and experience there had already confirmed that the problems associated with the production phase were significantly different from, and even more demanding of onshore support, than the earlier periods.

Each of the factors influencing the logistics of offshore maintenance services was examined in detail (see Fig. 9). They have been used to consider how the Tay Estuary and Dundee in particular can provide the necessary support to this phase of the offshore industry's activity. We attempted to assess the type of services needed, the way in which these services may be provided, and the

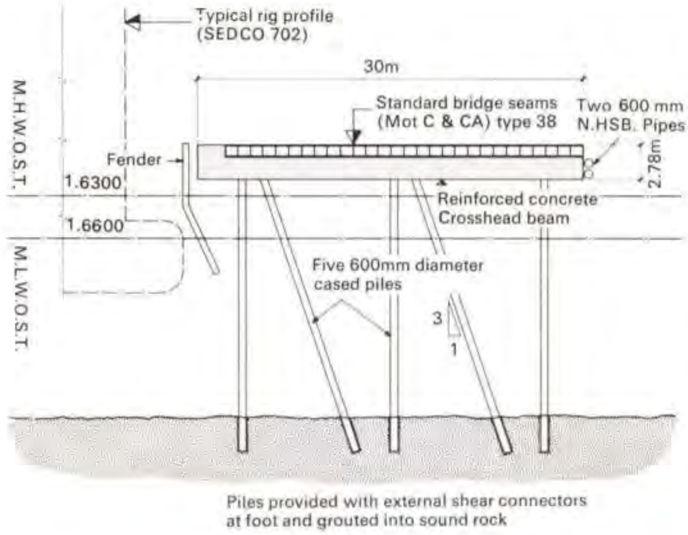


Fig. 6
Proposed quay, Peterhead Base

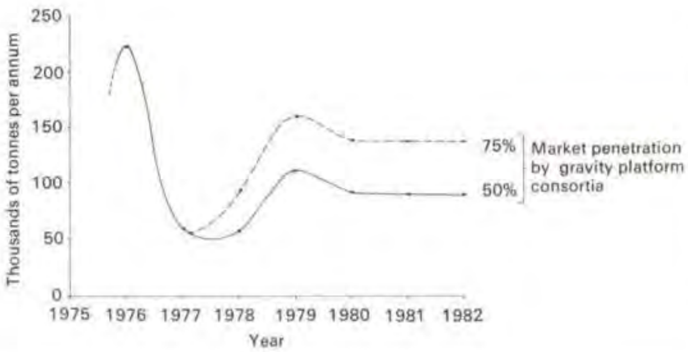


Fig. 7
Graph of stone needed to scour protect concrete platforms

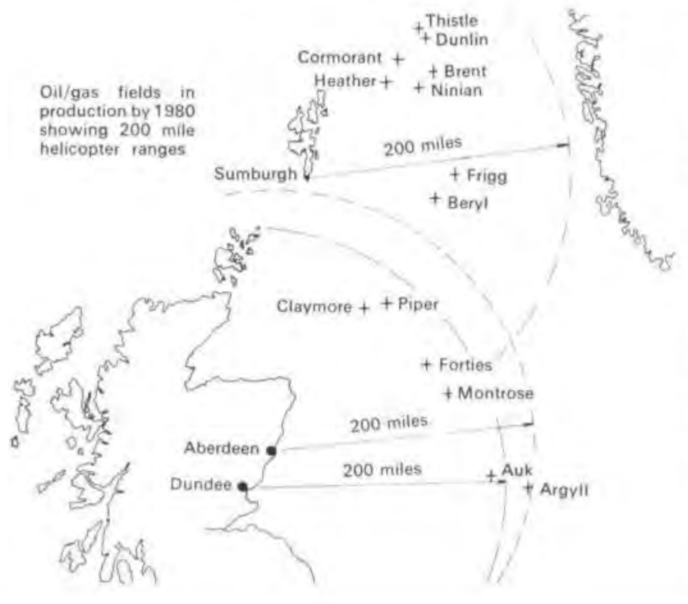


Fig. 8
Oil/gas fields in production by 1980

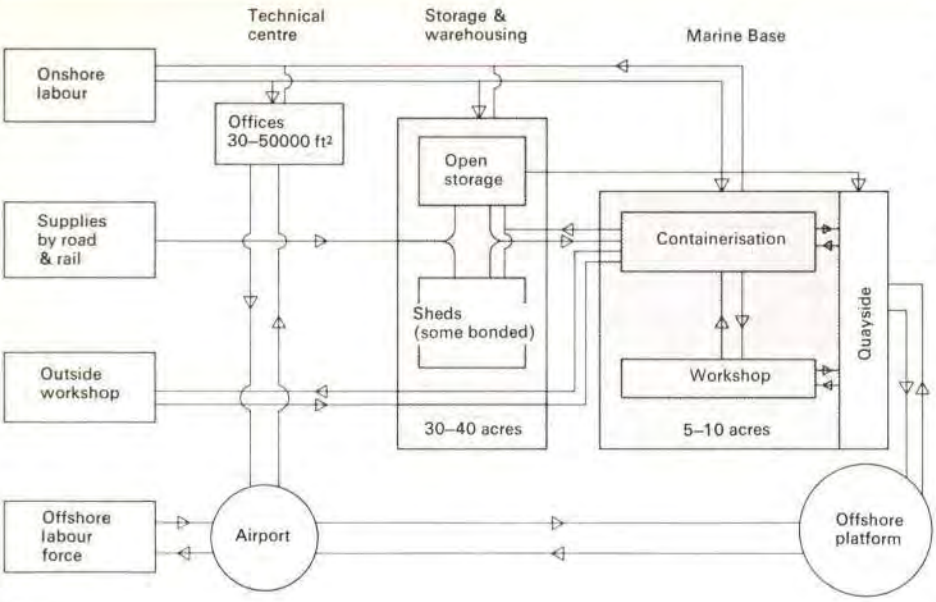


Fig. 9
Maintenance organization diagram

Fig. 10 above
Viking pipelaying barge in Dundee Harbour (Photo: Spanphoto, Dundee)

Fig. 11 right
Burntisland Harbour (Photo: McCorquodale (Scotland) Ltd., Glasgow)

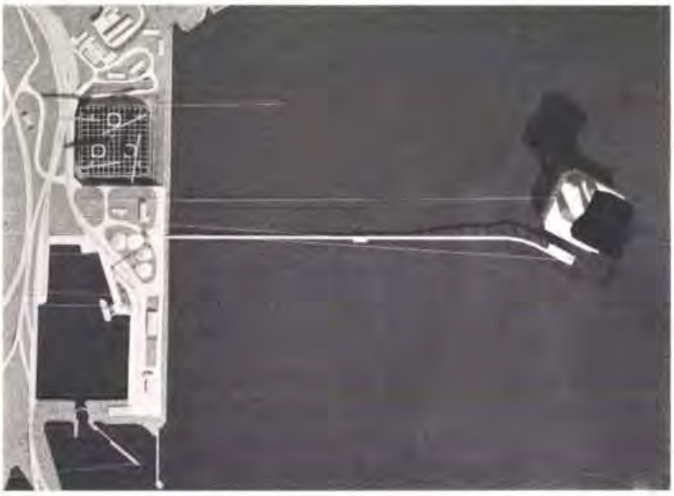


Fig. 12
Model of CPS, Burntisland concrete platform yard (Photo: A. L. Hunter, Edinburgh)

land and infrastructural requirements for the establishment of a base from which they could be offered. A visit was made to the Phillips Petroleum production base at Tananger in Norway to discuss their operational organization for the Ekofisk oilfield.

We considered the question of support services for quayside rig maintenance and refurbishing/repairing barges to be a separate element, as this is not directly related to the production phase. This question was examined from the point of view of extending existing facilities in the Dundee Harbour area to consider if there is a need for further development from which these services could be made more commercially attractive. At present these services are offered to the offshore vessel while it lies at anchor near to the harbour area (See Fig. 10).

Because of its geographical location there would appear to be no doubt that Dundee ought to be able to play a part in the new offshore maintenance industry, but this has not yet happened.

The reasons for this lie largely in Aberdeen's greater advantage in marine and air transport services which were exploited and expanded during the earlier (exploration) phases of activity. The production phase of oilfield activity is, by contrast, a long-term one, and Dundee's opportunity lies in taking initiative to gain a foothold in this phase.

The discovery of the Fulmar and Toni fields and the new BNOC find, in relatively close proximity to Dundee helps to strengthen the prospect of a larger number of oilfields being developed within operating range of the city.

Firth of Forth: Burntisland project

During the initial harnessing of the civil engineering industry to the construction of concrete gravity platforms for the development of North Sea oil fields, attention was directed mainly towards sheltered water providing floating drafts of 35-48m. Most of the sites which met this criterion were remote, principally on the west coast of Scotland, and presented acute planning, environmental and communications problems.

Caledonian Platform Structures Ltd. (a Joint Venture Company between Whatlings, Spie Batignolle and Fougerolle) decided that it would be preferable to seek a site where full use could be made of existing labour pools, housing and public services. This aim could only be realized by paying particular attention to limiting the tow-out draught of the platform to the more commonly dredged depths in the approaches to the North Sea ports. One of the most promising sites investigated, at Burntisland in the Firth of Forth on the east coast of Scotland, was a derelict dockland site owned by the Forth Ports Authority. The Authority granted Caledonian Platform Structures the option to develop concrete platform construction facilities at Burntisland and we were commissioned to undertake a complete feasibility study to confirm its suitability.

Studies were carried out of all existing facilities on the site, their condition and possible use (see Fig. 11). Scheme designs were prepared for a dry dock approximately 150m square and 15m deep. Hydrographic and soil studies were undertaken to ensure that a stable, dredged channel could be economically formed to allow the movement of the platform base from the Stage I Dry Dock to the Stage II finishing location, about 800m offshore, where it is serviced by a jetty (see Fig. 12). The prevailing sediment transport in the Firth, the effect of the dredged channel on the existing regime and the cost of its maintenance, were also investigated.

Recommendations that the site was suitable for construction of gravity platforms with tow-out draughts not greater than 23/24m with scheme designs and budget estimates for its development were accepted. We were instructed to proceed with the development of suitable designs to meet Det Norske Veritas and Lloyds quality assurance requirements. (See *The Arup Journal*, September 1975), and these are in 'cold storage' until future tender opportunities are won by the Joint Venture Company.

Fife region: Methil No. 3 Dock – reclamation and alternative uses

The No. 3 Dock at Methil was constructed in the period 1908 to 1912 to deal with the expanding coal export traffic (see Fig. 13). For several years now this traffic had been decreasing and the dock had fallen into a bad state of dereliction leading to its final closure by the Forth Ports Authority in 1977. However the geographical location of the dock (see Fig. 14) being the one nearest to the offshore operations to the east of the Forth estuary, has suggested that a new lease of life could be found if it could be restored into good working order.

We were appointed by the Scottish Development Agency in November 1976 to carry out a feasibility study for the future use of the dock with due regard to the social and economic benefits to be secured. The study was to take into account the work needed to provide environmental improvement to the dockland area by the removal of all dereliction from the coal trade. New use was to be investigated for the land thus created together with possible marine orientated activity from the restoration of the dock itself, by treatment of the badly eroded quay walls (see Fig. 15).

This project is still under way, and has evolved in a number of stages towards the objective of creating viable new industrial activity in this part of Fife, which is in sad need of employment opportunities. A land renewal contract has been started which will clear away the old railway embankments, derelict buildings, equipment, etc., and provide improved services and road access to the whole dockland area at Methil. This contract in itself will go a long way to make the location very attractive for both the use of the docks and the new industrial estate land area which will be created.

Our concept for the restoration of the No. 3 dock is to provide a type of 'offshore garage' where the operators of marine vessels servicing the offshore industry will be able to find a sheltered tidal anchorage alongside quays with back-up space sufficient to carry out a wide variety of maintenance-type services to their craft (see Fig. 16).

The idea is based on the use of the land facilities alongside the restored dock in a well-managed sequence of temporary leases similar to parking spaces, where the marine operator is free to organize his own work contracts using the engineering resources of the Methil area for the short-term work to be done. Access to the dock and the quayside berths will be incorporated into the management activity provided for the adjacent industrial estate. It is considered an added feature of the concept that longer leases of sites can be offered on the industrial estate for engineering organizations who will find it convenient to be located as near as possible to the 'offshore garage' service station. It is hoped that this may be operating before 1980.

Fig. 13
Aerial view of Methil No. 3 dock (Photo: W. Ralston Ltd., Glasgow)

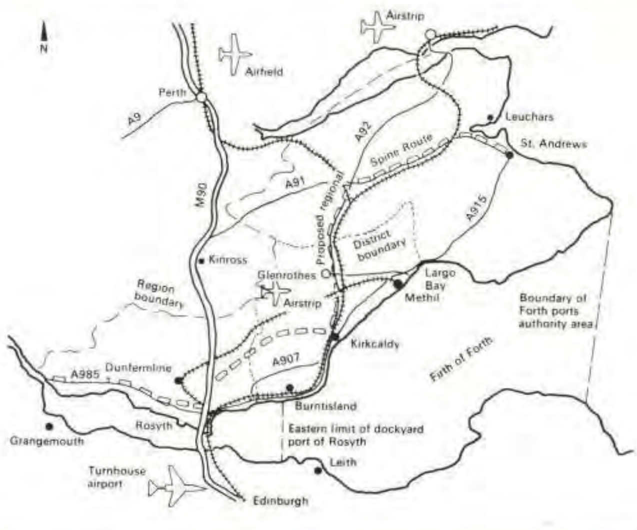


Fig. 14
Methil Dock location

Fig. 15
Collapsed quay wall at Methil No. 3 (Photo: G. W. Harvey, Fife)

Fig. 16
Drawing of Methil offshore garage

Overviews

The period 1971-78 has seen us more or less continuously involved in oil-related project work, mostly concerned with feasibility studies for proposed onshore services. This has enlarged our knowledge of the offshore engineering industry and its demands for services during the exploration, construction, production and maintenance phases of oil and gas developments. The greatest difficulty has been found in obtaining accurate information about precise scale of activity to allow our clients to forecast the commercial viability of these proposals.

More encouraging results for us have been obtained where obvious work has been needed to anticipate new marine oil-related activity in the work of the Scottish Development Agency's Land Renewal Unit. Their scope to provide for upgrading derelict industrial sites without profit motive has allowed essential improvements to be provided to encourage new activity with enhanced commercial viability for new use of these sites.

The production phase of the oil and gas developments in the Northern North Sea is only now getting into its stride, and already it has been shown that the impact of this phase will be even greater than the earlier phases of exploration and construction. Apart from the marine supply activity and air transport services which will continue to be intensively needed, proposals for the development of very large industrial projects for the petrochemical industry are already appearing. It is expected that the combination of all of these elements of the new oil scene will ensure that long-term prospects for engineers in Scotland will be very rewarding.

Alexander Duckham & Co Ltd: New Factory and Warehouse

Ernest Irwin
Keith Seago

Introduction

Alexander Duckham and Co. Ltd. have had a factory for blending, canning and distribution of oil in Aldridge, Walsall, West Midlands since 1968. During 1974 and 1975 Duckhams were contemplating expansion of their business and they looked at several possible areas in which development might take place.

Amongst these was the Aldridge site where, in addition to their existing plant, they also had a green field site but separated by a public road from their factory. The local authority were thought likely to permit a tunnel connection between the two sites but there were deep services in the road and economical integration of the two sites as one efficient factory was unlikely to be achieved.

A letter to the new Walsall District Council from Ove Arup and Partners outlined the problem and suggested that a bridge spanning the road could be of high visual quality and would possibly permit economical development. A favourable response from the District Council which agreed in principle to a good looking bridge, provided that it met a number of conditions, was sufficient to make the Aldridge site the most favoured location.

As materials handling and engineering considerations were central to the project, the client wished to appoint either a design construct contractor or a consulting engineer to take charge of the works. In our submission we said that we would require to include a firm of architects in the design team and this was accepted in our appointment.

Feasibility

The client's existing facilities in Aldridge consisted of an extremely densely developed site, with almost no room for expansion, surrounded on two sides by roads, on one side by another factory and on the remaining side by a canal. The parcel of land on the opposite side of the road is one hectare and bounded the front of the existing site. This site is adjoined on two sides by other factories and to the rear by land designated as public open space.

It was immediately obvious that any expansion in Aldridge had two very major problems to be solved:

(a) Communications between the sites

(b) The limited area of the new site.

We realized that any solution must be efficient in terms of materials handling by successfully using both sites as an integrated unit. Our materials handling study offered two solutions. Scheme 1 kept all bulk oil storage and blending on the existing site, and placed oil filling and storage of both empty and filled cans together with despatch on the new site. Scheme 2 kept all bulk storage, blending and filling operations on the existing site and used the new site for warehousing and despatch only.

In Scheme 2, cans of oil would have to be taken to the new site either by vehicle or by conveyor within a tunnel or bridge. In Scheme 1, the oil could be taken between the sites by pipeline, provided relatively few bends occurred. This was because balls known as 'pigs' are passed within the pipelines to keep different grades of oil separate, and 'pigging' cannot operate around a large number of bends.

With the principle of a bridge accepted, which allowed direct routes for the pipelines, the client opted for Scheme 1.

Planning

The constraints lead to the development of a scheme involving high density materials handling proposals to utilize fully the area available on the new land, and a bridge connection between the two sites to enable blended oil to be carried between them. The basic production split is:

(a) Unblended oil stored in tanks on the existing site, where it is then blended and stored in bulk prior to transit to the new site.

(b) On the new site the oil is filled into cans and barrels, then stored and subsequently despatched as required.

The bridge between the sites conveys 10 oil lines and, because of the range of some 200 products, each pipeline carries numerous grades of oil.

Fig. 1
Aerial view of new factory and bridge link to original facilities (Photo: Aerofilms Ltd.)

Due to the limited size of even the new site, and the lack of any further adjoining land, we advised the client to construct the maximum building envelope consistent with planning restrictions on height and allowing appropriate parking and vehicle manoeuvring areas.

Modern fork lift technology meant that the highest single-storey warehouse that was permitted could readily be utilized, but extension of this 10.5m clear height to the filling shop area was questionable, as the machines there would not exceed 2m or so in height. However an ingenious solution to the storage of empty oil cans, as described later, meant that the volume above the filling shop could be utilized, and our advice to build a 10.5m clear height throughout was adopted.

The back of the new building was placed at the rear boundary leaving sufficient width for fire engine access. The front of the building was set back to give a 22m depth for vehicle manoeuvring. This is the minimum for vehicles to use the development, but a careful balance had to be drawn between building area and external areas. Separate entrance and exit roads were permitted by the planners and, in addition, a third access from the main road was allowed to the 90 car parking spaces arranged on either side of the fire engine access road. The building was placed close to the fourth boundary, leaving space for fire escape only. Fig 1 shows the location of the building on the site.

A 6m clear height canopy along the entire building front was chosen to allow loading and unloading under cover.

All services were available from the parent site via the new bridge link. Locker rooms, toilets and a recreation room were positioned in an extension of the canopy over the car park entrance, which permitted clear views from the recreation room over the open ground at the rear.

Ground conditions

Natural ground was about 1m below road level and sloped down a further metre towards the rear of the site. A site investigation consisting of trial pits and bore holes confirmed our fears that the top 2m were a mixture of fill and organic material but overlying firm Etruria marl.

As the planners were concerned about the height of the new building in relation to its surroundings, it was beneficial both from planning and soil considerations to put floor

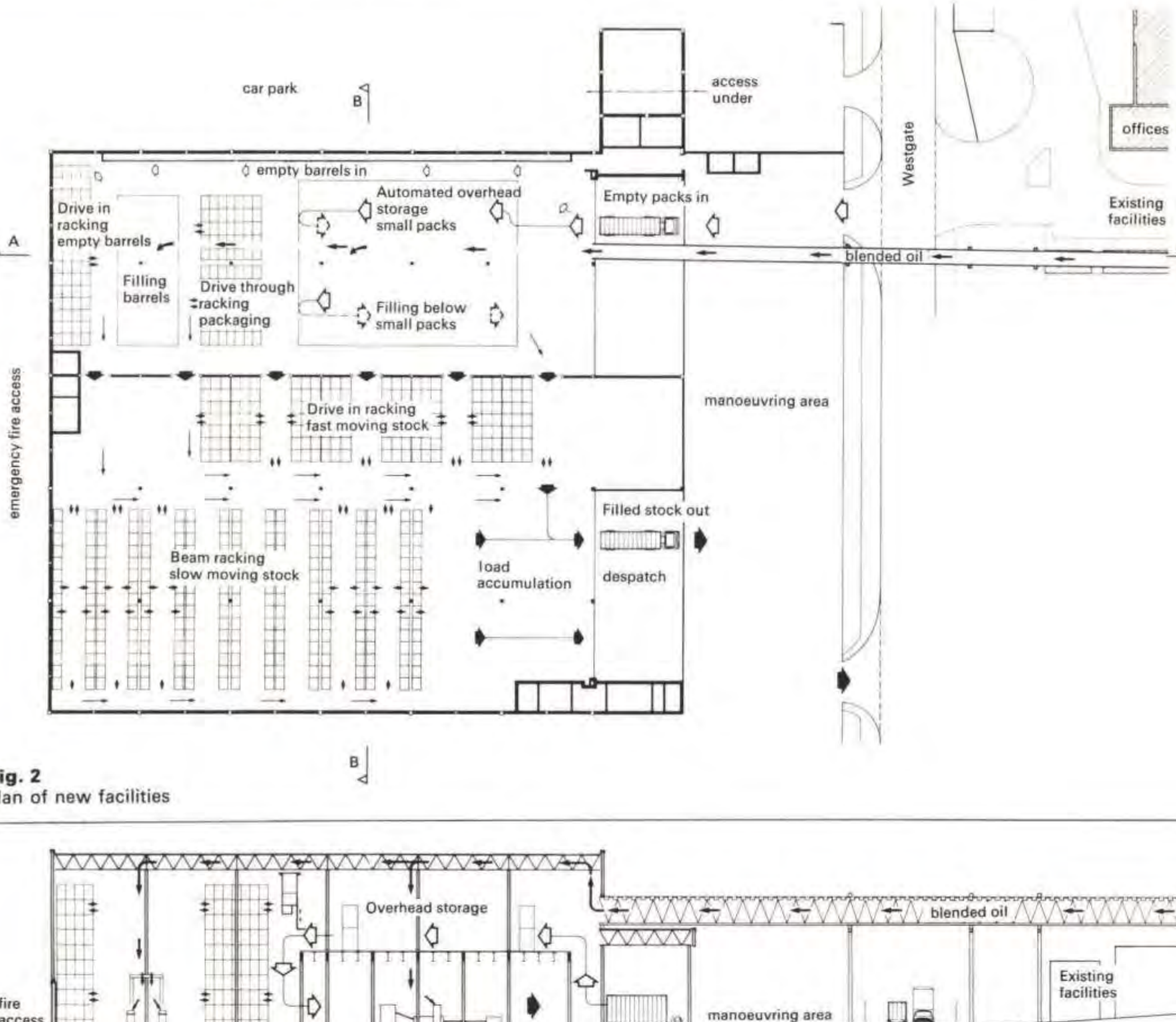


Fig. 2
Plan of new facilities

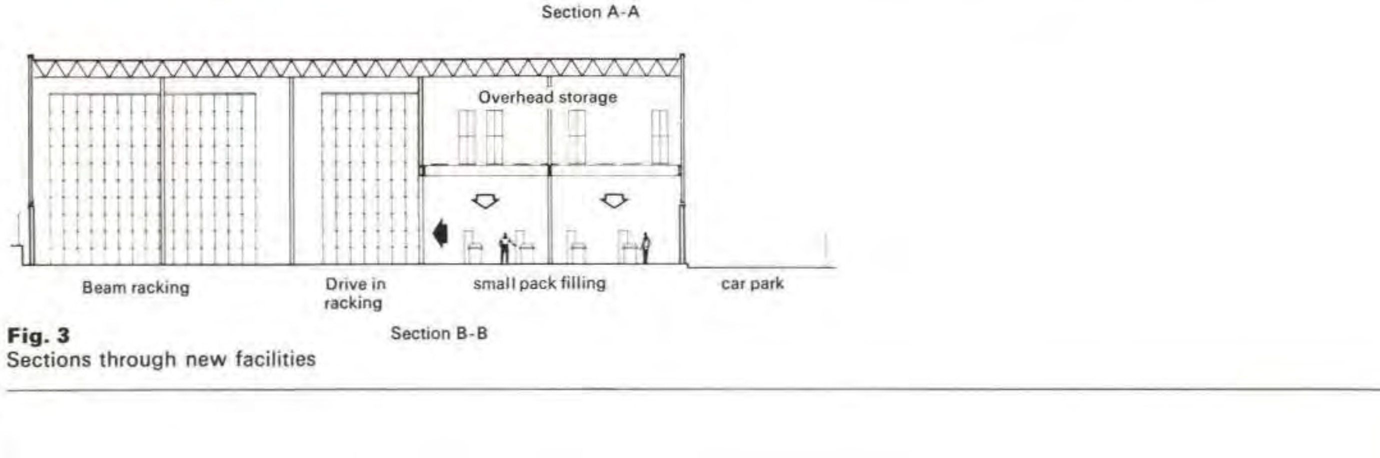


Fig. 3
Sections through new facilities

level about 1m below natural ground level. However, it was decided to excavate all material down to the Etruria marl and backfill with imported fill.

The fill material chosen was blast furnace bottom ash which, though expensive, was the only one of several materials which met our rigorous specification in all respects. Fortunately, the temptation to use a cheaper material was resisted, as a very wet winter followed, and the bottom ash proved an ideal material to work upon in wet conditions.

Materials Handling

The building is divided into two sections by a fire wall (See Fig. 2). The larger of the two areas houses the storage of filled products, whilst the smaller area accommodates empty pack storage and the filling operations. The small empty packs are in cartons stored two high on pallets. They arrive by lorry, from which they are unloaded onto a pallet elevator which lifts them on to storage conveyors at a mezzanine level (See Fig. 3). In this way the 10.5m height void above the filling shop is utilized to provide storage of empty cans which must be held in stock against delivery breakdowns. When the cans have travelled the full length of the storage conveyors they are removed by a gantry slung stacker crane which delivers them to the filling lines beneath the conveyor structure.

Here the cans are unpacked, filled with blended oil, packed, palletized and taken for storage to the warehouse area. (See Fig. 4).

Within the filling area, larger containers and barrels are also filled. These empty units are conveyed down the side of the filling area and stored in racking against the rear wall. They are then filled, palletized and taken for storage in the warehouse area.

The product split is such that the majority of output is in a small range of oils but a large variety of less frequently used oils is also produced. Two distinct paths through the complex have been provided to accommodate the fast moving and slow moving products and these paths can be represented in plan by two concentric letter 'U's. The first U is for slow moving products, requiring maximum access in store, whilst the second U is located inside the first and involves high density storage with less individual access.

Building construction

The new building is flat-roofed with precast concrete columns on the periphery and along

Fig. 4
Overhead storage and filling (Photo: John Whybrowe Ltd.)

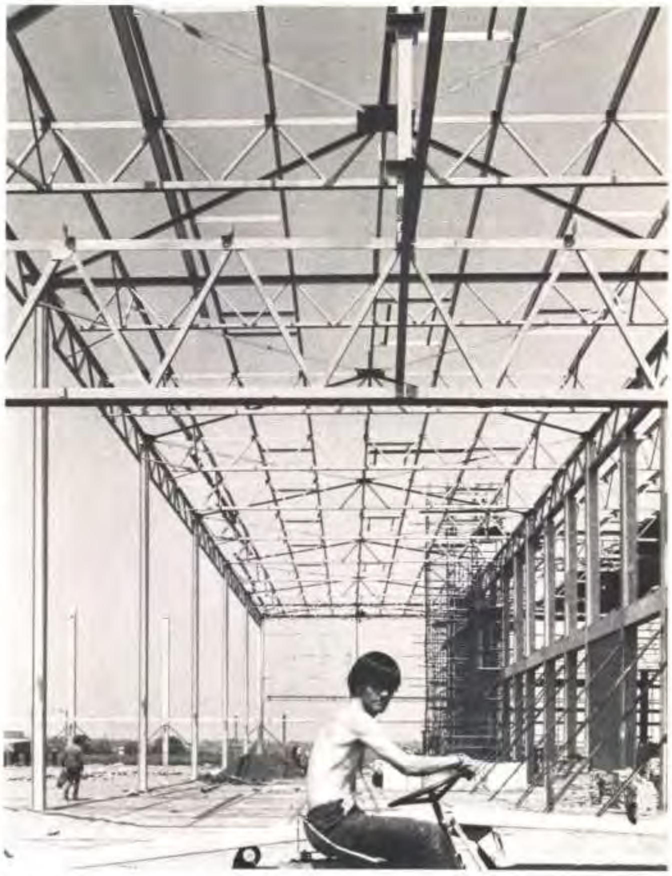


Fig. 5
Warehouse steelwork (Photo: Harry Sowden)

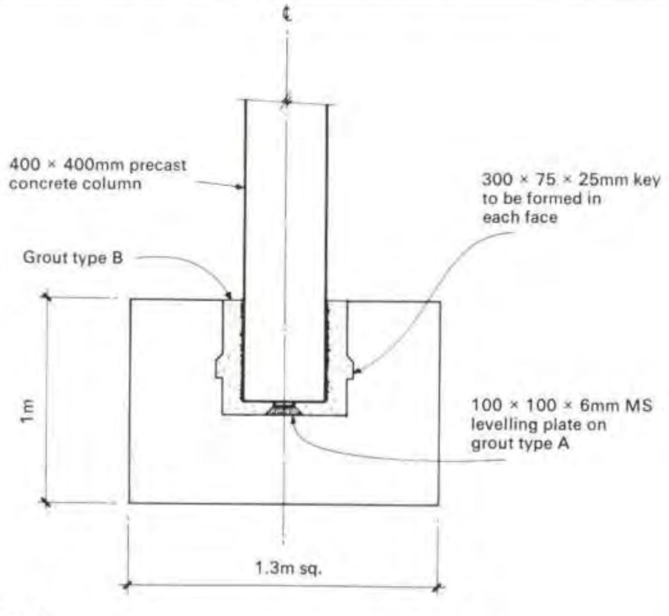


Fig. 6
Column base details

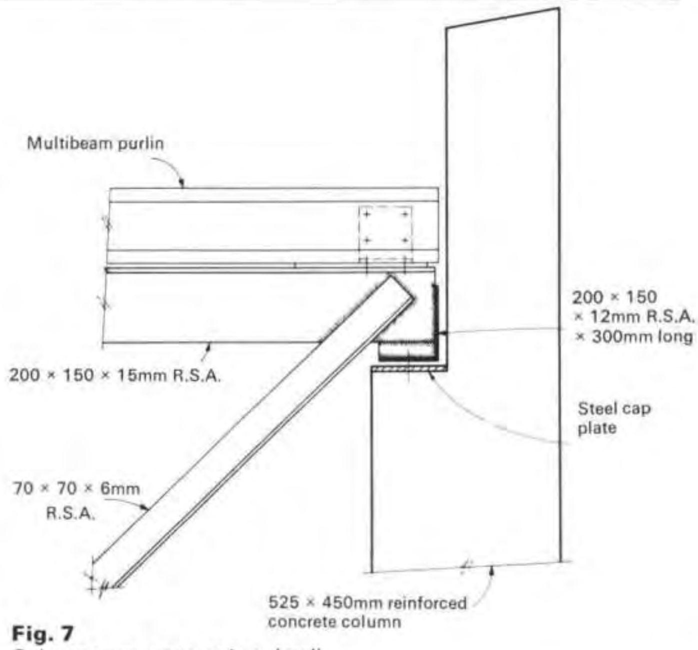


Fig. 7
Column truss connection detail

the internal dividing fire wall. Otherwise it has steel columns internally. The grid is 12m x 15m with a clear height to the underside of the roof structure of 10.5m. The roof is of steel trusses with multi-beam purlins spanning between them to carry a 35mm galvanized steel roof, together with 25mm urethane foam insulation and 3 layers of glass fibre based felt and stone chippings.
(See Figs 5, 6 and 7).

Daylight is provided by covering 7% of the roof area with wire-reinforced, single skin plastic dome lights on fixed aluminium curbs. These were supplied and fixed by the roofing contractor. There are also side windows at low level to the filling shop as described below.

Precast concrete columns were used in order to meet a four hour fire requirement on the perimeter due to the proximity of neighbouring buildings. The building is divided into two sections to meet fire regulations which required separation of oil storage and oil filling. This was achieved using brickwork and precast concrete columns along GL4, which became a fire wall dividing the filling and warehouse areas. This fire wall had to be taken through the roof of the building. (See Fig. 8).

The external walls are constructed in brick up to about 3m above floor level. Facing bricks are Butterley 'Jacobean' blue-red from Mold, North Wales, laid in Flemish garden wall bond. Internally the brick is painted, fair-faced commons. Recesses in the brickwork at column positions provided some moulding to the elevations.

There is a 1.5m high strip of back plastic-coated and capped patent glazing above the brickwork to provide daylight at lower levels within the filling shop. Above the patent glazing the external cladding, required to have a four hour fire resistance, is PVC-coated profile steel sheeting, the sheeting rails being lined internally with 9mm 'Superlux' screwed to galvanized T sections. There is 50mm glass fibre quilt insulation in the internal cavity.

Across the entire front façade of the building is a despatch area integral with the building, covered by a 5.5m high canopy (See Figs. 9 and 10).

The floor of the building is a 250mm-thick, doubly reinforced, concrete slab laid on a 200mm thick dry lean concrete. High tolerances were specified for the floor slab throughout the complex as at a future date turret trucks may be used to lift pallets to 9.5 – 10m.

Finishes are to a good commercial standard with standard anodized aluminium windows and door furniture, vinyl tile floors, painted plaster walls for the rest and office areas and full-height glazed wall tiling in the lavatories.

Within the filling area there is a mezzanine level which covers some 50% of its space. The mezzanine structure is of heavy steel beams which support a conveyor complex some 30m wide x 36m in length.

In the filling area, a warm air distribution system is employed fed by vertical ducts from air handling units mounted on the roof and fitted with heater batteries. (See Fig. 11.) In the warehouse area, high temperature radiant panels mounted on the roof trusses provide the heating.

Steam is provided from the boilers on the existing site to serve the air handling units and the radiant panels. The large external doors are each served with cold air curtains mounted in the floor. (See Fig. 12).

High pressure sodium lighting is provided at high level in the warehouse, and fluorescent tube lighting is provided in the filling shop area. Three-phase welding socket outlets, and 110 volt socket outlets for wander leads are provided.

The amenity area, consisting of a refreshment room and toilets, is provided at first floor level by extending the canopy over the car park where reduced headroom requirements permitted a second storey. Clearance beneath this structure is sufficient to enable fire engines to reach the rear of the building. Windows on the rear of the refreshment area give a view over the fields at the rear.

The bridge between the sites is in four spans, giving a 6m clearance above the highway. (See bridge support detail on Fig. 13.) Structurally, it is a double steel truss, clad on the sides and on the soffit with plastic-coated pressed metal sheeting, with the roof constructed with metal decking and felt as in the warehouse. As well as carrying oil pipe lines between the sites it also conveys electric power, steam,

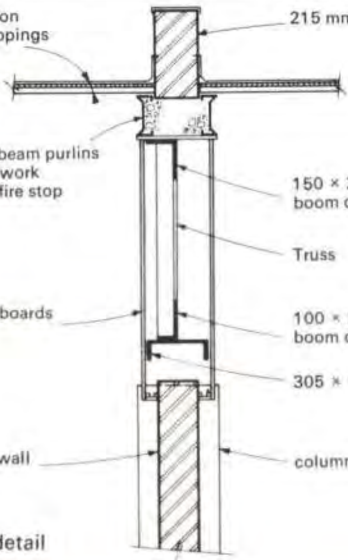


Fig. 8
Fire wall roof detail

Fig. 9 above
Despatch bay
(Photo: John Whybrowe Ltd.)

Fig. 10
Exit to Westgate
(Photo: John Whybrowe Ltd.)

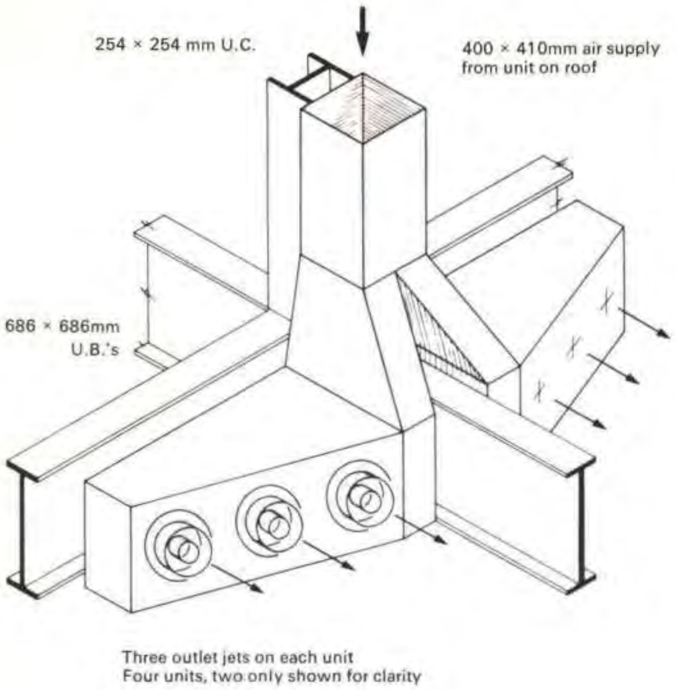


Fig. 11
Plenum header box

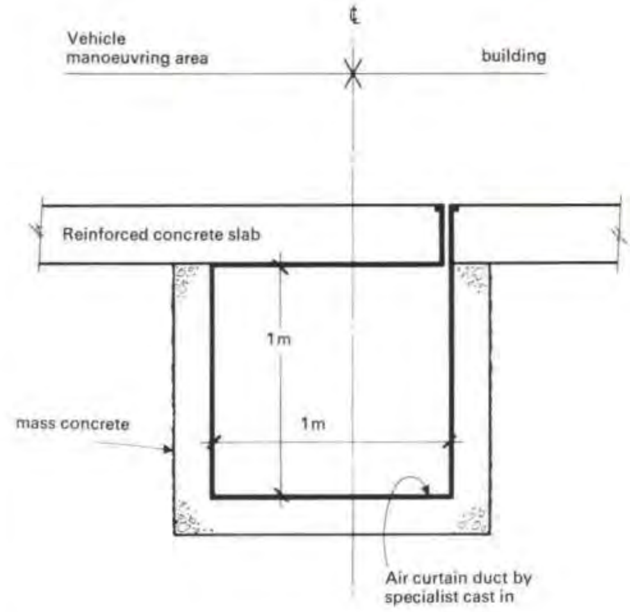


Fig. 12
Air curtain details

condensate, compressed air, telephone, document tube and alarm connections. The floor to the bridge prevents any leakage onto the public highway, and additionally a longitudinal slope to the floor will carry flow from any major rupture to the new site.

Design programme

We were commissioned in April 1976 and in order to achieve production of the extended facility by April 1978, a rapid development and early start on site was essential. To achieve this it was necessary to commence on site in January 1977 with a contract period of 14 months. This left six months for design and client approval leading to documentation for tender in November 1976.

A continuous dialogue between the client's project leaders and ourselves took place. It was decided to present our proposals to the client in three stages to give him maximum opportunity for comment and to ensure necessary approvals as the work progressed. These stages were:

(1) Scheme presentation held in July 1976. This was the client's last opportunity to make any major design changes in principle without suffering additional design costs and delay.

(2) Preliminary presentation held in August 1976. No planning changes could now occur without causing delays. Finishes were chosen but could be altered, thus permitting costs to be adjusted if necessary.

(3) Final presentation held in October 1976. This described the design at a very advanced stage, based on the earlier approvals and the opportunity for the client to change any elements was very restricted. Minor amendments were incorporated in the tender documents which were sent out in November 1976. This procedure worked extremely well, the development of the design having taken place at a series of regular design team meetings, which involved the client's own engineers. As a result there were no surprises to the design team at any presentation, which became opportunities to collate the design and to inform the client's senior management of progress on the project.

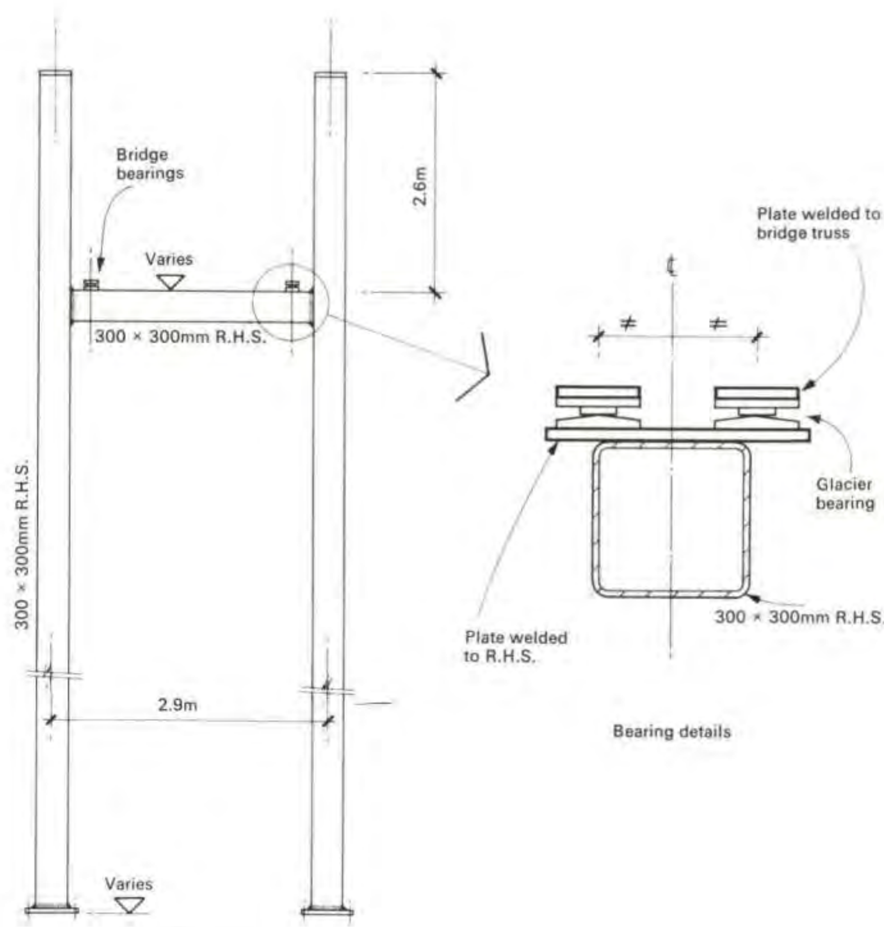


Fig. 13
Bridge support detail

Fig. 14 left
Warehouse truck aisle (Photo: John Whybrowe Ltd.)

Fig. 15 right
Warehouse beam racking (Photo: John Whybrowe Ltd.)

Fig. 16 below
New facilities and bridges (Photo: John Whybrowe Ltd.)

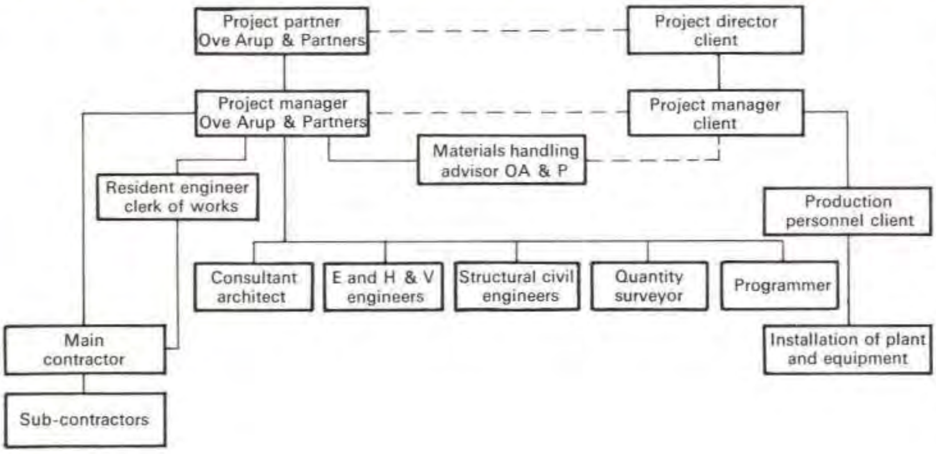


Figure 17
Design Team

Management structure and project team

Acting as prime agent requires close control and co-ordination of the different disciplines involved. The basic structure agreed was a design team lead by a project co-ordinator whose discipline is civil engineering.

The structure of the design team and its relationship to the client and contractor is shown on Fig. 17.

Contract arrangements

In order to set the construction works rapidly in motion to meet the early completion date, it was decided to carry out site preparation as a separate contract. This was completed in time for the building works to proceed in January 1977. Some basic decisions were therefore required early in the design process, but this caused few difficulties and the site preparation began in October 1977 and was completed in December. It was carried out under the ICE Conditions of Contract (5th Edition).

Because of the large building element of the second phase contract the JCT form of contract was chosen. However, due to the rapid development of the design it was not possible to take off exact quantities in the usual way. Therefore the private edition of these conditions of contract, for use with approximate quantities was chosen and the bill was split into two sections:

(1) Architectural elements measured under the standard method of measurement for building quantities

(2) Civil and structural elements measured under the standard method of measurement of civil engineering quantities.

Mechanical and electrical services were carried out by a nominated sub-contractor as were other large elements of the work including roofing, cladding and the structural frame. The materials handling was arranged as five separate contracts direct with the client and not as sub-contracts to the main contractor. A phased hand-over of the building in sections was organized so that installation of critical items of plant could begin in these sections before the remainder of the building was finished. Co-ordination of these separate contracts on site was carried out by a site manager, who was an engineer employed by the client, and he also organized the installation of process pipework and filling machinery. Ove Arup and Partners were responsible for overall programming and control of building works on the new site.

In parallel with the new site construction, works on the existing site proceeded under the ICE Conditions of Contract directed by the site manager. These works were largely process installations but in addition the Arup design team designed and supervised all the civil works comprising road widening, plant supports and pits and ancillary buildings.

Site supervision

The client's site manager is a mechanical engineer who directed the contract on the existing site and co-ordinated the materials handling contracts. In addition we had a full-time resident civil engineer throughout the contract together with a clerk of works.

Credits

Design Team

Project co-ordinator and civil engineering:
Keith Seago
Architecture:
Harper Fairley Partnership (Brian Witheridge)
Materials handling:
Jolyon Drury
Mechanical services:
Barry Magee
Electrical services:
Barry Leftley
Building quantities:
Harper & Birch (John Harper)
Structure:
David Symonds

Contractors

Site preparation contract:
George Wimpey Ltd.
Main contractor:
R. M. Douglas Ltd.
M & E services:
Brightside Heating & Ventilating Ltd.
Process:
Wm. Press & Son Ltd.

Client team

Director:
J. R. M. Hill
Project Manager:
P. E. Williams
Project Engineer:
R. G. Pugh
Site Manager:
D. Wilkinson

The Tower Computer System

Graham Thomas

Introduction

The Tower computer system is a system for the analysis, design and plotting of self-supporting steel lattice microwave towers. It was developed in Ove Arup and Partners between June 1977 and June 1978 for Building Engineering Group 9, which specializes in structures of this type.

The towers are of square or equilateral triangular cross-section and are made up of statically determinate pin-jointed panels, which the program numbers consecutively from the top. For each tower type (square or triangular) wind forces are applied in each of two critical wind directions for a specified wind velocity profile. Applied loads including cross-wind forces, torques and moments due to offset vertical loads may also be entered. Secondary bracing may be entered for each panel to reduce the effective lengths of the main panel members, and allowances may be made for connections, platforms, ladders and waveguides. A thickness of radial ice may be added to all members.

Each of the main members and secondary bracing members may be specified by size, in which case a straightforward analysis is carried out. Otherwise the program performs an iterative analysis of each panel, selecting from library files those member sizes not specified, until a satisfactory design is achieved. Results include weights, lengths, forces and buckling capacities of each member.

Deflections and rotations are calculated at the top of the tower, at the top of each panel and at the level of each applied load. The foundation forces are calculated at each leg of the tower, and steel weights are totalled by member type and steel grade. Views on plan, in the critical wind directions, and in three dimensions, as well as true views of secondary bracing, may be screened on a Tektronix screen or plotted on A1 sheets at the Benson plotter.

The Tower computer system includes an Aerial Forces program which calculates the loads on the tower due to face-mounted or leg-mounted aerials, system data files for member types, aerial types, secondary bracing, messages and program 'Help' as well as a Data Files program which allows the user to set up personal data files for member types, aerial types and secondary bracing. In all there are 28,000 Fortran statements, an average of nearly 400 statements/man-week throughout the development.

Organization

The Tower computer system was funded by the Ove Arup Partnership Development Fund with an allocation for the 1977/78 financial year. A client committee drawn from Building Engineering Group 9, was established to provide technical advice, monitor progress, organize user trials and verification of the system, and to approve the various stages of the development. A project team, consisting initially of a project director and a project engineer drawn from Building Engineering Group 2, later to include an engineer from Group 9 and a member of the Computer Group, was set up to carry out the work to the satisfaction of the client. The client committee wrote a brief including an outline technical specification to the project team in June 1977, and in July a feasibility report was submitted back to the client. Discussions on the scope continued and a draft user manual including a detailed technical specification was submitted to the client in November 1977. The system was made available for user trials in January 1978, although interactive design and plotting facilities were developed subsequently. The verification, which included extensive hand-calculations as well as comparative runs against other programs, took place over the next six months, at which point the system was given final approval by the client and the user manuals were printed. The system is now maintained by the Computer Group, a transition made possible by including a member in the project team for the development.

There are two points particularly worthy of note for future computer system development, the first being that half the resources of the project team were used in developing the technical specification before any coding could begin. The second is that the resources required for user trials and verification were comparable to the resources required for specification and coding. Adequate provision should always be made for this, since it is through the trials and verification that potential users are introduced to the system and gain confidence in its application, as well as providing valuable feed-back to the client.

Operation and user language

The programs are run in time-sharing at any terminal linked to Arups' DEC-10 computer. The TOWER program is initiated with the monitor (.) command /TOWER.

The user language is modelled on the GLADYS system (described in *The Arup Journal*, March 1978). After data is entered, the user runs the programs by command, selecting the operations and facilities he requires. The TOWER program command level is denoted by an asterisk (*), and a facility selected at this level may have a subsidiary command level, denoted by an arrow (>). For example, should the data modification facility (*MODIFY) be selected, the modifications are specified by the user at the subsidiary command level. Other facilities, such as *GO which causes a complete non-interactive analysis of the tower to be carried out, return immediately to TOWER level. The HELP command may be given at all command levels to list the options available, and the programs may also be run with step-by-step help which causes explanatory text to be output at key points.

The volume of data which must be entered for a tower means that interactive input to prompts typed by the program is not the obvious solution. The additional requirement that data set up on punched cards should be accepted leads to adopting the method of a data file (with extension .TOW, a TOW file) being set up on disk in the computer either from cards, or by typing in at a terminal. Data sheets such as that shown in Fig. 1 were produced using the Arup draughting program CADRAW, to facilitate correct data entry. The TOWER program reads the data from the TOW file while carrying out extensive error and 'idiot-value' checking, and arrives at the (*) command level.

When a complete calculation has been carried out, it is stored in a file in the computer with extension .RES, a RES file. The RES file is a binary file containing both data and results, and is used to print the calculation (*PRINT) at the lineprinter. Once a RES file has been created, it is quicker to use it as the data file in place of the original TOW file, since all the data is known to be free of errors. If required, a new TOW file can be created from the RES file with the *SAVE DATA command, which will contain all the selected member sizes as data and can be listed and edited by the user.

Method of analysis

The tower is made up of a number of panels, which are analyzed in turn starting from the top. A geometrical matrix, which depends only on the type of panel and the direction cosines of all the main members at one corner, is made up from the equations of equilibrium between member forces and external loads. Loads from above, with a proportion of the load on the panel being

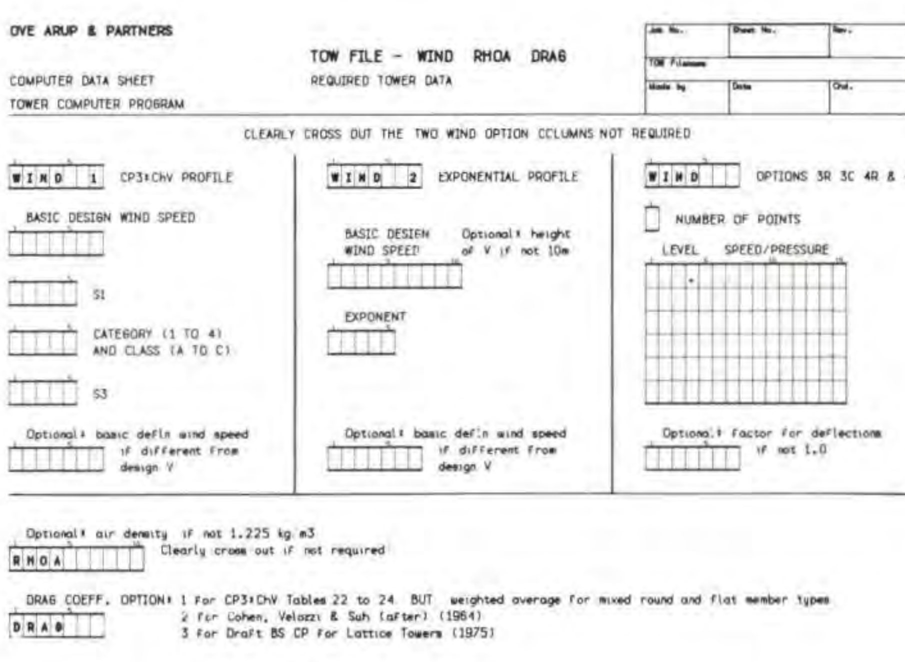


Fig. 1
Example of data sheet

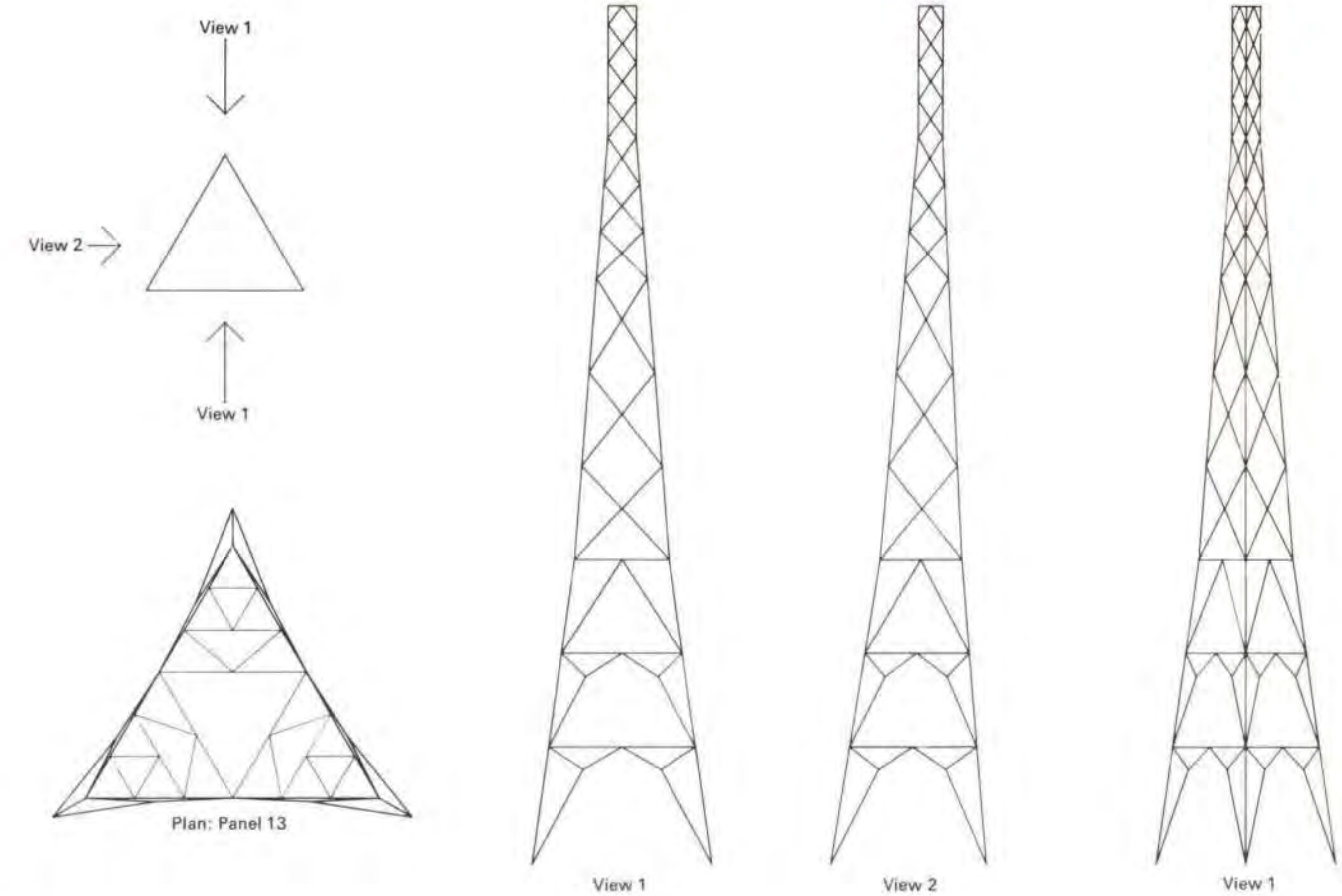


Fig. 2
Plotted views of a triangular tower

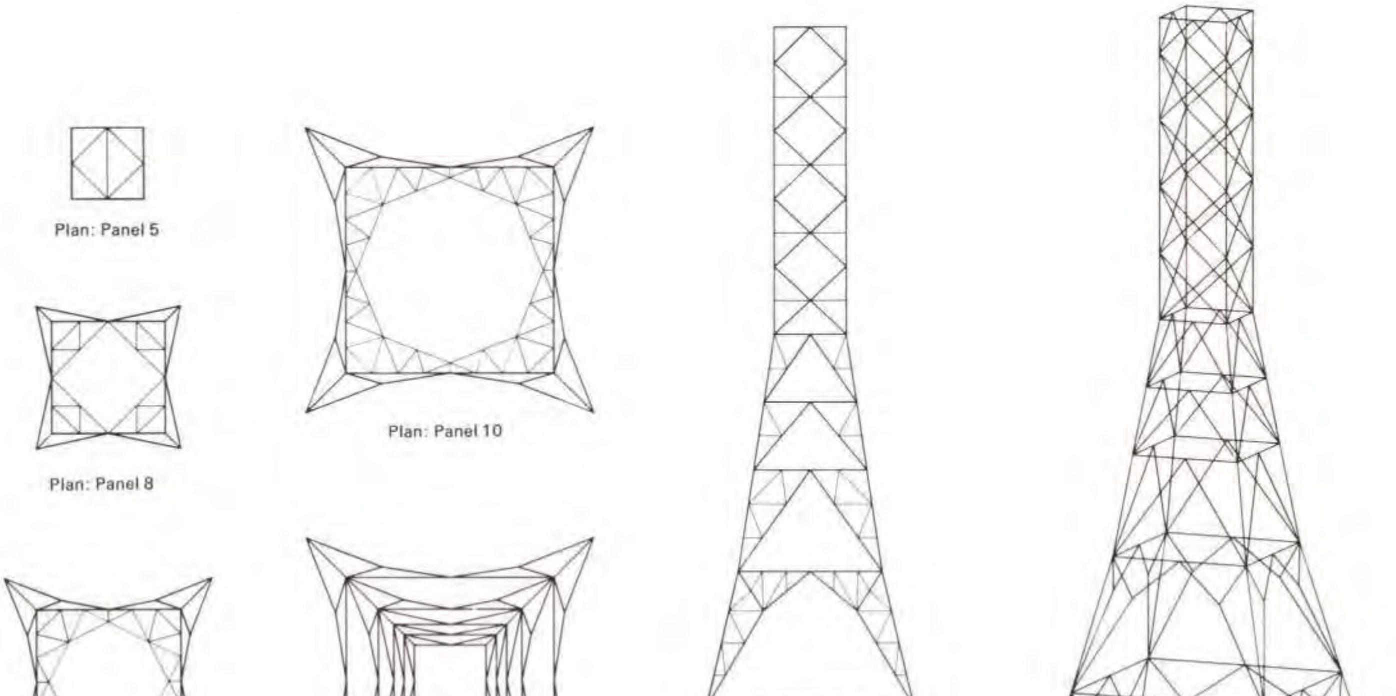


Fig. 3
Plotted views of a square tower

considered, are applied to the top of the panel and divided into sets of three orthogonal forces acting at each corner, from which all the main member forces are found.

The weight and wind loads on the panel depend on the sizes of the members. If the sizes were specified by the user, the panel is analyzed once only. Otherwise sizes are first selected from the data files which satisfy the required slenderness ratio limits, and the forces are calculated. Sizes are further selected to satisfy these forces and the loads recalculated. This iterative procedure continues until all the design criteria are met (or the program reaches the end of the data file).

The secondary bracing design is purely a geometrical problem. Secondary bracing braces the main members to reduce their effective lengths, and thus carry unquantifiable stability forces which may be approximated at 2½% of the main member force. In practice it is sufficient to design these members only to a slenderness ratio limit, and so these loads on the panel are determined before the main member selection is begun. Given the apparent simplicity of the above, the logical complexities of the interaction of the possible bracing configurations may easily be underestimated. There are three types of secondary bracing: face bracing which restrains the main members in the plane of each face of the panel; hip bracing in up to five different planes which generally runs across the corner of the panel and restrains the main members out of plane; and plan bracing which restrains the cross-over point of the main members at the centre of each face and may provide additional horizontal restraint to the horizontal main members. A system had to be devised whereby the user could select configurations from a standard library or else define his own and the program could carry out full data and compatability checks and evaluate the main member effective lengths for vv, xx and yy axis buckling. In the event it was found necessary to limit the selection of plan bracing and some of the planes of hip bracing to the configurations available in the program library.

Interactive design facility

The Tower program incorporates an interactive design facility which is initiated with the command *INTERACT. After the analysis of each panel, a subsidiary command level (>) is reached at which point the user may change the panel type or geometry, respecify member types or sizes, or try different configurations of secondary bracing while optimizing the design. When he is satisfied, he may continue to the next panel with the same facility, or else cancel the interaction and carry out a straightforward analysis on the rest of the tower, or as far as the next panel at which he wishes to interact.

Plotting facility

The plotting facility allows the tower or groups of panels to be viewed on a Tektronix screen or plotted at the Benson plotter. Some of the views available are illustrated in Figs. 2 and 3. Views not illustrated include true views of face bracing where the face of the panel is sloping, three-dimensional views of one corner of a panel with face bracing, and true developed views of the various planes of hip bracing. At the plotter, the user may position several different views on a single A1 sheet, and position and enter titles or other text as appropriate. A standard Arup A1 border is optionally provided, complete with titles and drawing number.

Aerial Forces program

The Aerial Forces program is initiated either at monitor level with the command /TOWER AERIAL or from within the TOWER program with the command *AERIAL. In the latter case, data concerning the tower geometry and wind velocity profile is taken from the current tower data.

A group of up to 12 face-mounted or leg-mounted aerials at a given level are specified by type, position and angle of fire. The program calculates the forces and torques on the tower for wind directions at 5 degree intervals from 0 to 360 degrees, from data stored in files for each aerial type. If the orientation of the tower is unknown, the program considers at 5 degree intervals all possible orientations within the constraints of the specified aerial positions and angles. Aerial fixing offsets may be given individually, and a tolerance of 5 degrees may be allowed on the angles of fire. The results include the maximum possible forces and torques resolved to the critical wind directions of the tower.

Final output for this program is at the lineprinter to be compatible with the main tower calculation.

Conclusion

A log file included in the Tower system records details of all program runs. From this a pattern of use should emerge over the next two years which will aid evaluation and help to direct future development effort. Meanwhile the system has yet to be used on its first full production job. Interest has already been expressed by both the Irish and Australian offices of the practice, and it is hoped that the development of the system will soon be justified by its use in production.

Emgas Service Centre, Leicester

Ken Tune

Introduction

The predecessors of the East Midlands Gas Board have been producing gas at Aylestone Road in Leicester for approximately 100 years, and not unnaturally, in 1973, the site had all the characteristics and disadvantages of the traditional gasworks. Some grandiose Victorian retort houses remained, surrounded by more or less demolished buildings and foundations of superseded production methods, including an area where gas had been produced from oil. With the arrival of natural gas and the rationalization of the industry, this site was available for redevelopment. Surrounded by a railway embankment, a neglected river and the remaining gas works, it was evident that an imaginative approach would be required.

Architects Design Group were therefore commissioned by Emgas to design a service centre for the Leicestershire region which would embrace, in one complex, all the necessary facilities for installation and servicing of mains distribution and customer services. The main building houses, under one roof, both management and operatives, thus enabling a good work flow between the large telephone bureau, work planning supervisors, operatives and stores. Both routine and emergency work are handled, and in addition to extensive storage facilities for appliances, spares and equipment, adjacent buildings house industrial and technical workshops and comprehensive vehicle maintenance and repair facilities.

The Emgas headquarters are located in Leicester, and as major employers in the city, they sought 'a new and attractive building to enhance the image of industry in Leicester to the general public'. No restrictions were placed on the development of the site by the planning authority other than the retention of the Victorian brick clock tower and gatehouse, and landscaping of the riverside area.

Foundations

Like many redevelopment sites, the level brick hardcore surface concealed a variety of obstructions in the form of basements with heavy brick piers, concrete slabs and filled tanks. Beneath this fill, which is 2-3m thick, the underlying strata consist of soft, compressible alluvial clays and silts, overlying gravel and mudstone.

The client wished to use a mechanical storage system which involved stacking large appliances, four high, on racking which is set at a slight slope, thus gravity feeding the delivery bay. This demanded minimal settlements, whilst imposing large and uneven live loads (up to 25 kN/m²). In addition, due to the low lying nature of the site, the floor slab level was set above existing ground level, thus further adding to the possibility of settlement.

Piling would have provided an ideal solution, but had to be ruled out because of the nature and depth of the below ground obstructions. It was therefore decided to use a system of ground consolidation. By this means the fill could be compacted to a uniform density to support the floor slab evenly, whilst column loads were spread further through the clay to the gravel below. 'Hard spots' due to existing mass brick walls were to be cut back to provide a cushioning layer of at least 1m of granular fill.

Tenders were invited for two proprietary systems and the sub-contract was awarded to Cementation Ltd. for their *Vibroflotation* technique. This involves vibrating a large probe into the ground with water flushing to remove soft material. The probe is slowly withdrawn whilst clean stone is vibrated into the resulting void. Obstructions were broken out by conventional means, but the system proved very flexible in practice and it was often possible to re-site compaction points without incurring standing time. The large volumes of water involved (5 l/sec.) required the construction of large settling lagoons and special disposal arrangements with the water authority.

The main contractor was then able to construct conventional pad footings for columns bases, with a safe bearing pressure of 170 kN/m², and complete filling and compaction of the sub-grade for the floor slabs.

Superstructure

The initial architectural concept was of exposed steelwork for all structural elements, as an integral part of the building. This required also that all visible joints were welded. The planning grid is square, which is somewhat unusual for a steel frame, and this basic squareness gives rise to some unusual features. The columns are cruciform in shape, being formed from two 305mm x 102mm universal beams, one of which is split in two and continuously welded to the other. The cap detail was evolved to combine clean lines with ease of erection.

The main 14.4m bays of the 'tartan' grid are defined by primary beams. Each of these areas is largely self-contained as regards main services, and the beams provide the necessary void. Above this is a single layer, two-way grid of main purlins of minimum depth, their clean lines providing a pleasant contrast with the 'nuts and bolts' appearance of much exposed steelwork, whilst their 3.6m spacing defines the basic module and is convenient for supporting the ribbed metal-insulated decking.

Studies of the problem of solar gain showed that even though the external full-height windows were of reflective glass (and double glazed), a canopy to provide direct shade was desirable. The main roof beams are therefore cantilevered 1.6 m beyond the face of the building and support a steel channel fascia to all office areas. The stores rely largely on artificial lighting with occasional roof lights, and are thus clad in profiled metal sheets, with a large canopy over the loading bay.

Of the two smaller buildings on the site, the workshops repeat the same structural form as the main block, but the vehicle repair building, with a rectangular grid, features castellated roof beams and conventional one-way purlins.

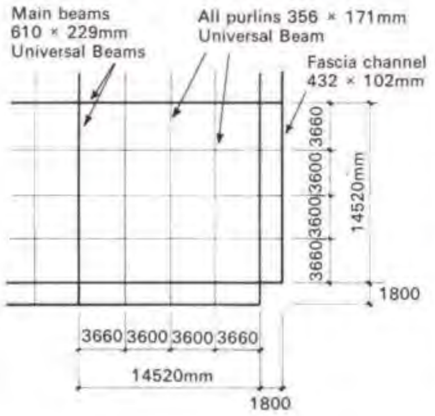


Fig. 1
Typical corner roof bay

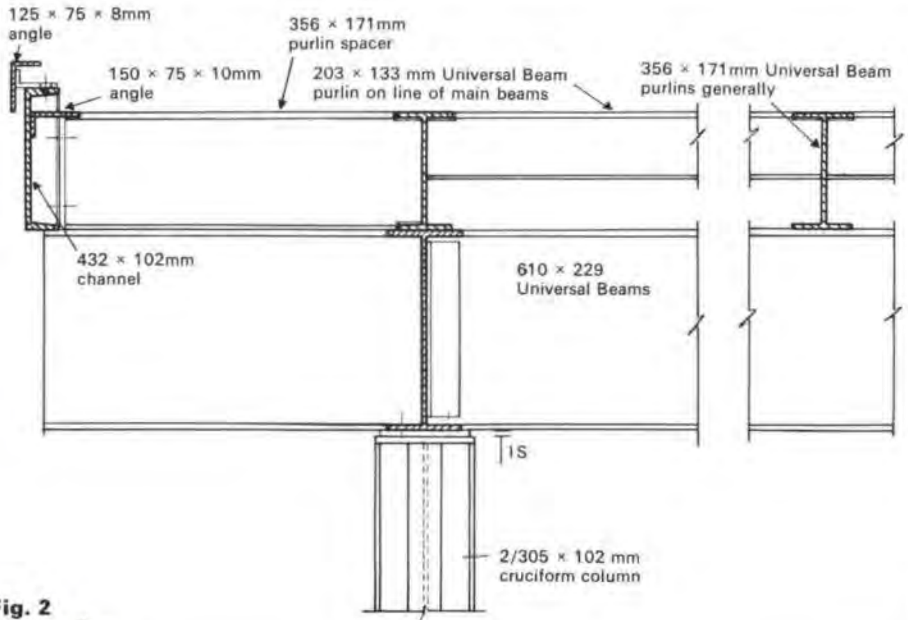


Fig. 2
Window line

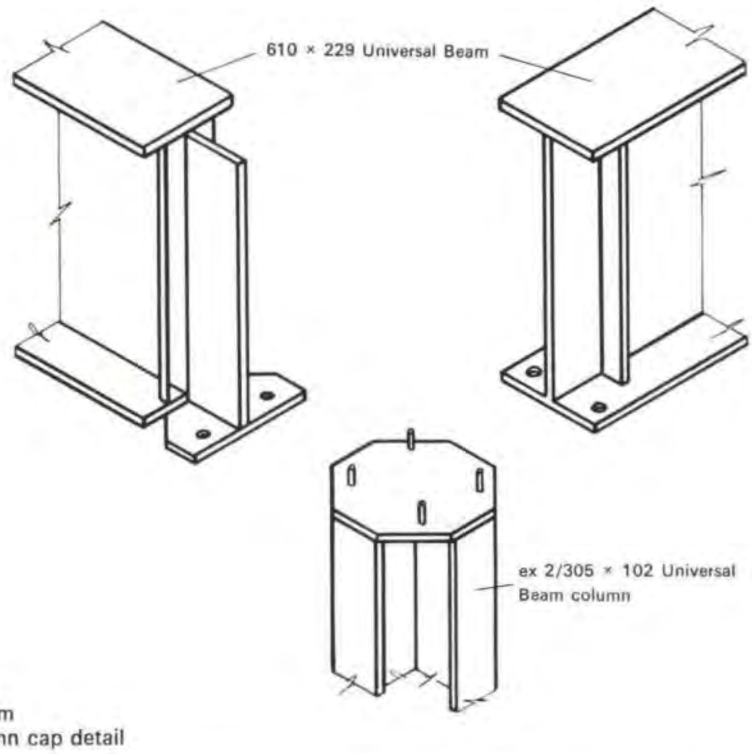


Fig. 3
Main beam
and column cap detail

Fabrication

The fabrication of the purlins into 14.4 m square units clearly demanded site welding. It was therefore proposed that the vehicle repair building be erected first and used as a fabrication shop. Whilst some use was made of this facility, the sub-contractor, Carter Horseley Engineers, (Clarke Chapman Ltd.) chose to erect a further temporary building for site welding. In addition to calculated deflections at each node point, allowances were made for welding shrinkage and distortion, and a trial panel was successfully fabricated. Remaining units were then jigged up and welded, being moved from the shop to a site storage area on bogies. The full protective treatment, including grit blasting, has also to be carried out on site.

All other steelwork was fabricated in workshops in the normal way, and all but the final coat of paint applied in the workshops.

All steelwork was blast cleaned and in addition external steelwork received a coat of flame-sprayed zinc, followed by two coats of chlorinated rubber paint. The internal steelwork was finished in silicone enamel over zinc phosphate priming coats.

During the course of the contract, some problems were experienced in applying the second coat of chlorinated rubber paint to certain components. The second application tended to soften the first coat and made it difficult to produce an acceptable finish. These problems were obviated by using a micaceous, iron oxide, chlorinated rubber paint, which is also greatly superior in resistance to mechanical damage, at little extra cost.

Some difficulty was envisaged in obtaining the required standard of straightness on the cruciform columns, due to both welding distortion and initial distortion of the universal beam when this was split into two 'T's. In the event, a very good standard was achieved. The work was sub-let to a fabricator who normally provided split 'T's for British Steel Corporation, and had straightening facilities. The critical continuous fillet-welds were also of a high visual standard.

We were fortunate in having the services of a resident steelwork inspector who is also a qualified welder. Although primarily employed to supervise the extensive site welding and erection, he was required to make frequent visits to fabricators in various locations. Close supervision of the painting was also necessary.

A further area requiring care was that of cambering of beams. Whilst it is relatively easy to obtain members with a camber upwards of 50mm direct from the mills, smaller cambers are difficult to control. The degree of success achieved may be judged from the line of the canopy beam, which is seen from a critical angle when entering the site.

Constrado commendation

It must be said that, at the pre-tender stage, the steelwork construction industry was not seen in its best light. Even allowing for delivery problems immediately following the so-called 'Three-day week' (in 1974) the general approach to being invited to tender for over 800 tonnes of steelwork was disappointing. Anything unusual was treated in many cases with mistrust or incredulity. The idea of finished steelwork in 'domestic' surroundings was clearly outside the experience and imagination of much of the industry. However, a competitive tender was obtained from a selected list, after much interviewing.

Fortunately the Constructional Steel Research and Development Organization (Constrado) did not share this opinion, and the building was commended in the 1977 Awards.

A few facts and figures

The two-year contract commenced in December 1974. The final value was approximately £3.3m, covering approximately 1,400m² of building, in addition to site works. The structural steelwork subcontract was worth £475,000.

In addition to the Constrado award already mentioned, the scheme was one of six finalists in the Financial Times Industrial Architecture Awards for 1977.

Credits

Client:
East Midlands Gas

Architects and landscape consultants:
Architects Design Group

Mechanical and electrical engineers:
R. W. Gregory and Partners

Quantity surveyor:
Felton and Partners

Main contractor:
Shepherd Construction Ltd

Structural steelwork:
Carter Horseley Engineers Clarke Chapman Ltd.

Figs. 4 & 5
Main block under construction
(Photo: Emgas)

Construction

The building floor slabs were laid by the now well-established 'long strip' method using 30 N/mm² concrete power-floated and surface hardened to support small – wheeled fork lift trucks in the stores area. The office areas incorporate a screed in which small services are buried. The floor slabs were generally laid after the roof sheeting was fixed.

Internal partitions are kept to a minimum, and are formed of painted fair-faced blockwork. All office and public areas are carpeted.

Services

As previously mentioned the services are related to the main 14.4m grid. Air conditioning is provided by roof-mounted, gas-fired units in the office areas, the air being distributed by large ducts within each bay. These are painted bright red and are clearly seen, with other piped services, through the open-slatted ceiling. The ceiling void thus not only contributes in interest, but also adds a feeling of spaciousness within the large open-plan areas, avoiding the oppressiveness of a solid ceiling whilst still providing more intimate surroundings.

In the stores and workshops, heating is by unit heaters only, with air curtains as required.

Landscaping and external works

Much of the site is, of necessity, taken up with access roads, car and lorry parks and a large pipeyard. Roads and the loading bay are of concrete, to cater for heavy vehicle movements, and other traffic areas and the pipeyard are of bituminous construction. Extensive use has also been made of concrete block paving for parking and pedestrian areas around the main building. This has been densely interplanted with dwarf shrubs and trees. The perimeter railway embankment and river bank have also been landscaped, and might be considered pleasant enough, if somewhat unremarkable, to the casual visitor. However, to anyone who knew this site in its previous condition, particularly in the dull November weather which makes up so much of our climate, the transformation is most impressive, and creates space that apparently did not exist before.

Particular mention must be made of the inner courtyard, heavily planted and with attractive paving and pools, and much frequented by birds.

Fig. 6 below
Office block under construction, showing main air ducts (Photo: Ken Tune)

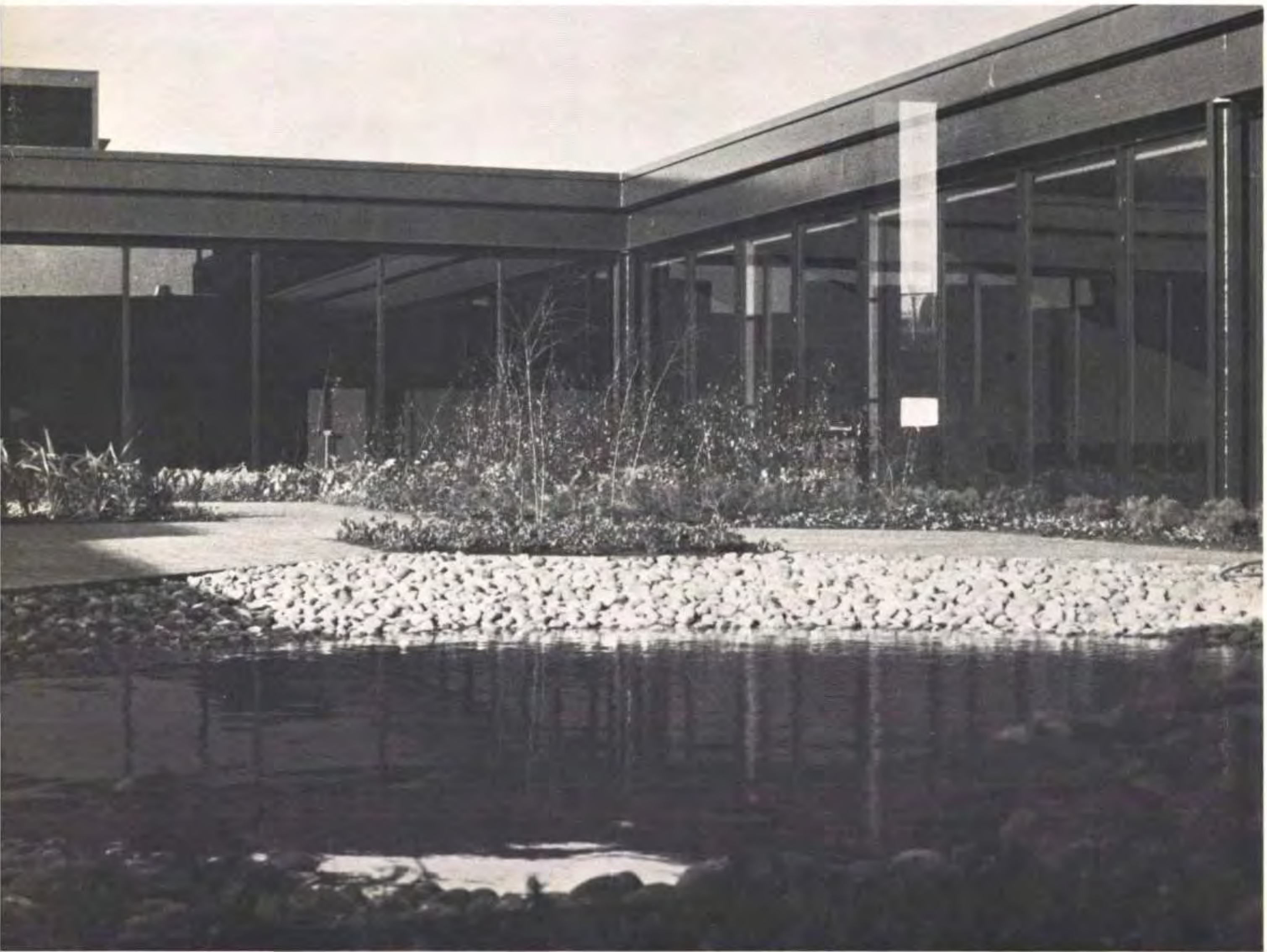
Fig. 7
The staff canteen (Photo: Architects Design Group)

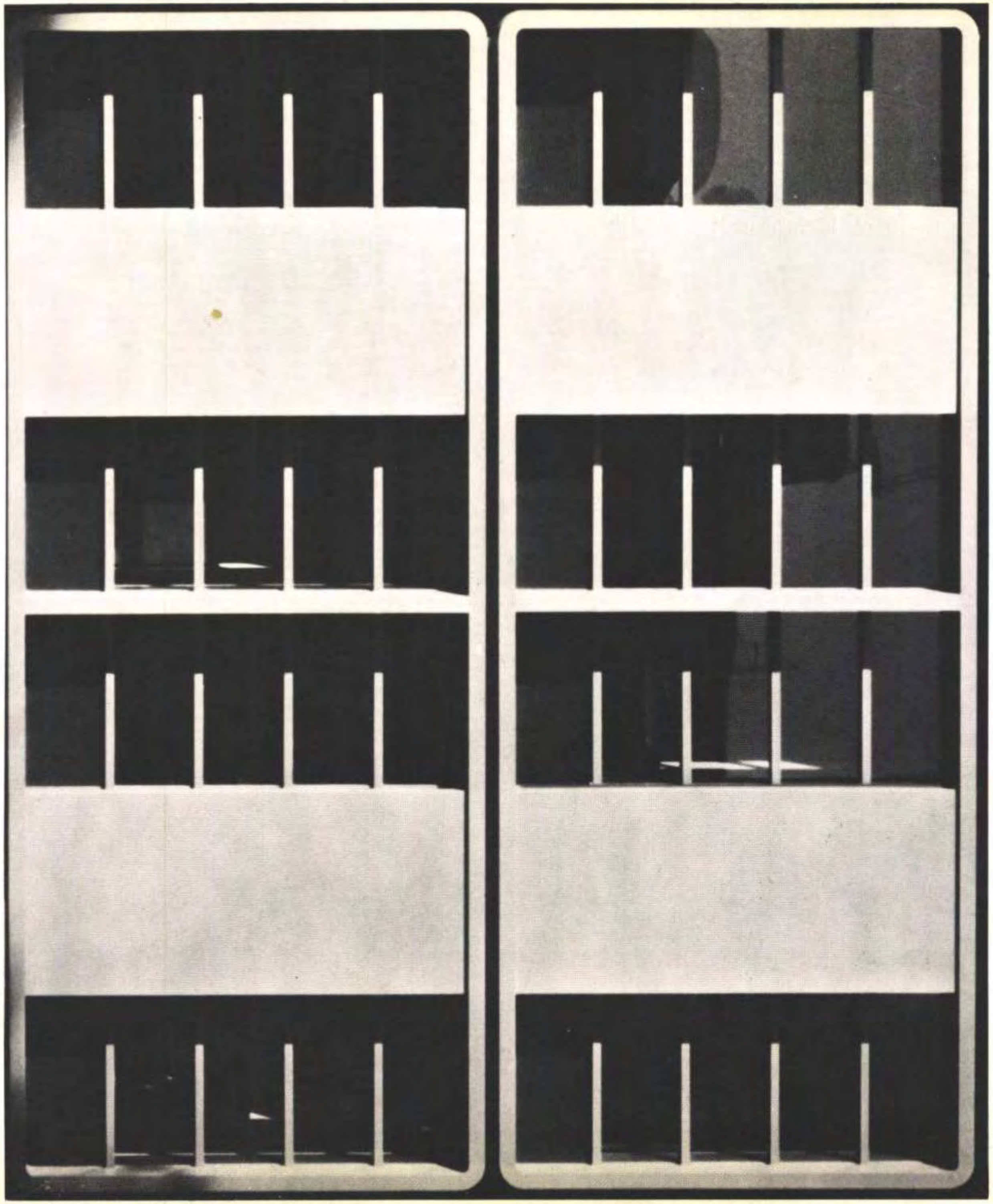
Fig. 8
The service centre as seen from the main entrance gate (Photo: Architects Design Group)

Fig. 9 above
South east elevation of office block (chimneys are 1/4 mile away) (Photo: Architects Design Group)

Fig. 10 below
The courtyard (Photo: Architects Design Group)

Fig. 11 right
South west elevation (Photo: Architects Design Group)





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