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IBM North Harbour, Phase 4: Photographs by Stephen Outlaw (front cover) and Peter Cook (back cover)

Swire Bottlers redevelopment, Tsuen Wan

Michael Harley

Introduction

In most parts of the world, warehousing tends to be developed horizontally. In Hong Kong, and to a lesser extent Singapore, where the cost of land is a dominant factor, warehousing (inappropriately called 'godowns' in Asia) is built vertically.

This article summarizes a successful competition submission that we made in association with YRM International. The project is a mixed development for industrial, warehouse and commercial use involving a floor area of some 180,000m^2, which for the most part is heavily loaded. The building is to be constructed on a 1 ha site and will stand 145m high.

Our client is, in fact, two separate but related companies; Swire Bottlers Ltd., who hold the franchise for all Coca-Cola products in Hong Kong, and Swire Properties Ltd., who handle the development and management of property for the Swire Pacific Group.

Swire Bottlers have two existing bottling plants in the crown territory: one is a modern factory recently completed on Hong Kong island, the other a much older development built in Tsuen Wan in the late '60s. Already the capacity of these two plants is being stretched, and on the basis that the current trend of an annual 10% increase in the sale of soft drinks would continue, Swire Bottlers decided to increase their capacity. An obvious solution was to redevelop the site at Tsuen Wan, and Swire Pacific decided to build a new bottling plant on this site, with warehousing, industrial and commercial developments built above, which would subsequently provide revenue toward the costs for the whole project.

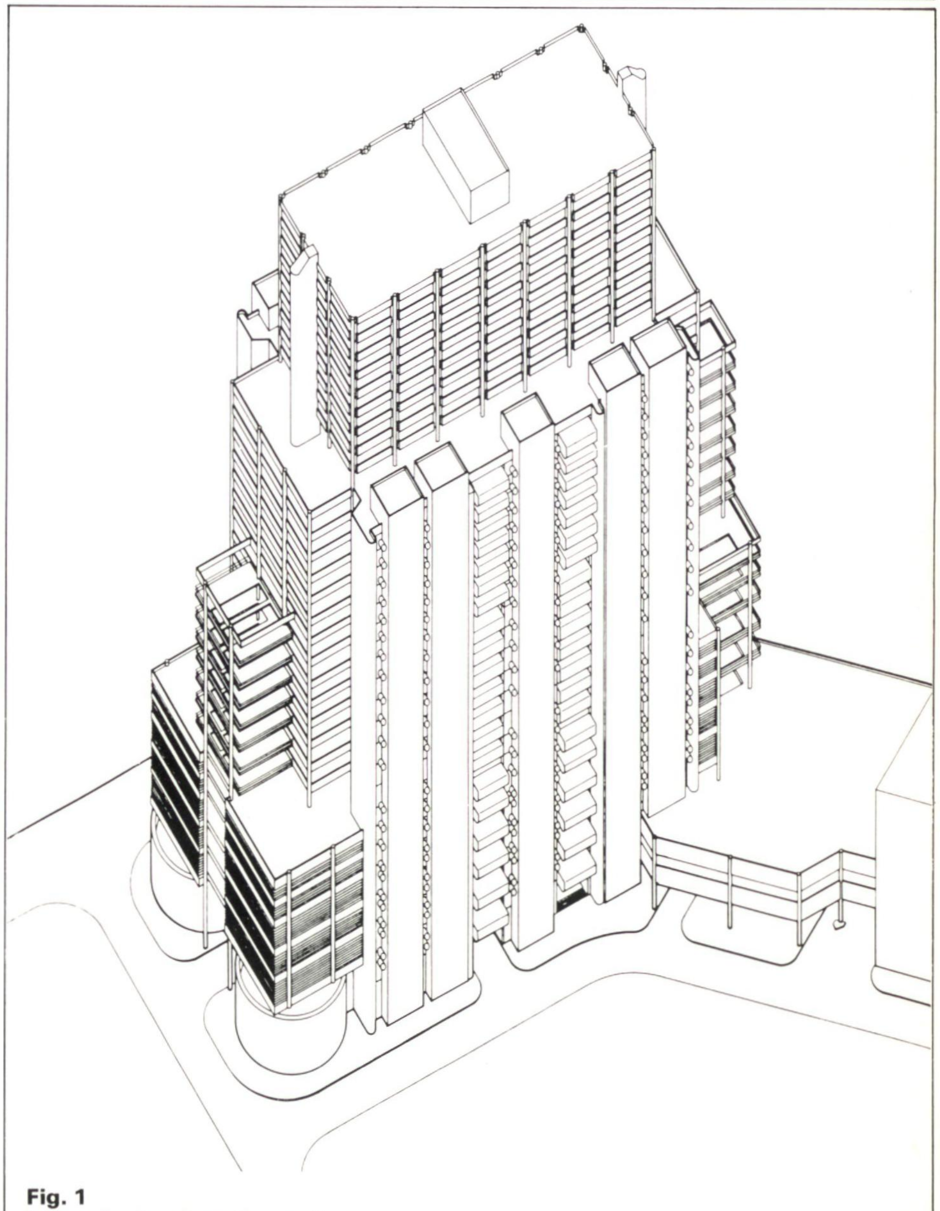


Fig. 1
Isometric view from the south west

In April 1981 Swire Pacific invited four groups of architects and engineers to enter a limited competition for proposals to develop the site. We were invited as the lead consultants, and elected to work with our architectural neighbours YRM International. It was a fortunate choice, and the collaboration on the competition, and subsequently on the main job, proved to be extremely happy and productive.

Our brief was to submit proposals for a new building which was to comprise two independent parts; a bottling plant for Swire Bottlers Ltd., and industrial/warehouse/office accommodation for lease. Special emphasis was to be placed on goods handling and distribution facilities, and each of the two sections was to have separate vehicle access, loading and unloading facilities and building services. Construction was to be phased to permit Swire Bottlers to continue bottling operations on the site during the redevelopment period.

The site

The site is located on reclaimed land in Tsuen Wan close to the main container terminal of Kwai Chung and facing the islands of Tsing Yi and Lantau. The reclamation involves some 5 to 10m of fill placed on soft, compressible marine and alluvial soils, which in turn overlie in situ weathered rock and granodiorite.

The Public Works Department's current road construction programme provides for a number of new links of particular importance for the site. The Tsuen Wan By-Pass and the Texaco Road improvements will eventually link up with Route 5, providing a direct link to Sha Tin and the North East New Territories. In addition Lantau will be directly accessible from the site once the proposed new bridge crossing has been built. Existing highways provide good connections to the north west and to Kowloon and Hong Kong.

Locally the development is bound by roads on three sides. To the north, Yeung Uk Road and Ma Tau Pa Road are dual, two-lane district distributors with connections to the Tsuen Wan By-Pass and Texaco Road.

To the south and west lie Fui Yiu Kok Street and Wang Lung Street, which are both one-way, west-bound streets. Existing access points to the site are on the south and west. Although there is provision in the lease for access from the north, discussions with the Government revealed that this would be overruled on safety grounds, and consequently no access from the north was provided in our scheme.

Since the whole of the local road network is under review by the PWD, and there is a possibility that traffic directions on the one-way streets could be reversed, our scheme was developed so that the building would operate efficiently from a traffic point of view, irrespective of the direction of traffic flows on Wang Lung and Fui Yiu Kok Streets.

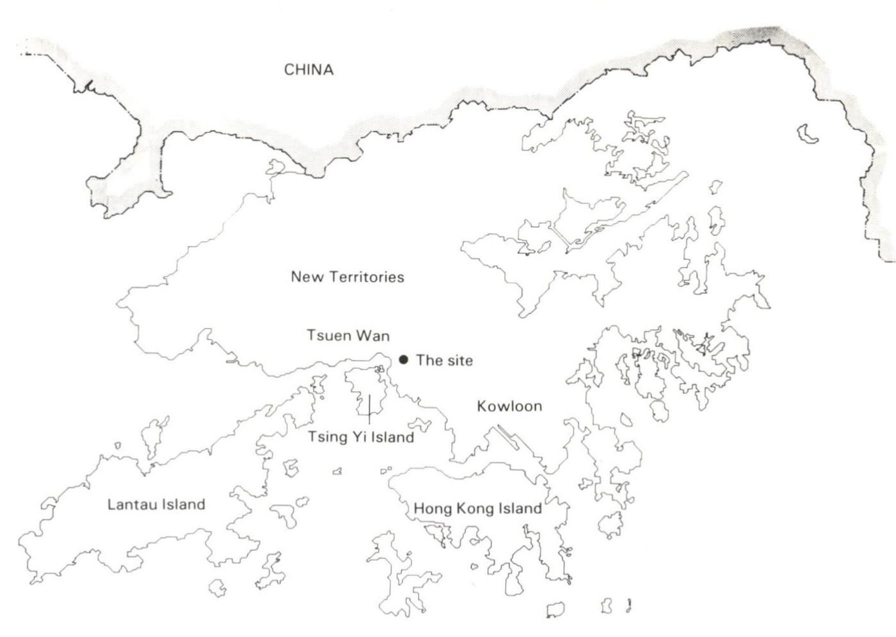


Fig. 2
Map showing position of site in relation to Tsing Yi and Lantau islands

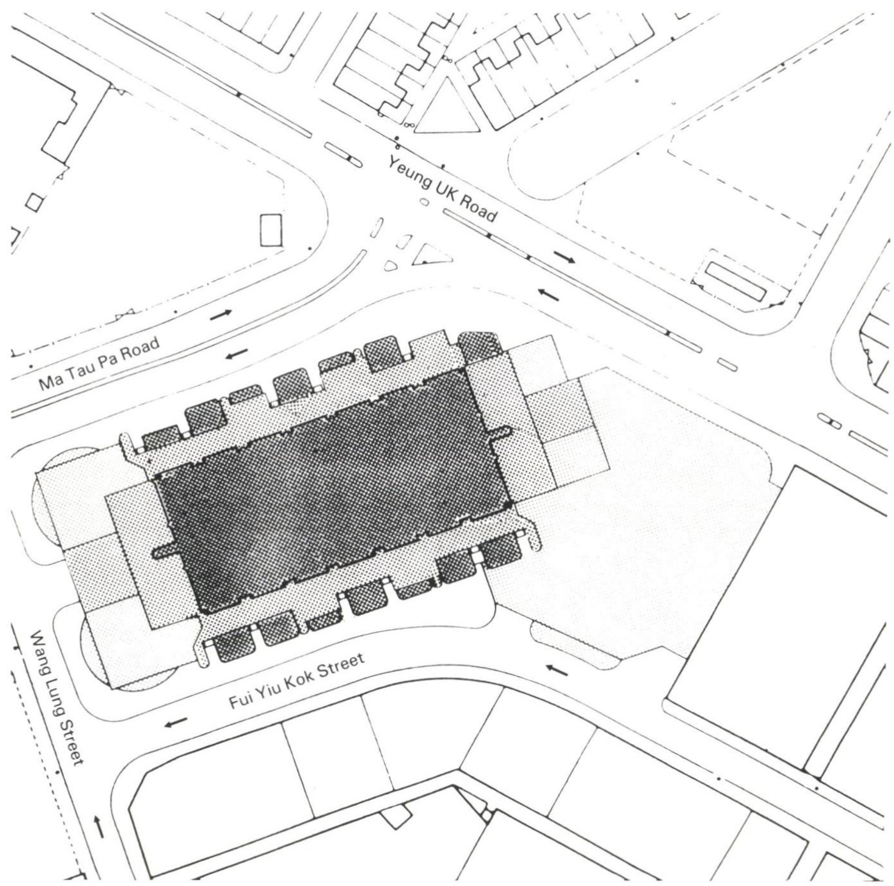


Fig. 3
Site plan

Building layout and design

The design originated around the nature of the building's functions: specifically Swire Bottlers' need for flexibility and expandability and Swire Properties' letting policies. The intention, therefore, emerged of creating well-serviced spaces with minimum obstructions to allow maximum freedom to plan immediate and future internal layouts with the greatest flexibility and economy. This freedom is manifest on all floors above podium level and is only compromised on the lower levels by the irregular site configuration and the demands of vertical vehicle movement.

After investigation of various layouts and phasing options, the proposed solution was adopted as the most favourable in terms of minimizing operational disruption during construction and, from a planning point of view, allows the largest rectilinear space configuration. This results in the bulk of the building being weighted towards Wang Lung Street on the western end of the site. It was decided to adopt, over the whole development parallel to Ma Tau Pa Road, a simple rectilinear planning and engineering grid, which clearly has constructional, planning and financial benefits.

The four different categories of occupier, i.e. bottling plant, warehousing, industrial and office, require an integrated approach to the vertical, as well as horizontal, movement of materials and personnel. A centralized lift arrangement proved unacceptable to the basic principle of unobstructed space, and a perimeter arrangement of goods, passenger lifts and container hoists emerged as the most equitable in terms of serving individually the requirements of four separate zones and affording better servicing and structural economies.

The resulting design separates access for pedestrians, cars, Swire Bottlers' route trucks and container vehicles and industrial/godown lorries and container vehicles. Within the building every pedestrian or car access point can be linked to every lift bank without intruding into goods handling areas. Four container hoists and 48 lifts working on minimum horizontal travel distances provide for the distribution of personnel and goods to all parts of the building. Routeing from the basement and ground floor to different floors is by category of use: bottling plant, warehousing, industrial and offices. Each sector of the perimeter has a complete set of lifts that reach all floors; this, in addition to the requirements of the brief, ensures adequate provision for maintenance and fault downtime.

The regular perimeter service routes and lift arrangement allow Swire Bottlers to expand or contract their operation, so that even if they chose not to increase their capacity in Phase 2, the new part of levels 2-6 could be let for either godown or industrial use.

The offices have been set back from the main faces of the building for two reasons: the depth of plan required by the lower zones is excessive for general offices and limitations are also imposed by the permitted shadow area. The offices are served by a central core of high speed lifts, originating from the ground floor main lobby.

The concept of planning flexibility also implies the adoption of a structural module which leads to economy of construction. Several grid options were explored and at the competition stage a square structural grid of 10.8m was selected as the most appropriate.

It was proposed that externally the reinforced concrete lift towers and structure be used either in white glass mosaic or Bonntile to avoid staining, discolouration and mould growth, while maintenance-free, vitreous enamel steel or grp would be used as the exterior finish for the toilet modules.

The appearance of the building is defined by the clearly expressed structure of the external lift towers along Ma Tau Pa Road and Fui Yiu Kok Street, which descend in progressively increasing masses at the ends of the building and will appear stabilized by the container hoists which emerge from the lower storeys at either end. It is recognized that these would create a dramatic and memorable effect in addition to being the principal key to operation of one of the most advanced packaging, goods handling and distribution facilities in the world.

Fig. 4
Short section

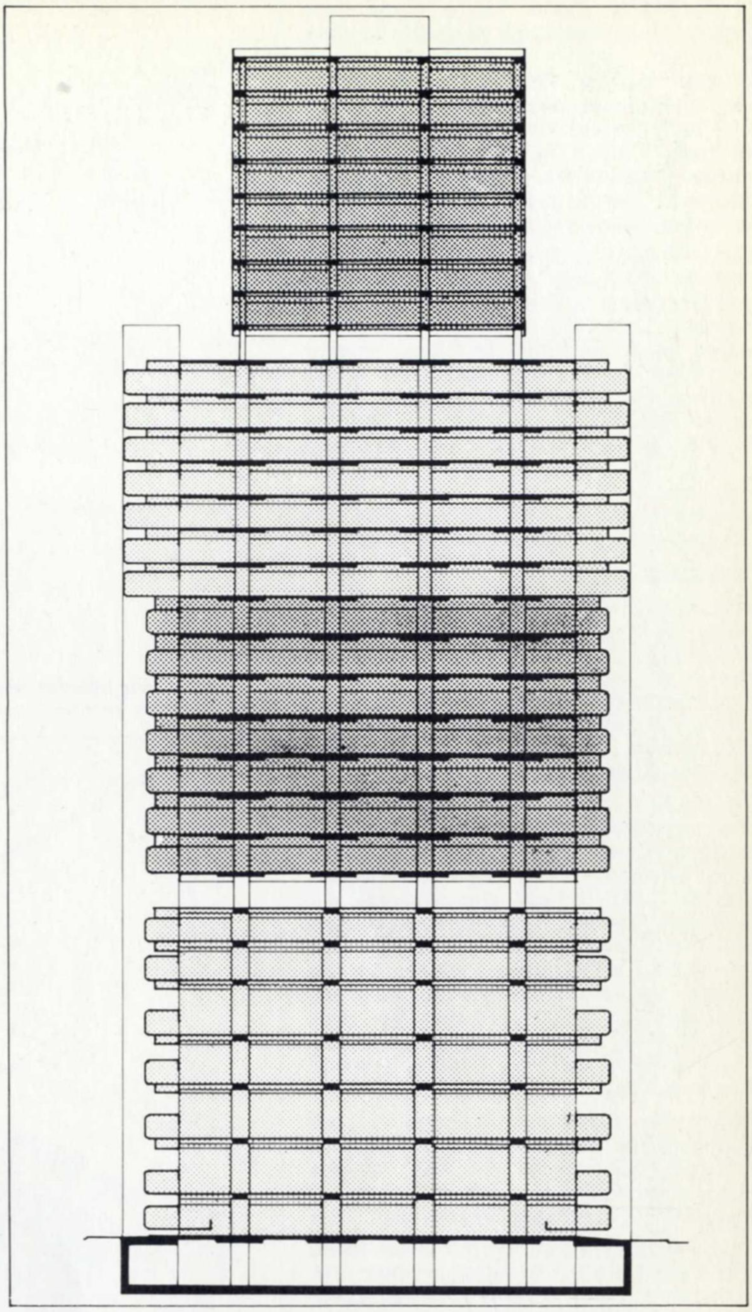
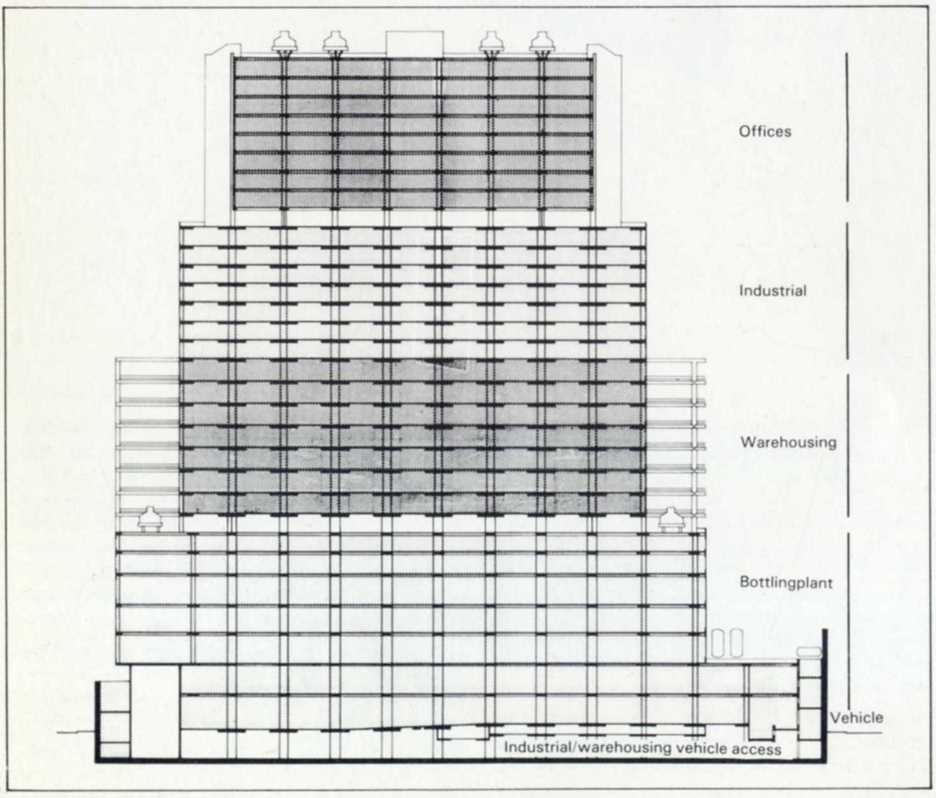


Fig. 5
Long section



The structure

Floor loading in much of the building is high, resulting in column loads for this 31 storey building of around 75,000 kN. These loads will be carried on large diameter foundations, end bearing on rock. Three different types of large diameter piles were considered and hand-dug caissons, with a range of sizes of shaft and underseam to match the column loads, were chosen as the most appropriate.

The 10.8m square structural grid was determined primarily by vehicular traffic requirements, and in particular by the space requirements for manoeuvring 12.2m container vehicles and parking for the delivery trucks. In view of the heavy imposed loads, and the requirements for minimum floor-to-floor heights, simplicity, economy, and low structural maintenance, in situ reinforced concrete emerged as a clear choice for the principal construction material.

To keep column sizes within reasonable proportions (and to minimize the structural depth of the floor systems), lateral stability for the main tower is provided by shear walls rather than through framing action. The offices above the tower, however, are stabilized only by frame action.

The overall plan dimensions of the building are approximately 160 × 60m, and to minimize thermal and shrinkage strains, 30mm

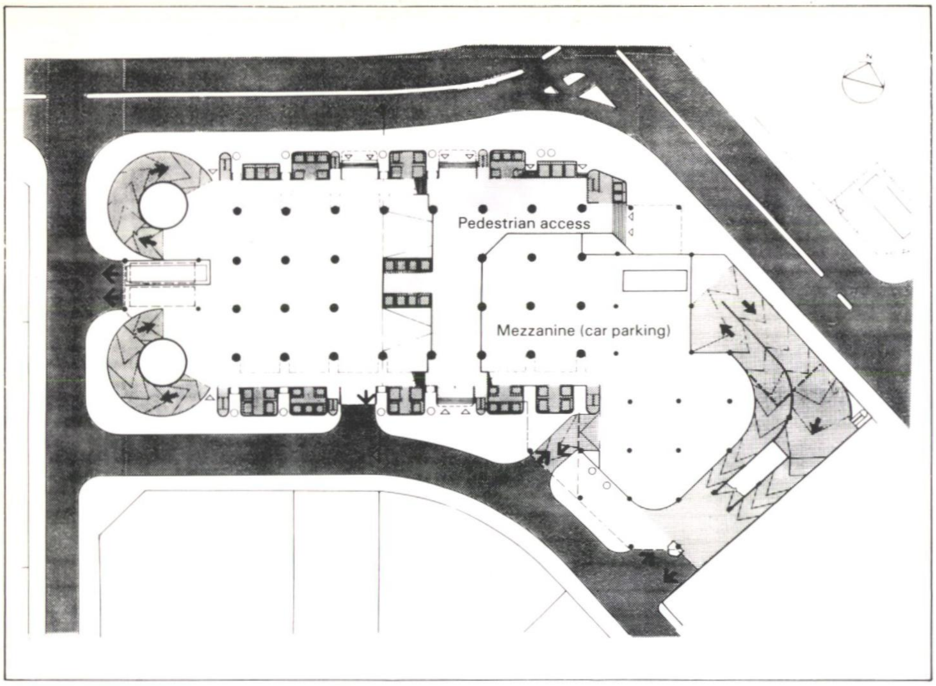
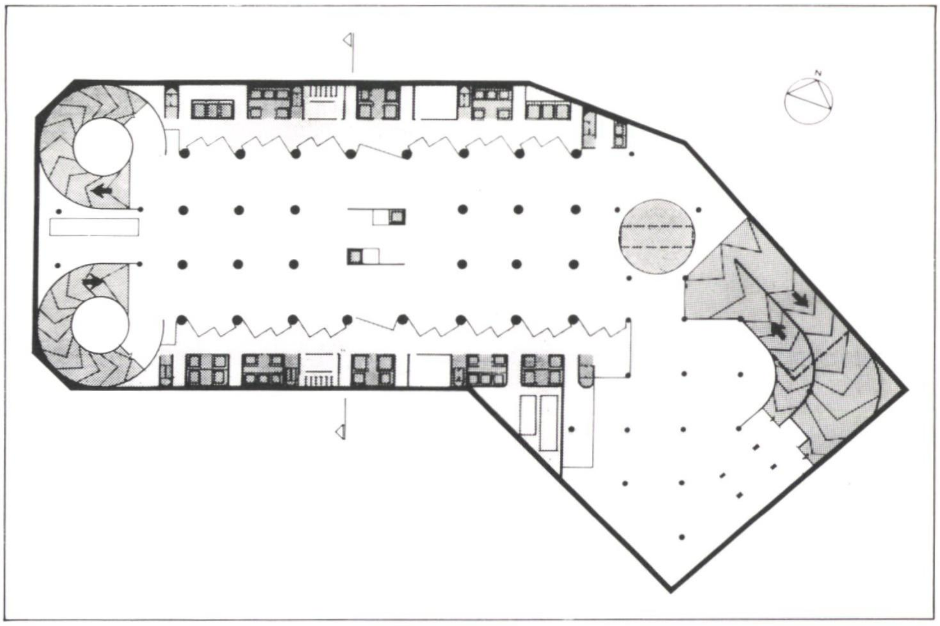


Fig. 6
Ground floor plan showing mezzanine entrance and car parking area

Fig. 7
Basement plan



wide expansion joints were introduced on the phase line and at the junction between the tower and the podium.

To enable the site to be developed to its full potential, the major criterion for the floor construction is minimum structural depth. For the preliminary design a structural/services zone not exceeding 1000mm was adopted. In the industrial and warehouse sections of the building a flat slab form of construction with drops at the columns works efficiently within this constraint, and provides the maximum uncluttered zone for services distribution.

In the bottling section, however, there is a further requirement for 2m square pallet hoists to be installed between floors some time after the building is complete. The adoption of a 1.2m module waffle slab for the bottling section meets this requirement, enabling 2m square openings to be made with the loss of only one rib in each direction. Minor penetrations for future vertical services distribution are also accommodated in this form of construction through the topping between the ribs. This floor structure also works well within the 1m deep structural/services zone requirement.

Mechanical and electrical systems

The principal factors governing the services strategy adopted were determined by the facilities required in the quartered zones on each floor level in the industrial and office sections, the concentration of process areas in the lower section of the tower and the constraints generated by the location of vertical transportation through the building.

Planning considerations determined that the north and south perimeters of the building are predominantly used for lifts and toilet facilities, leaving the east and west perimeters free for the accommodation of ventilation plant, air-conditioning and the vertical distribution of associated services and electrical power.

Refuge floors are required by the Fire Services Department (FSD) in Hong Kong for highrise buildings. Central plant for the process and environmental services is located at these refuge floor levels to economize on the use of this space and because these areas are conveniently close to the centres of demand.

For the basement, ground and upper podium floors where substantial vehicle movements occur, supply and exhaust ventilation is provided to restrict the levels of exhaust gases and build-up of heat, and to provide smoke extraction in the event of fire.

Chilled water plant with a capacity of around 2500 tonnes of refrigeration, necessary for air-conditioning and cooling throughout the building, is located on the upper refuge floor. Various types of condenser cooling were considered, and open circuit cooling towers located on the roof were chosen as the most economical solution for the chilled water system. Although this method rarely meets with water authority approval because of the water losses involved, we believe it will be possible to use recovered and treated wastewater from the bottling plant as make-up water for the cooling condensers.

Chilled water is piped vertically on the east and west facades to four plantrooms per floor arranged in pairs at the ends of the building for the bottling section and offices.

For the warehousing/industrial floors, branch terminations will be provided for connection to tenants' or landlords' equipment as appropriate. Each termination will be metered, and logged by a central electronic monitoring system.

A separate process refrigeration system will be needed for the bottling plant due to the low evaporation temperatures involved. It is estimated that ultimately 1500 tonnes capacity will be necessary, and a space allocation for this has been allowed at the lower refuge/plant floor level with condenser cooling located on the roof.

Estimated consumption of CO_2 for the bottling plant will be approximately 2500 tonnes per annum, and it is proposed to recover CO_2 from the boiler stack gases.

The installed boiler capacity in the existing bottling plant is 6700 kg/hour steam, and total boiler capacity for the redevelopment will be in the order of 20,000 kg/hour. In the absence of demanding process requirements, a circulating hot water system could be a more efficient solution.

The development will be required to comply with the new FOC rules covering multistorey building, and at least some of the areas will be classified as extra high hazard category. Automatic sprinkler systems, hydrant/hosereel systems, and fire alarm systems will be provided and a water storage capacity of some 600m^3 will be provided in the circular cores of the spiral ramps.

The estimated maximum demand electrical load for the development is approximately 25 MVA, of which some 7.5 MVA is required for the bottling section. Despite the stringent requirements of the electricity supply authorities and FSD for high level substations, it is our intention to locate substations as close as possible to the load centres. Four substations are to be installed on both the upper and lower refuge floors and two on the ground floor. Standby generation will also be provided for all equipment associated with the fire services.

Transportation within the building

The brief calls for the building to be split into two operationally independent units, each containing separate access and vehicle loading and unloading areas.

At the east end of the building, linear ramps are provided between the ground floor and basement where 28 sawtooth loading bays are provided, serviced by high speed goods lifts. These lifts are grouped into four segments and feed the warehousing and industrial levels.

Container lorries, using the same ramps, are manoeuvred by turntable or hydraulic lorry lift, into the correct position under the container hoists on the east and west ends. These hoists can handle jumbo containers (12.2 × 2.4 × 2.9m) weighing some 30 tonnes. The container is lifted from the flat bed to the required floor level where the container is transferred horizontally onto a landing and can then be unloaded. Operating at 20m/minute, the round trip cycle time for a vertical lift of 70m is under 10 minutes; in practice however it is unlikely that more than four containers can be moved to this height in an hour.

Swire Bottlers container traffic has direct access to the ground floor, and containers are transferred by separate container hoists to the required levels within the bottling plant. The most significant traffic flows are generated by Swire Bottlers route (distribution) trucks, involving up to 600 vehicle movements a day. Provision has been made for overnight parking for 200 vehicles. Two spiral ramps at the west end of the building provide access from ground level to parking and loading floors for these lorries.

The spiral ramps between ground floor and basement will only be used during Phase 1 of the development, providing additional route trunk parking for that phase.

A mezzanine floor is provided between basement and ground floor and permits pedestrian traffic across the building and provides additional car parking. This parking is intended primarily for office use, and is serviced by a central core of high speed passenger lifts.

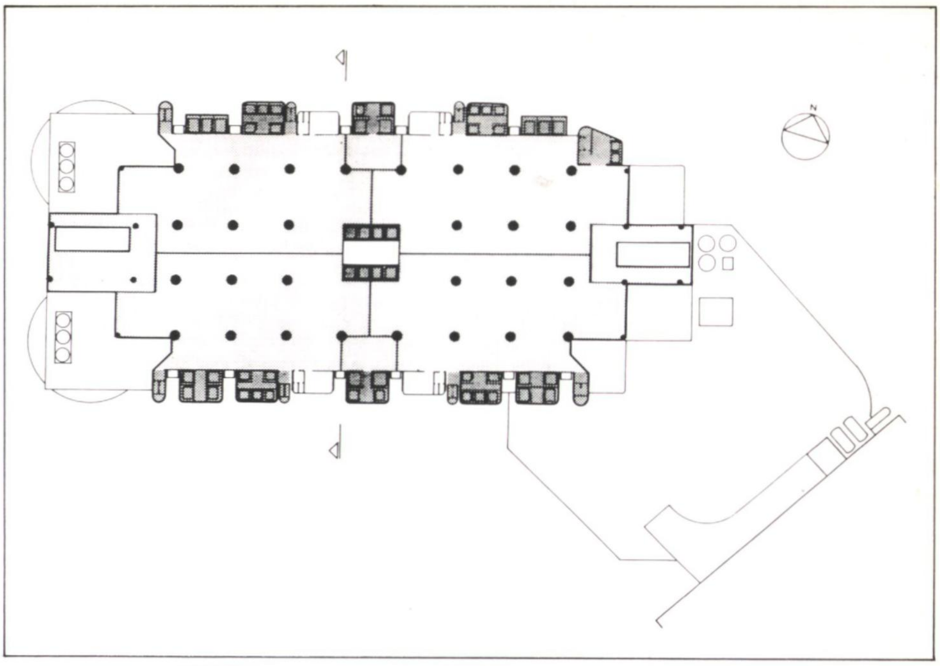
Phased construction

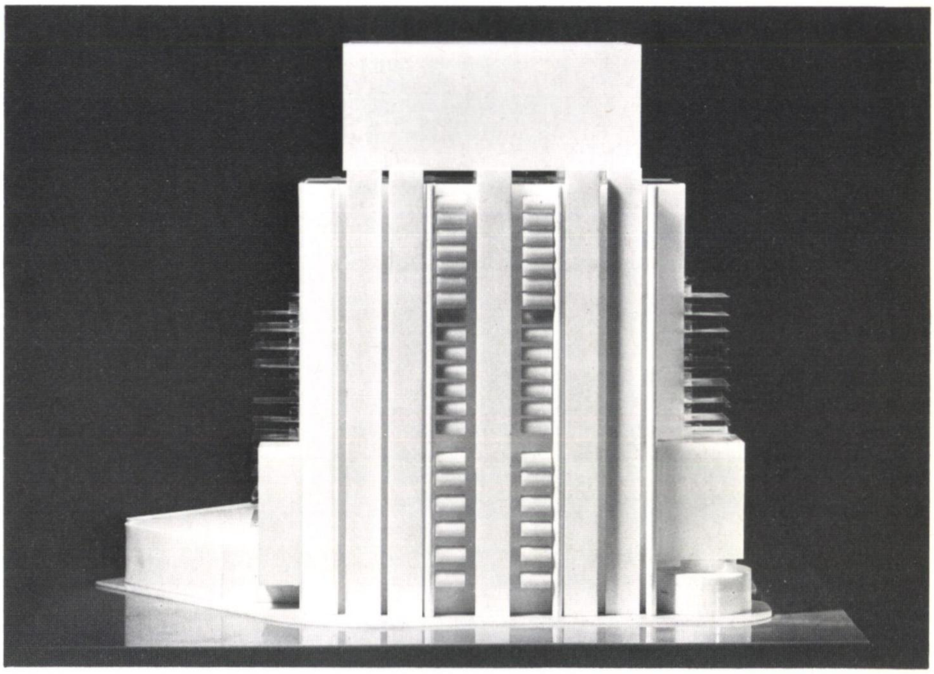
The brief required that the project should be constructed in two phases, and that bottling operations should be able to continue on site during the redevelopment period. This latter requirement implied that the existing bottling area, which is located at the centroid of the site and contains three bottling lines, should be retained during the first phase.

A number of phasing options were considered, but the constraints of adequate access to the site, efficient vehicle flows within the building, the massing of the building itself, and reasonable access for the contractor during construction determined the type of phasing chosen.

Phase 1 consists of the construction of the west end of the building up to and including the lower refuge level, which will be provided with sufficient central plant for this phase to operate as an independent unit.

Phase 2 comprises the construction of the east end of the site up to podium level. The third phase is the construction of the main tower above these levels, and would not be started until Phase 1 was operational, and the structure for Phase 2 had been completed up to podium level.





On the basis that a three-phase construction approach was adopted, it was projected that if preliminary design started in July 1981, production for Phase 1 should be possible during 1984 and substantial completion of the entire scheme should be achieved before the end of 1987.

Postscript

Submission and presentation of the competition schemes were made in June 1981, and within a month we had been told that our entry was successful and that we had been appointed as prime agents for the project.

Since then a contract for the relocation of the existing services has been completed to enable bottling operations to continue on one half of the site during the construction of Phase 1.

In the development of outline proposals a great number of alternative schemes were examined and costed. It is gratifying to record that although the structural grid has been modified, parking facilities extended and the lorry lift and turntable deleted, the basic overall concept of the competition entry has been retained.

Credits

I would like to record special thanks to my friend and colleague John Fraser of YRM International; not only for his help in preparing this article but for his major contribution to our successful design entry.

Client:
Swire Bottlers Ltd.
Architect
YRM International
Quantity Surveyors:
Franklin, Andrews & McDonald
Contractor (Relocation of Services):
Haden International (H.K.) Ltd.

Earthquake damage and repairs to historic buildings in Montenegro

Poul Beckmann

The Mission

When Bernard Feilden, who as surveyor to the fabric of York Minster had got us involved in the structural restoration, retired from the Directorship of the International Centre for Conservation in Rome (ICCROM), he nevertheless maintained contact with the Centre and particularly with one of its architects, Jukka Jokilehto whom I had also met when I lectured at the Centre in 1977. It was through this connection that Bernard had been to Kotor in Montenegro to look at the damage caused by the earthquake in 1979 and in particular to look at some of the schemes proposed for repair and restoration of the buildings in the historic centre of Kotor in general and the Maritime Museum building in particular.

Fig. 1
The upper chapel at Praskvica

He had found the proposed measures rather heavy-handed and wanted a second opinion from an engineer.

Thus it was that I received an invitation from Jukka Jokilehto to go to Kotor on a UNESCO-sponsored mission. We arrived at the Municipal Institute for Restoration in Kotor on Saturday 27 February and were given a very friendly welcome by the Chief Architect of the Institute, Mr Martinovic. After the refreshment customary in those parts of the world (small Turkish coffee and large brandy) we were taken on a tour of inspection of the Maritime Museum building after which we had a quick glance at some of the earlier projects for its restoration and strengthening against future earthquake effects.

We were then taken on a conducted tour of the city centre in order to gain an overall impression of the extent and severity of the earthquake damage.

At 3 p.m. our hosts took pity on us and gave us lunch. The food and the wine were superb and doubly enjoyable, as it was our first meal of the day (our journey not having gone entirely on schedule).

After lunch our tour of inspection was resumed in a slightly euphoric state of mind and the day's business was concluded by a more detailed (and more uninhibited!) critique of one of the strengthening projects prepared by a team with no connection to anybody present.

We stayed overnight in a very modern hotel in Tivat some distance from Kotor and, on Sunday morning, Mr. Martinovic collected us and drove us to Kotor. On the way we passed several villages and had the opportunity of observing the great variation in the degree of damage sustained by the buildings. The rest of that morning was spent making further observations and further studies of the strengthening projects. We also had further discussions with the Institute staff. Sunday afternoon was partly spent preparing a preliminary statement for Monday's meetings.

On Monday morning we were collected by an official car which took us along a road near the Albanian border through some snow-covered and very wild-looking mountain country to Titograd.

We were cordially received by Mr. Bozidar Pavicevic, the Director-General of the Republic of Montenegro's Institute for Town Planning and (Building) Projects, and those members of his staff who were concerned with the plans for Kotor. After the customary refreshments we then discussed general principles for restoration and strengthening of historic buildings.

Together with Mr. Stankovic, one of the Institute's structural engineers, we again examined the strengthening schemes, and whilst some of the heavy-handed features were explained to arise directly from application of the national building regulations, Mr. Stankovic conceded that they were not strictly relevant to the buildings in Kotor.

Up to that point the discussion had been conducted through a very efficient and elegant young lady, but as we both started to sketch alternative details, the need for an interpreter vanished, engineering drawing took over as a common language, and a general rapport was quickly established.

At the end of the session, Mr. Stankovic and I appeared to be in full agreement on the principles to be followed and the practical features to be adopted for the buildings in Kotor.

When we parted, Mr. Pavicevic seemed very pleased that there appeared to be an agreed way of strengthening the buildings in Kotor without destroying their historic character in the process.

We were then taken on another drive of great scenic beauty to Budva, stopping on the way to inspect two damaged churches at Praskvica. One was only lightly cracked; the other, only 30m away up the hillside was in a state of partial collapse: stripping of the frescoes and reinstatement after rebuilding of the vault seemed the only remedy.

The earthquake damage in Budva was far more severe than in Kotor, but showed the same structural patterns. As in Kotor, the population had been partly re-housed in modern blocks of flats outside the city walls pending reconstruction. As the damaged buildings had been left without shoring or protection, several secondary collapses had occurred in Budva.

From Budva we were taken to Dubrovnik and returned to Rome on the Monday afternoon.

The city and the buildings

The city of Kotor is situated on the foreshore of an inlet from the Adriatic which is so reminiscent of the Norwegian coast line that it is referred to as a 'Fjord'. The mountains rise steeply immediately behind the

Fig. 2
The lower chapel at Praskvica

Fig. 3
House in Budva with characteristic pattern of damage

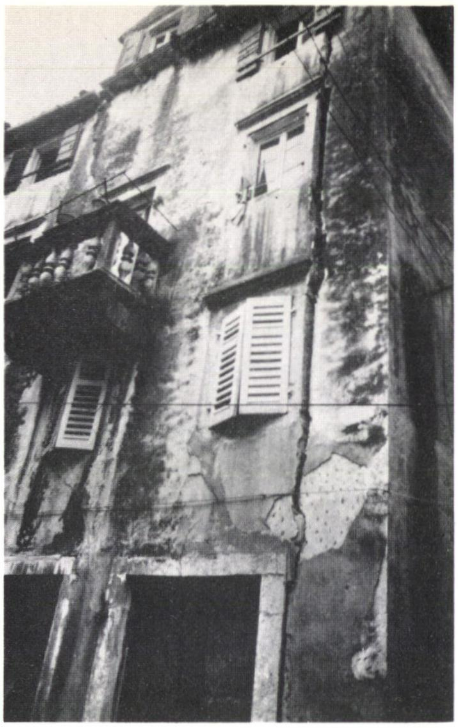


Fig. 4
Kotor: crack following straight joint between stone window surround and corner masonry

Fig. 5
Kotor: Maritime Museum Building, note tie rod anchors

foreshore but nevertheless the 16th century city centre was, in its day, heavily fortified and the defensive wall climbs the mountain in a most spectacular fashion.

The buildings within the fortification appeared generally to be of a fairly uniform type of construction with masonry walls made from the local, very hard, stone. The walls themselves were very thick in the piers between the windows, 0.6-1.0m, but they had thin undersill panels under each window. The windows were set in stone surrounds of which not only the lintels and the sills were single pieces of stone but the vertical jambs as well. The whole stone surround to a window would have straight butt-joints to the rest of the masonry.

The floors were traditional timber construction and so were the fairly shallow pitched, tiled roofs.

Our observations of the general earthquake effects

In the city centre the most widespread earthquake damage was seen to be nearly vertical cracks associated with the window openings. In most cases these would join the outer corners of the stone window surrounds and would continue along the butt-joints between these and the rest of the masonry.

It was very noticeable that even where complete corners, four storeys high, had detached themselves from the remainder of the house the corner masonry itself had remained intact and was practically uncracked.

Another consultant to ICCROM had been making studies of damp-proofing problems and had in that connection taken samples of mortar. Analysis of these samples had shown the mortar to be of a very good composition and this confirmed the superficial observation that the mortar was strong and the workmanship in the construction of the houses in Kotor generally of a high standard.

In Budva we had observed that the damage was far more severe in general. It was, however, of similar pattern to that found in Kotor: walls had cracked vertically corner to corner of window surround and sometimes here the thin undersill masonry panels had fallen out completely. In one house the whole front had fallen out between the windows nearest to the (still largely intact) corners. Here we could see that the floor timbers were spanning parallel to the front and therefore had not provided any tying in of the fallen wall. We also found a wall which had been fractured down to ground level and we could see that the mortar in the core of this masonry was brown in colour and of an earth-like crumbly consistency significantly different from the hard mortar in Kotor. In Kotor itself as well as in the villages along the road from Tivat to Kotor we found many instances where a nearly intact house would be standing immediately adjacent to a very severely damaged one and, whilst in some instances the differences could be ascribed to early repairs being undertaken by private initiative, this was not always so.

We did not on any of the houses we observed see any large inclined cracks such as would be evidence of gross differential settlement movements.

The roofs seemed in general to have been the most vulnerable part of the buildings. Tiles had been shaken off and timber rafters had collapsed but there was relatively little evidence of the rafters pushing out the thick piers of the walls.

What was slightly surprising to find was that, although it was nearly three years since the occurrence of the earthquake, some buildings still had potentially dangerous parts of masonry left without temporary bracing or tying back such as could prevent secondary collapse caused by high winds or similar causes. Part of the cause for the delay in reconstruction was that it had been decided to make and implement a master plan for general improvement of the buildings in the city centre so as to upgrade its potential as a tourist attraction. Part of the population had meanwhile been rehoused in new blocks of flats on the outskirts of the town but a considerable number appeared to have remained and were living in quite badly cracked buildings.

The museum building and its condition

The maritime museum building had been chosen as the subject for a number of studies of restoration and repair techniques. The reasons for the choice were not quite clear as the building in some respects was untypical of the majority of the buildings in the city.

The general construction, however, is typical of the buildings in the centre of Kotor: stone walls, timber floors and low pitched tiled roof on timber rafters. The building is only three storeys high against the more common four storeys in the majority of the dwelling houses. The rather elaborate balconies on the front suggest that it might have been owned by somebody better off than the majority. At the back of the house there were some later extensions which appeared to be far less solidly constructed.

At the first superficial examination of the front elevation there appeared to be no evidence at all of earthquake damage. Even a detailed inspection inside and out revealed very little evidence of damage which could be clearly seen to have been caused by earthquake effects. In fact the general condition of the building up to eaves level was no different from what one would have expected in a building of that age in a location not subject to earthquakes.

In the basement one could see that some door frames had been planed slightly out of square to ease the opening of the doors; this might indicate that some differential settlement had taken place in the past.

There was no evidence of the internal walls debonding from the external walls and the amount of cracking in the external walls was very slight indeed. Such cracks as there were were quite fine, no worse than is commonly found in buildings of this age in non-seismic areas. The same applied to the cracks that were found in the staircase walls.

There were some cracks in a couple of stone door surrounds but these appeared to be old and did not show any signs of recent movement.

Fig. 6
Typical example of minor damage at Kotor

Fig. 7
Kotor: Clock tower nearly intact adjoining building badly damaged

Fig. 8
People have to live somewhere—cracks or no cracks!

The timber floors felt very slightly springy but otherwise sound. Where beams and/or joists were visible there were no signs of their ends having pulled out of the walls. (It was not practical on this occasion to expose the beam ends so as to examine them for rot.)

A considerable number of anchors for tie-rods could be seen on the external walls. This suggested that there may have been some tendency for the walls to move outwards in the past, possibly as the result of a past earthquake. It did, at the same time, indicate that the building was probably well tied together at the levels of the floors.

In the upper storeys there were many cracks to be seen in the ceilings but the majority of these were seen to follow the courses of past plaster repairs to old cracks. These were indicated by bands of smoother texture about 50mm wide and very slightly raised above the surrounding original plaster surface.

Both the roof and the rear extension appeared to have been much less well constructed than the remainder and showed a fair amount of damage, the roof rafters having slid on their supporting walls and deflected rather badly with a fair amount of tiles becoming dislodged, the rear extension having cracked away from the main building and suffered some further cracking in its walls; none of it, however, was disastrous.

With these exceptions the building appeared overall to have withstood the effects of the earthquake remarkably well and in this respect it was, perhaps, rather better than the buildings in the city as a whole.

General principles for strengthening of historical buildings

In our submission to the Republic's Institute for Town Planning and Building Projects of our comments on the schemes for restoration and strengthening, we included the following statements of general conservation and strengthening principles for historical buildings:

'A historical building has a value which goes beyond the accommodation and facilities it provides. This extra value may derive from the proportions of the rooms, the features and textures of external elevations, the materials of the interiors or many other things. If, in the process of strengthening such a building, these characteristics are lost, the building loses its historical value.

If a refuge for occupants can be provided nearby and any precious contents of such a building can be protected against falling debris, it is better to provide only such a modicum of strengthening as can be incorporated without significantly altering the character of the building, rather than to strengthen it against the maximum predicted earthquake and leave it unrecognizable.

It should also be remembered that standard design codes and building regulations are written for modern types of construction and have to allow, in their safety factors, for all the uncertainties in the design assumptions, the inaccuracies in the mathematical models used in normal calculations, the inevitable construction inaccuracies and the unknown differences between the strengths of the materials in the actual construction and the strengths specified in the contract documents. In an existing building all these mishaps have already taken place and the safety factors need not cover them, when the structural adequacy is being checked against future events: past performance can hence be a good guide to future behaviour'.[1]

It is worth noting, in this connection, that in New Zealand, a country of high seismic activity, most municipal authorities will not require any strengthening of old buildings, if it can be shown that their resistance to seismic forces is greater than 50% of the requirements for new construction. If strengthening is deemed necessary, it should provide a total resistance which some local authorities stipulate as two thirds of the requirements for new buildings, whilst others are satisfied with half.*

It should finally be remembered that even if the money could be found, schemes for strengthening which are too ambitious could require an input of manpower of such magnitude that the restoration of the city centre would not be completed for several decades.

Deductions from our observations

In spite of the brevity of our inspections, we felt justified in drawing the following conclusions from what we had observed:
The corners of the typical buildings appeared to have great inherent strength and integrity. This was no doubt due to the quality of the materials and the workmanship in their construction. It seemed that this should be recognized and utilized in any strengthening scheme and that nothing should be done which would significantly disturb the integrity of the masonry corners.

The reduced thickness of the spandrel panels under the windows appeared to create serious weakenings of the walls which would be aggravated by the sharp transition between the full thickness of the 'piers' and the thin undersill panels. The stress concentrations that such sharp transitions could generate would of course be particularly serious under dynamic loading such as would be experienced from earthquakes. It seemed that any strengthening scheme for these buildings should mainly aim at compensating for these weaknesses.

The maritime museum building demonstrated that a generous amount of cross-tying of the external walls would contribute greatly to the capacity of the structure to resist seismic forces. Conversely, absence of lateral restraint, whether by ties or by floor beams bearing on external walls, would predispose such walls to fall out.

The striking difference in the damage sustained by buildings adjacent to each other suggested that the conditions of the soil strata under the foundation would in this case be less significant than the quality and integrity of the original construction. The sediments under the main part of the town would in theory be considered to predispose to greater damage from earthquakes but it was difficult to see how this could account for one building standing practically undamaged and an adjoining building having suffered very greatly indeed.

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*This information was supplied by David J Dowrick of Brickell, Moss & Partners, Wellington, New Zealand.[2]

Our recommendations

The official approach up to that time appeared to have been one of trying to devise systems and methods for repair and strengthening which could be applied in a standard fashion to all the buildings in the city. This explained the somewhat over-conservative nature of the proposals which we had seen, as such standard solutions would have to cater for the worst instances of damage. In our report we advised against this approach because the application of the maximum strengthening in all cases would in our opinion be unnecessary and in any case excessively costly.

We recommend that each building should be appraised, however briefly, and its performance in the latest earthquake be taken into account as a measure of its inherent resistance and integrity before any strengthening was prescribed.

We outlined our general approach as follows:

Timber roof structures should be repaired and retained wherever possible to avoid adding mass to the top of the building. Rafters should, however, be tied at eaves level so that they could not exert any outward thrust on the walls.

In the case of the walls, strict interpretation of the building regulations for seismic areas would have required reinforced concrete columns to be built into niches in the re-entrant corners of the walls and at intervals along the insides of the walls. The cutting of the niches would seriously weaken the masonry of the corners and the piers and these had shown themselves capable of withstanding the seismic effects particularly well. We advocated therefore that the inherent strength of intact corners and piers should be recognized. The obvious weaknesses at the window reveals should, however, be remedied by the provision of ties.

The project for the museum building had included tie-rods of *Dywidag* bars in plastic sleeves along and across the walls. The drawings appeared to show the tie-rods below the ceilings. We thought that if these tie-rods were supposed to be temporary (which was not clear from the drawings, despite their detail) they would seem to be hardly necessary in view of the sound condition of the museum building; If, however, they were intended to be permanent we considered that they should have been placed in the reinforced concrete slabs shown on the drawings.

In this connection there was the question whether such tie-bars should be tensioned. If they were left untensioned, cracks would have to open a finite amount before the restraint from the bar made itself felt. On the other hand, such tensioning could cause crushing of stone fragments which had previously been dislodged and had wedged themselves into the cracks and, for this reason, it was probably best avoided. We were not happy about the plastic sleeve either, as corrosion problems seemed likely to arise at the joints in the sleeve and at the end junctions where the sleeve abutted bearing plates, etc. There was finally the problem of installing a single large diameter bar in the thickness of the wall. This would require a continuous rebate along the wall, a detail which would be unlikely to be practical in any but the very best preserved masonry. We suggested that some temporary supports leaving the innermost part of the rebate clear might be necessary to prevent collapse of part of the undermined skin of masonry. We therefore thought it preferable to form the ties of several small diameter reinforcing bars which could be sprung into position behind the temporary supports in shorter lengths and, having staggered joints and being bedded into the rebate with dry-pack, would give the added advantage of having continuous bond between masonry and tie.

The walls should be connected to the floors with anchors grouted into holes drilled in the walls, and in the case of timber floors, screwed to the joists (whether these be parallel to or at right angles to the wall). In the case of new concrete slabs being required for replacement floors, the anchors should be cast into these.

Where cracks in the walls were wide, i.e. 10mm or more, we recommended that the receptivity of the masonry to injection of a cement-lime grout should be tested and if significant 'take' was found the walls should be injected at low pressure starting from the bottom of the cracks and working upwards.

Where there had been significant movement out of the plane of the wall, partial rebuilding might be necessary.

Where timber floors were found to be still structurally adequate for their function, they should be retained. Some diagonal bracing within the ceiling void might, however, be necessary to enable the floor to act as a rigid plate and thus maintain the plan shape of the walls against cracking.

If it was considered necessary to replace the timber floors with reinforced concrete slabs, these should be supported on, and be anchored to, walls in both directions, i.e. at right angles to each other. Tie-reinforcement, continuous through holes in the cross-walls, should be provided if, in order not to weaken the cross-walls too much, it was decided to make the slabs simply supported in rebates either side of the walls.

The earlier project for the museum building had shown a complete new reinforced concrete raft under the entire building. As we could see no visible evidence of serious past or recent foundation problem, we had thought this rather extravagant. We were also concerned that the extensive and deep excavations necessary for the installation of such a raft would, even if carried out in chequer-board pattern, introduce serious risk of differential settlement during the works, particularly as the ground water level apparently could rise to within 1m of street level.

We therefore recommended that the need for foundation strengthening, if any, should be established, for each and every building, beyond any doubt: If a building had suffered more damage than its neighbours it must be first ascertained that the cause was not inferior quality of the superstructure. The existing foundations should be exposed in selected places to enable an assessment of them to be made. If, then, strengthening was found necessary, consideration should be given to widening the foundations without increasing their depth by 'bolting on' reinforced concrete strips either side of the existing footing.

Items for early action

It was mentioned earlier that parts of walls which had partly detached themselves had been left freestanding since the earthquake. Some of these had appeared potentially dangerous to us and we recommended that, as a matter of urgency, they should be shored or tied back to prevent secondary collapse.

Where the main damage to a building had been in the roof a temporary roof covering should be applied immediately to arrest the deterioration and the decay which inevitably follows the ingress of weather through holes in the roof of any building.

Our final concern was that, due to the striving for theoretically perfect solutions, no physical repairs had been carried out in the three years since the earthquake. We recommended that in order that any practical problems in the execution of strengthening schemes could be brought to light and solved before the main repair campaign was started, physical work on strengthening, in accordance with the principles which we had outlined, should be undertaken on a small number of (less valuable) buildings as soon as preliminary schemes could be worked out. This should not only help to bring out any snags in the schemes but also establish the time and cost of these operations. It would, in addition, also enable the authorities to train local artisans in any special skill required so that they could tackle the main programme with confidence.

The sight of repairs being undertaken would also, we thought, help to restore confidence in the future of the city centre and encourage people to return from the modern if somewhat soulless flats in the suburbs.

References

(1) INSTITUTION OF STRUCTURAL ENGINEERS. Appraisal of existing structures, ISE, 1980.

(2) DOWRICK, D. J. Earthquake resistant design, John Wiley, 1977.

Asahi fibre and spinning plant, Tawnaghmore, Killala, Co. Mayo

Rory Glynn

Introduction

The £52 m. Killala complex was opened in May 1978 and established in the west of Ireland a synthetic fibre manufacturing and spinning plant for Asahi Chemicals Ltd.

Asahi synthetic fibres are based on acrylonitrile. The liquid chemical is imported through Dublin Port, stored on site there, and transported by rail and road to the Killala site, approximately 170 miles away.

The process consists of mixing the acrylonitrile with the other chemicals to form an acrylic polymer; this is dissolved and mixed with acid to form a dope which is pumped through a spinnerette to form single filaments of raw fibre. The fibres are then treated mechanically to produce tow from which the final fibres are spun in the spinning plant.

The project started in 1973 with the granting of Outline Planning Permission and fibre spinning commenced in April 1977.

Ove Arup & Partners were appointed in March 1974 as civil and structural consultants responsible for the project within the site boundaries and for the civil and structural works connected with the import of the raw materials through the Port of Dublin.

The general arrangement, layout and elevation of the complex were set out in Japan by Asahi Engineers. These designs were in general accepted by Ove Arup & Partners with the exception of the office block which was redesigned to offset the functionalism of the main industrial buildings. As the complex is in a prominent elevated position over Killala, landscaping was introduced which should, when fully grown, help to screen the development.

The design and procurement of the process equipment was handled in collaboration with Asahi Engineers by Matthew Hall Engineering, London, and the effluent treatment works and discharge into Killala Bay by McCarthy & Partners, consulting engineers, Dublin.

The complex is divided into four main sections; the fibre production plant of 27,000m^2, the fibre spinning plant, 12,000m^2, the off-site section which contained the power plant, water cooling, acid recovery, effluent treatment, water treatment compressors and ESB transformer station, and the main office and canteen.

The area on which the complex was constructed was part of a 170ha site bought by Asahi.

The requirement of level floors for the production plant and for the spinning plant, and the anticipated 100% expansion, required the levelling of a 120ha area in decomposed limestone. This oversite levelling was carried out as a separate contract under the control of McCarthy & Partners.

Site works

Excavation in the weathered rock was carried out using heavy civil engineering plant; where hard limestone was encountered this was broken by blasting. At an early part of the contract the site was cleared of personnel and plant for safety. Later in the contract, long lengths of pipe runs, foundations for pipe racks and plant foundations had to be excavated using controlled blasting adjacent to completed buildings. Following some unsuccessful attempts in which roofs were damaged by flying overburden, a method using a transportable steel-framed cover to contain the overburden breakout was successfully used up to 2m from finished work. One bonus from the rock site was that site roads, usually a problem, needed little maintenance and could be readily used by stacker trucks to handle plant installation.

Offices and canteens

The main offices and canteen buildings are located outside the main industrial compound on the approach road. They are rectangular, single-storey buildings clad in brickwork. The facade is constructed in alternate panels of brickwork with 450mm deep reveals and narrow, full-height windows separated from the fairfaced concrete edge beam to the concrete roof by clerestory glazing. The brickwork is used throughout the elevation to provide window cills and entrance steps. The area between the buildings, which, due to rock outcrops, are at different levels, has been landscaped.

Production plant

The main fibre production plant is divided into three structures: the first section, in which the acrylic polymer is made, is in reinforced concrete, four storeys high; the second section is a single-storey steelwork shed in which the fibres are drawn, dried and textured, and finally there is a two-bay, single-storey warehouse.

The reinforced concrete structure is 30m wide by 125m long and has four production floors at 6m floor-to-floor. The single-storey fibre drawing shed, 30m wide by 220m long, is in structural steelwork with 30m span, 15° pitched portals at 7.5m spacing, carrying double-skin insulated asbestos roofing. The warehouse is 60m × 90m with double-skin, 30m span, pitched portals at 7.5m centres. The structural steelwork, encased in boardmarked concrete, is expressed externally and infilled with fairfaced concrete blockwork of cavity construction.

A feature of the fibre filament production is the use of acid baths located at first floor level. Timber construction was designed to support the loads from the plant and the solid working platforms. Acid-resisting tiles were used at all acid transfer points such as pump, filters and floor ducts. Working areas and protection to concrete machine plinths were protected with *U-crete*. A testing laboratory and administration offices were located within the production plant.

Along one side of the production plant are the perimeter, open, concrete channels to which plant effluent was led, constructed in parallel, one lined to take acid and one unlined. These open channels were bridged at entrances to the plant. The channels, culverted under the main roadway, lead the effluent to the effluent treatment plant.

The process pipework and plant services are carried at high level from the off-site area to a main elevated pipe rack which runs the full length of the production plant and crosses the access road to service the spinning plant. The total length of the pipe rack is about 600m. Services are taken directly from the pipe rack through the external wall to plant locations. This arrangement allowed the building construction and main services installation to progress in parallel.

Spinning plant

Spinning of the tow requires an unrestricted floor area. Following discussions with Asahi Engineers in Japan, a 66m 15° propped portal was agreed, the structural grid being 66m portals at 6m centres with central props at 12m centres, every second portal being propped by a ridge beam. A fibreglass, tiled ceiling is provided over the whole of the spinning area which is air-conditioned to provide the humidity and temperature required. The levels are not as critical as for nylon spinning. The air is fed from ducts in the roof space and returned through the spinning frames. Along the side walls are located the plantrooms, testing laboratories, local store rooms, workshops and staff facilities. The main product is warehoused in the last two bays, separated from the production by a fire wall.

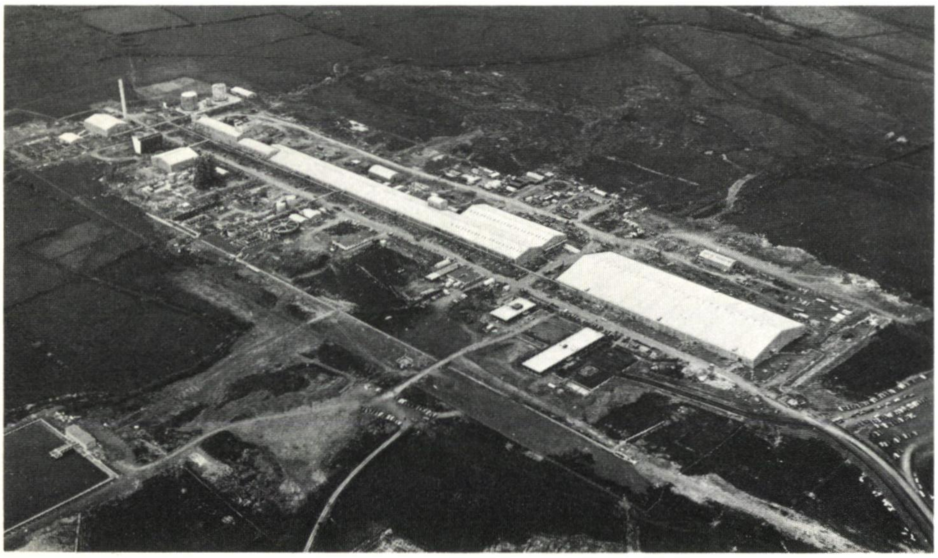

Fig. 1
Aerial view of Asahi Killala complex

The steel structure is concrete cased and exposed externally, and in-filled with fairfaced blockwork.

The suspension of the ceiling within the cost limitations provided a problem in that the ceiling at 3.5m over floor level was some 12m below the roof apex. The final solution was to suspend the ceiling on wire hangers from the roof, providing a series of crossbraces to prevent sway. The location of the air-conditioning ducts within the hanging space had also to be integrated into the wire hanger system.

A requirement of the fire office for 1% roof venting required that fire vents be provided in the ceiling. Following discussions with the fire officer, it was agreed that venting into the roof void from the production area was acceptable and a control system was set up that would open the outside roof vents immediately over the fire location following opening of the ceiling vents. The ceiling unit, which dropped down when operated, was electrically activated and the roof vents pneumatically. The roof vents were also fitted with fusable links.

The floor was covered in vinyl asbestos tiling; the expansion joints in the floor slab created a problem in that the joint was trafficked and the width of the joint was larger than specified. The method finally adopted was to tile the floor leaving out the tile along the expansion joint. When the moisture content of the floor had stabilized after three to four weeks the joint was filled with hard filling and tiled over.

Off sites

Water treatment

The water for the project is taken from Lough Conn by Mayo County Council and stored on site in an open reservoir. The water is from a peat area and must be fully treated and clarified before it can be used in the production.

The water treatment system was designed by Permutit Boby. The civil works consist of a 6.75m high inverted conical truncated structure, 15m in diameter at the base, fanning to 24m at rim level. To reduce the mass of this stilling basin it was sunk 4m into the ground. It acts as a primary stilling basin with a specially designed recovery for the flocculation blanket. The structure is in board-marked, fairfaced, in situ watertight concrete. The launders were of precast concrete, constructed off site by the main contractor. The water treatment section provides clarified industrial water, industrial water, potable water, soft and demineralized water for the total complex. The capacity of the plant is approximately 22.7 million litres per day.

Boiler house

The boiler house is a pitched portal structure, $960m^2$ in area by 12m height by 30m wide, roofed in double skin insulated asbestos. The main portal legs are expressed in boardmarked concrete infilled with fairfaced concrete blockwork. The boiler house, designed for four 60 tonne per hour boilers, three of which have been installed, is served by a 50m high by 3m diameter steel freestanding chimney.

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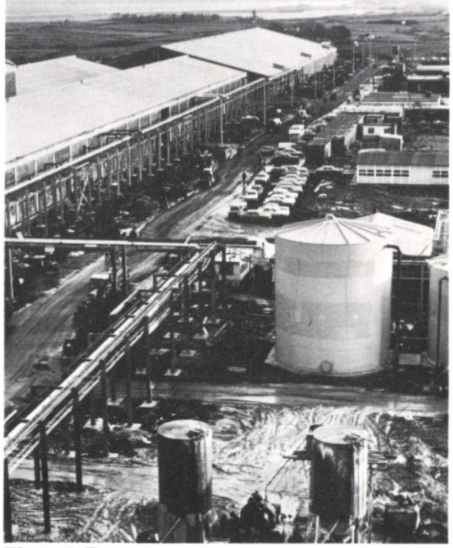

Figs. 4-5
Main fibre production, spinning plant, pipe racks, main access road, chemical store for water treatment

Tank farm

The tank farm contains a bunded area for the storage in two 3000 tonne tanks of acrylonitrile and one 100 tonne tank of methyl acrylate. The tanks are fitted with flame assessors and water sprinkling system to comply with EEC regulations. The liquids are brought on site in specially designed transportable tanks carried by road transport from the rail head in Ballina, 7 miles away.

As acrylonitrile is a highly dangerous, heavier than air product, the containment area and lorry unloading yards were designed to prevent contamination of the underlying strata and to direct accidental spillage directly into the dilution area connected to the production plant.

Preliminary studies identified Dublin as the best port for the importing of the acrylonitrile liquid chemical required for production. The tanker ships of about 2000 tonne capacity would be off-loaded at the oil jetty and the liquid stored, prior to transportation by rail to the Killala site.

The site acquired by Asahi from the Dublin Port & Docks Board was in the area recently reclaimed by hydraulic filling. Site investigations showed a layer of soft mud overlying sea gravel, the top layer of which had some soft mud layers.

The normal foundation for bulk tanks in this area is a raft foundation of broken stone. By pre-loading the tanks with water, primary settlement takes place before the main fuel pipes are connected. Due, however, to the toxic nature of the material it was decided to support the 3000 tonne storage tank on a piled raft to eliminate settlement and to line the containment in asphalt. The storage complex contains the loading platforms for the rail containers and is designed to channel all spillages and wash-down water into a special chamber. The spillage waste is containerized and transported to the Killala site for treatment and disposal. All surface water is collected within the site area and is tested before being released to public sewers.

The building was handed over to the client on 21 April 1978 and, so far as we are aware, has been performing satisfactorily since then.

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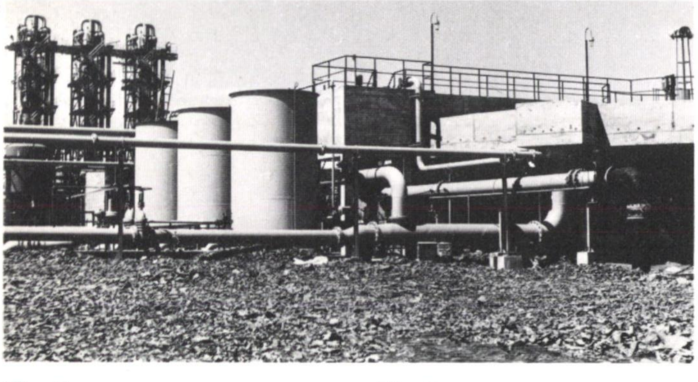

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Fig. 2
Water treatment plant

Fig. 3
Fibre production plant

Fig. 6
Office block: Fibre production—left, spinning—right

(Photos: Ove Arup & Partners)

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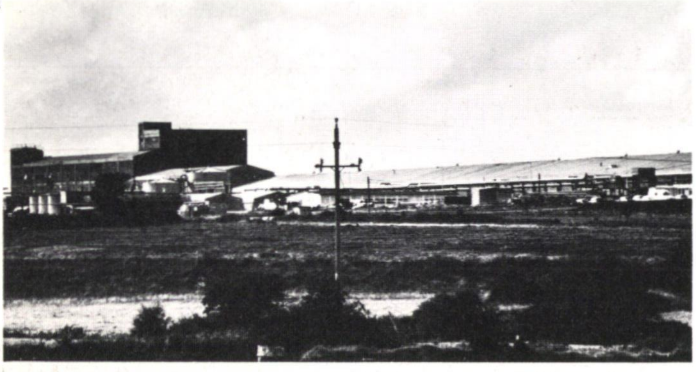

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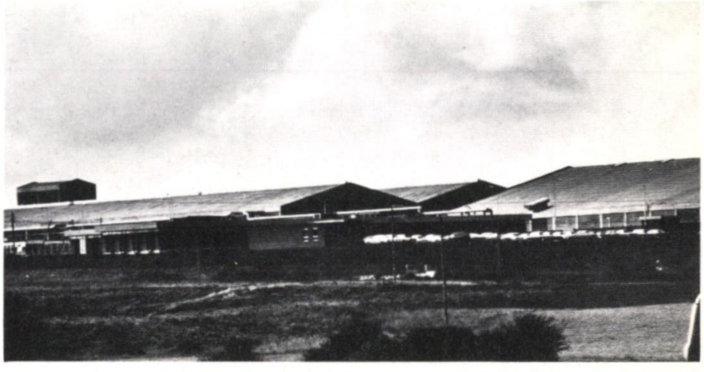

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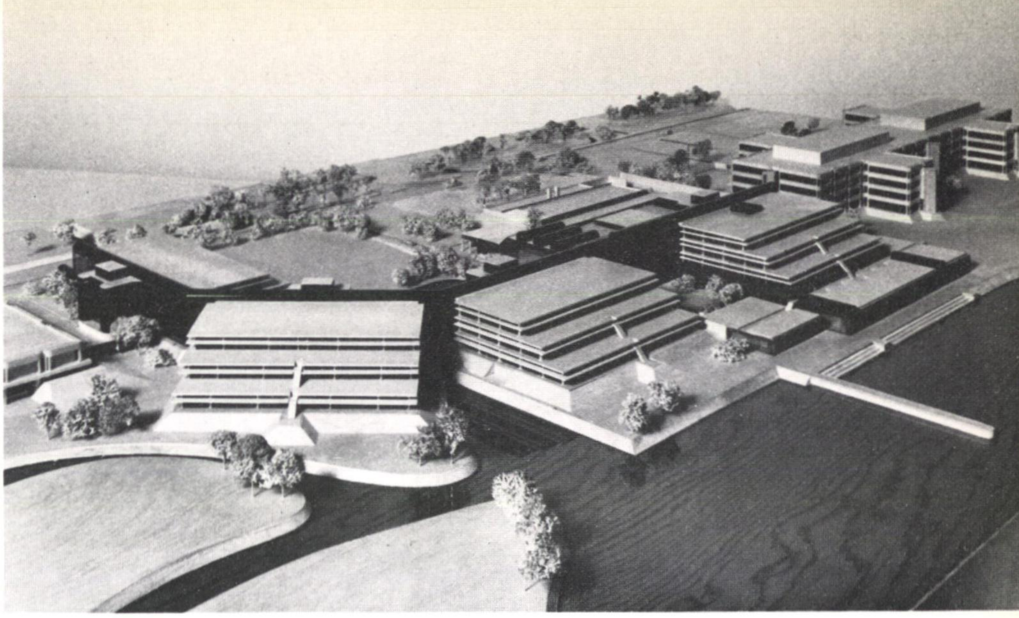

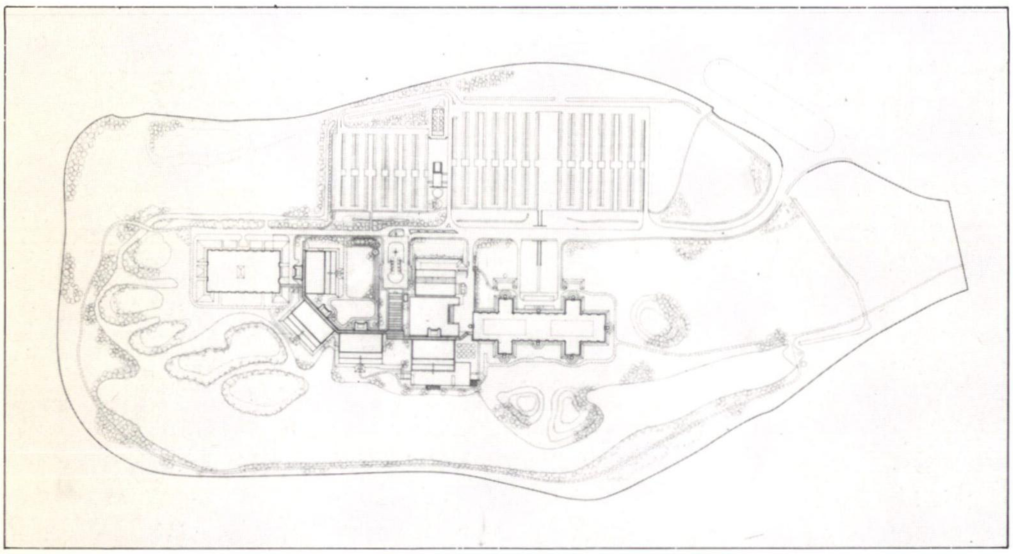

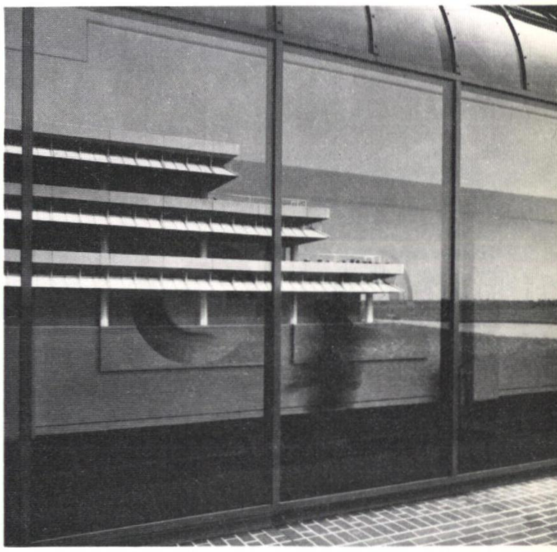

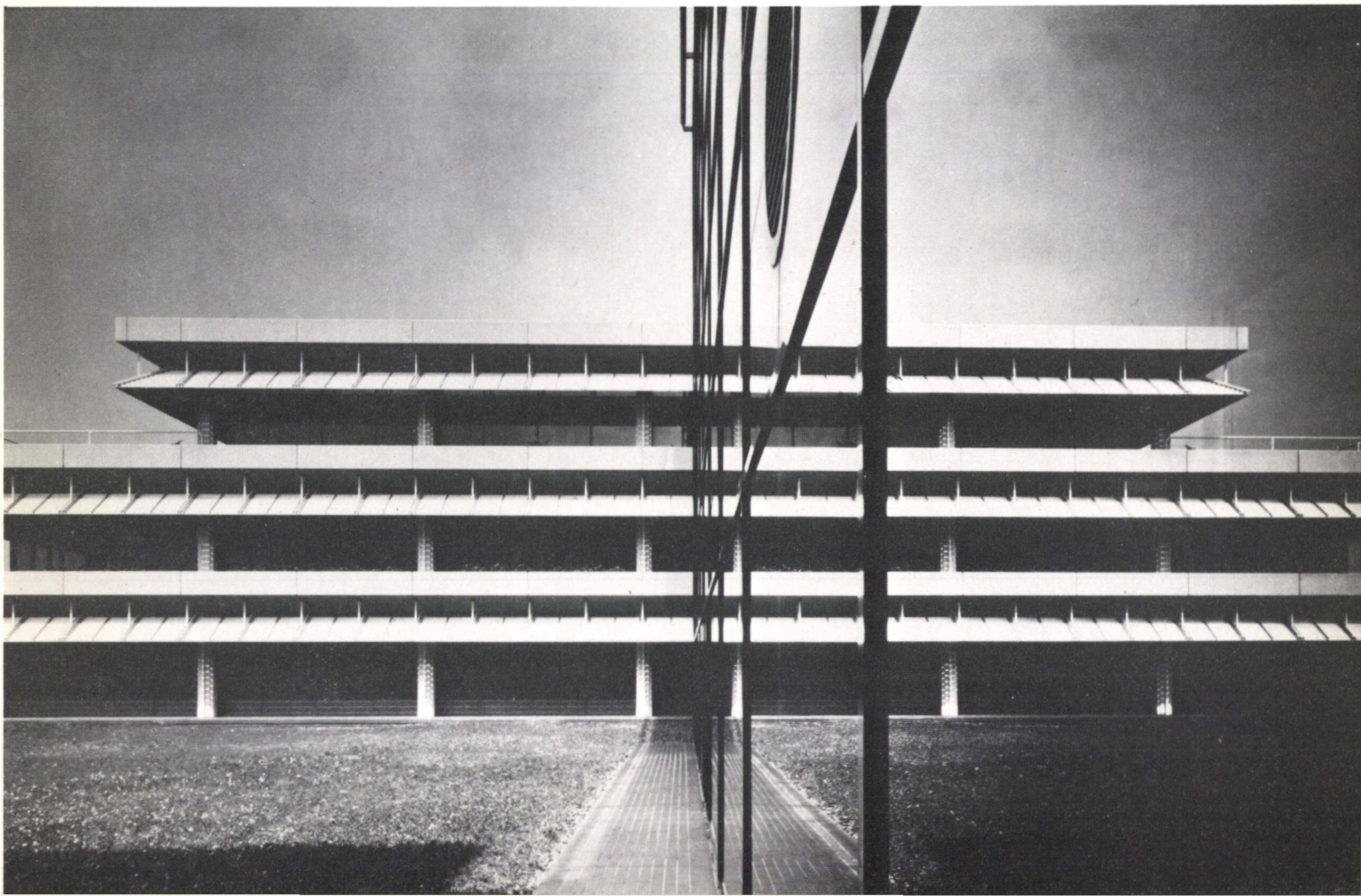

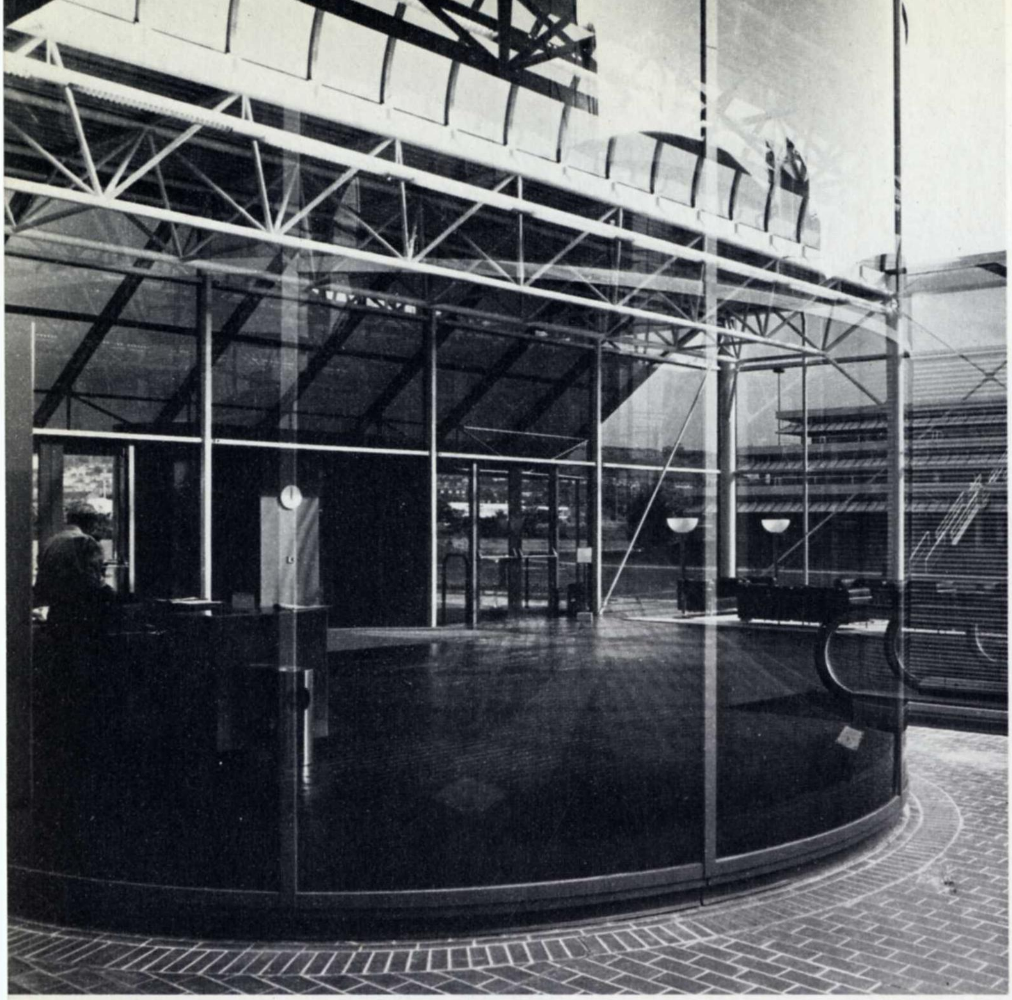

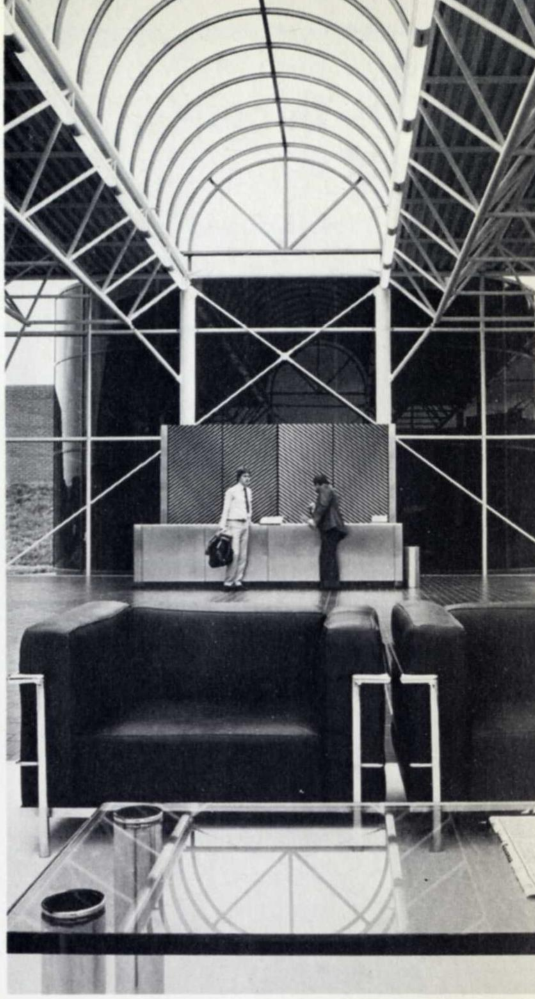

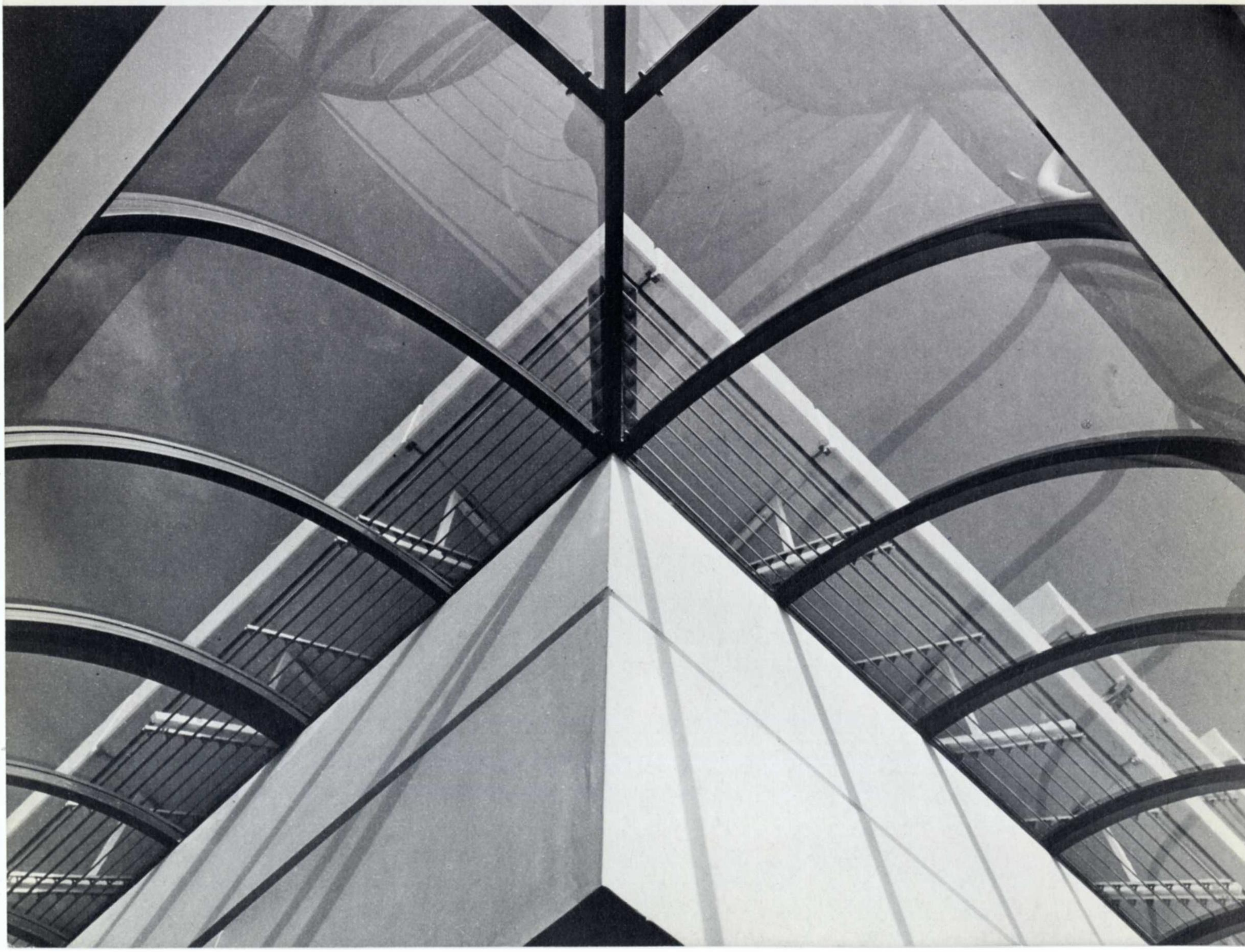

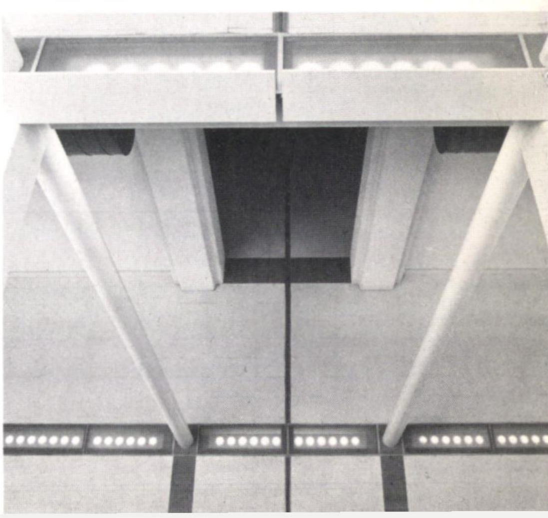




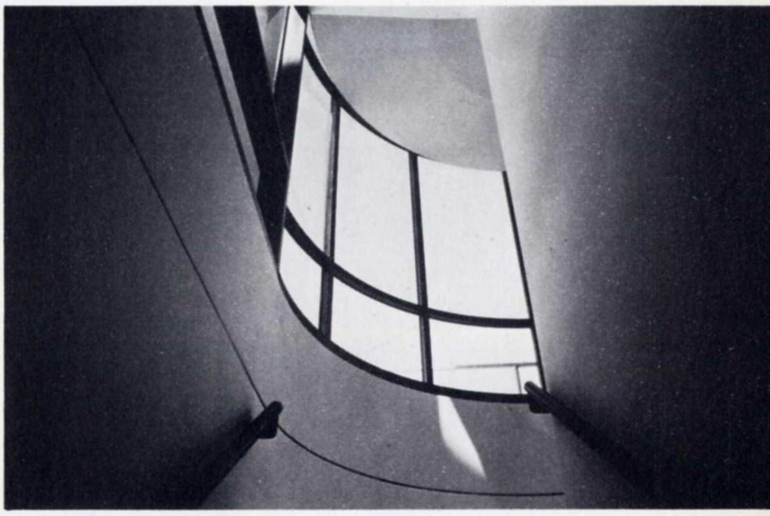


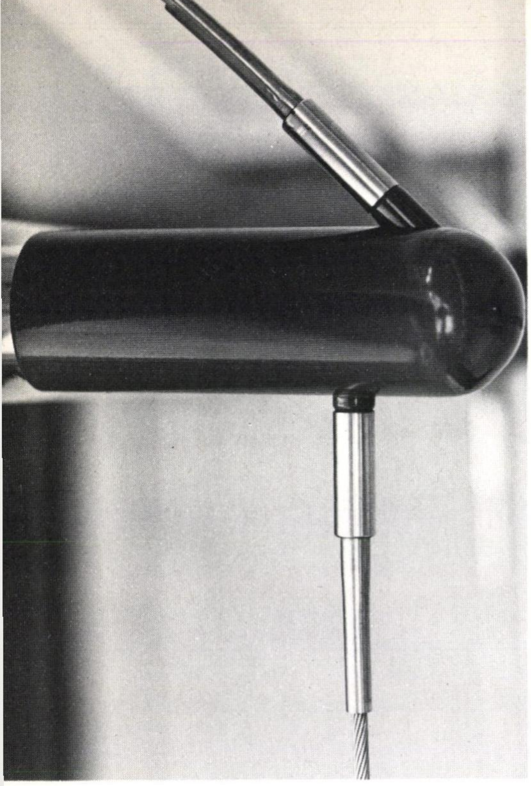
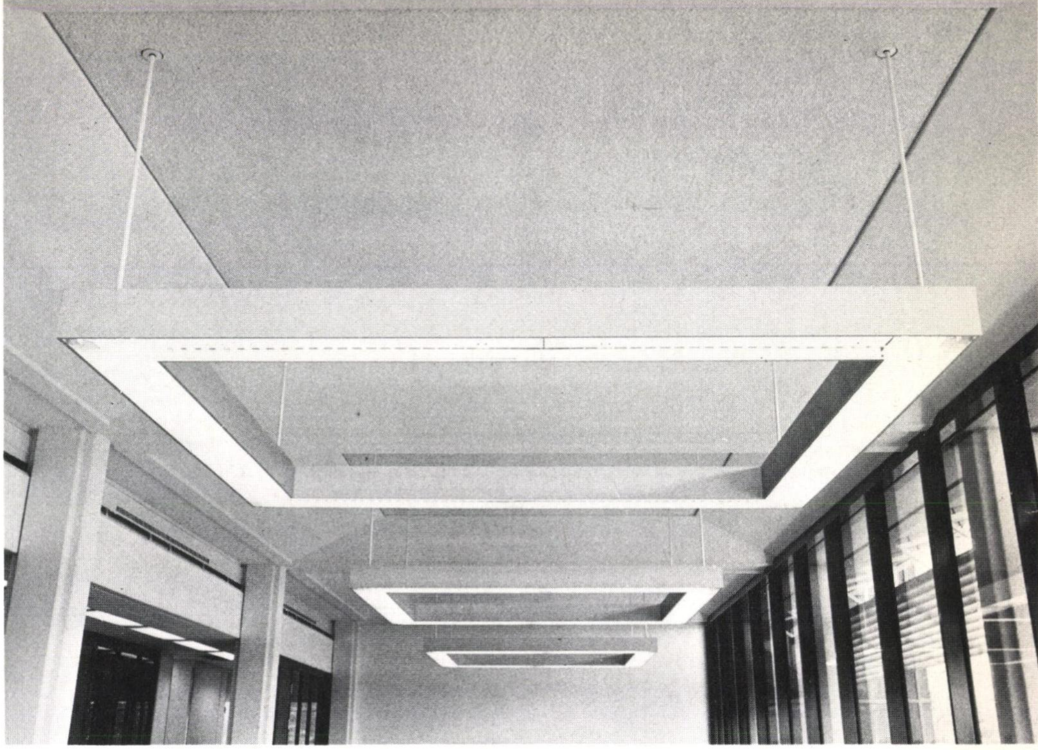
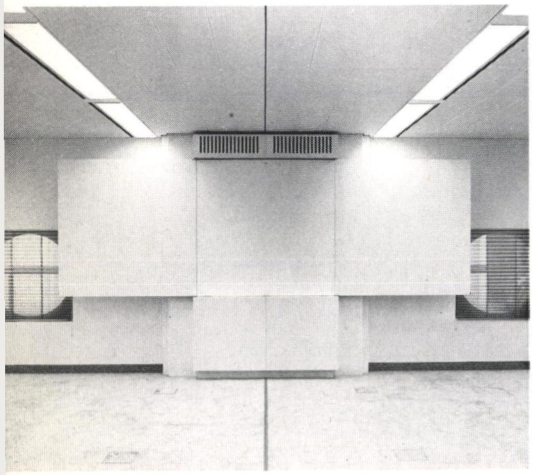

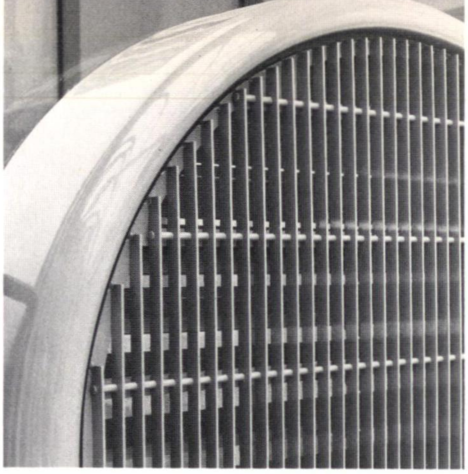

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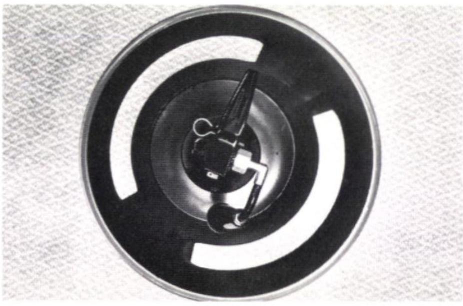

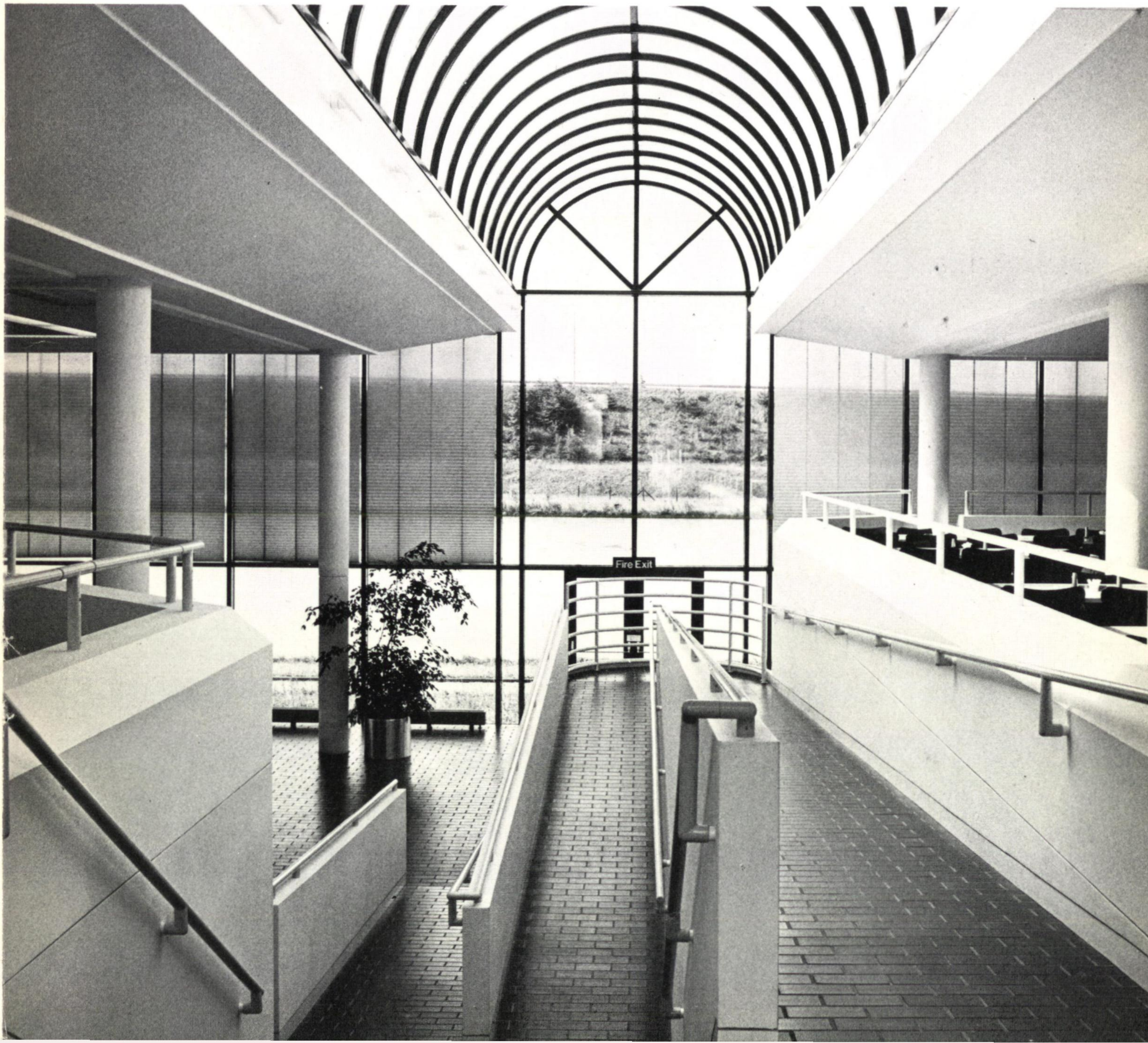

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