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PHILIP DOWSON 1981

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Editor's note

Sir Hugh Weeks recently wrote to me to point out that we had incorrectly dated the Raleigh Arena as being completed in 1963 (*Arup Journal* 15(3) October 1980, p.9). The date should in fact have been 1953 and I apologise for this error.

Front cover: RIBA Gold Medals
Back cover: St. John's College, Oxford (Photo: John Donat)

Tsuen Wan Residential Blocks

Brian Parkinson
John Hirst

Architects: Choa Ko and Partners in association with Lee & Zee Associates

Introduction

The Tsuen Wan Estates Development which, when complete, will be known as Luk Yeung Sun Chuen (The New Green Willow Village), is to be sited on the 5.5 ha podium deck above the Mass Transit Railway depot at Tsuen Wan, and consists of residential tower blocks, schools, banks, shops and other public amenities (Figs. 1 & 2). It will provide accommodation and facilities for 20,000 people.

There are 17 residential blocks with a total gross floor area of 215,000m². Each block is of cruciform shape in plan and is between 28 and 30 storeys high. The structure of each block consists of reinforced concrete shear walls and floor slabs, supported on a grillage of 2m deep beams that transmit the loads onto columns which pass through the railway depot below.

There are two basic floor arrangements referred to as type A and type B. Although these types are in many ways similar there are significant differences in the arrangement of the loadbearing walls. The two floor arrangements, combined with the variation in number of storeys, results in four basic block types and within each block type there are variations in the arrangement of the central lift and stair cores. Fig. 3 shows a typical floor plan for a type A block.

Preliminary stage

Scheme design

The scheme design for the depot structure was carried out in 1977. At this time no detailed information was available on the residential blocks as the developer had not been appointed. Depot members were sized to be capable of supporting blocks up to 30 storeys high and block loadings were calculated based on experience gained on the Telford Gardens Development above the MTRC depot at Kowloon Bay.

Preliminary analysis

The initial schemes proposed by the developer in 1978 were similar to the arrangement shown in Fig. 3. The majority of the walls, however, were 150mm thick and simple hand calculations showed these to be inadequate in many cases. In order to determine which walls needed to be thickened and to what extent, a more detailed analysis was necessary to determine the degree of coupling between wall sections provided by the spandrel and lintel beams under wind loading. A three-dimensional, 10-storey model was analyzed in which full fixity was assumed at transfer plate level, and horizontal wind loads, calculated in accordance with the Hong Kong Regulations, were applied. This analysis showed that the stresses in some walls and beams were high, though not excessively so.

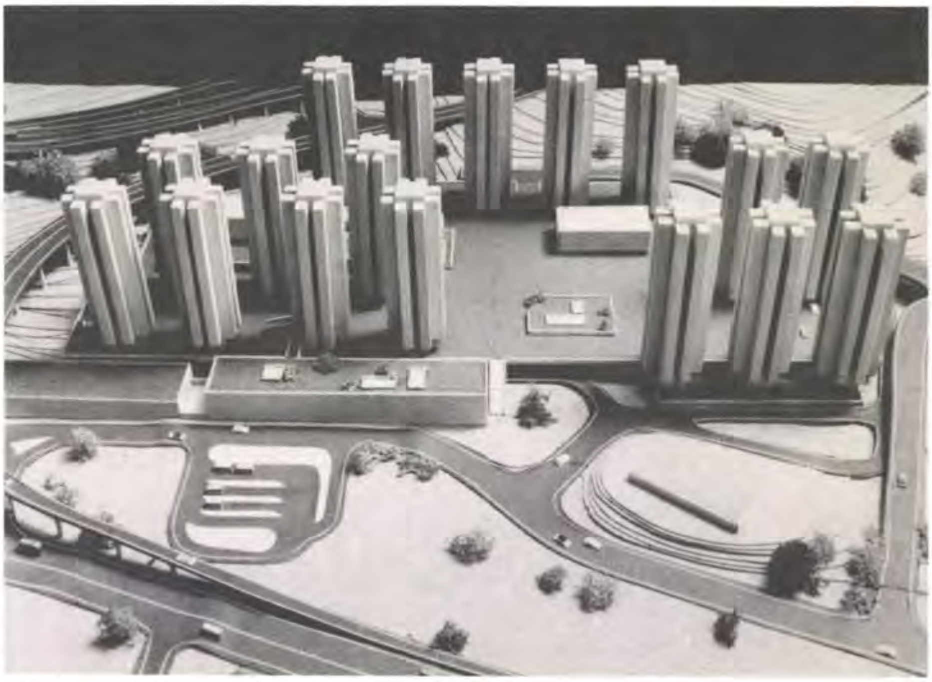

Fig. 1
Architectural model (Photo: Neil Farrin)

However, it was recognized that these stresses would be increased as a result of the deformations of the transfer plate and depot structure. It was therefore recommended that the thickness of critical walls should be increased. Additionally, in view of the size and nature of the project, it was recommended that a wind tunnel test should be carried out.

Wind tunnel test

The wind tunnel test was carried out in early 1979 by the Department of Aeronautical Engineering at Bristol University as described in *The Arup Journal*, December 1979. As a result of these tests it was proposed, and subsequently agreed with the Building Ordnance Office (BOO), that each block should be designed for a uniform pressure on the face of the building calculated from a basic pressure at 2.7 kN/m^2 multiplied by force coefficients as follows:

Block	Type	Storeys	Cf N-S	Cf E-W
A-E incl	B	30	1.25	1.25
FGHL	B	29	1.1	1.15
JK	B	30	1.1	1.1
MNP	B	28	1.15	1.1
QRS	A	30	1.1	1.1

The value of 1.1 was chosen after discussion with BOO so that the total shear force on the structure would not be less than that given by the Hong Kong wind code. Some blocks, therefore, are designed for a greater total shear force than is necessary to conform with BOO requirements. However the test results justify the assumption of uniform pressure up the buildings and in most cases the associated total bending moments are reduced.

Depot analysis

Final design and working drawings for the depot foundations and structure were commenced in 1978. The effect of residential block loading on the depot was assessed using three-dimensional computer analyses (Fig. 4). In these analyses the transfer plates were modelled as a grillage of beams with properties modified to represent, approximately, the stiffening effect of the walls above. Loads from the residential blocks were applied to the grillage based on the results of the preliminary analysis described above.

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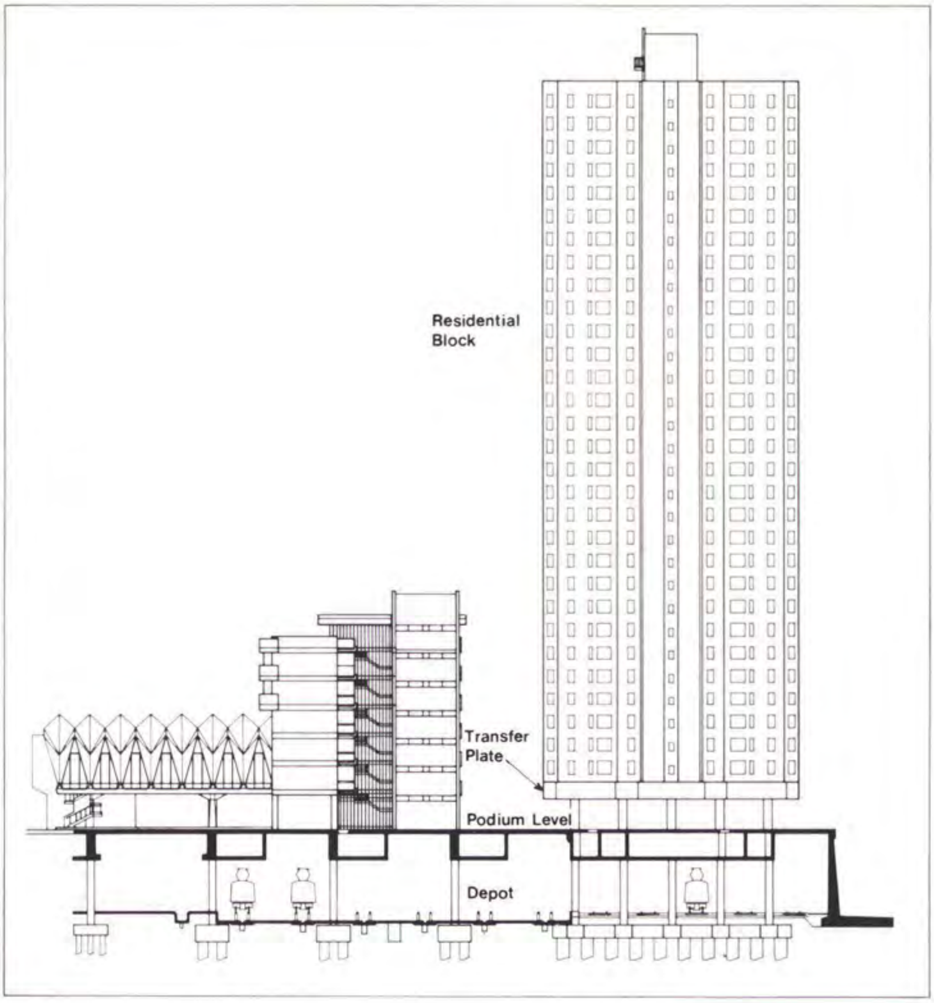

Fig. 2
Part section through depot

Fig. 3
Typical floor plan – type A block

Fig. 4
Computer model – depot

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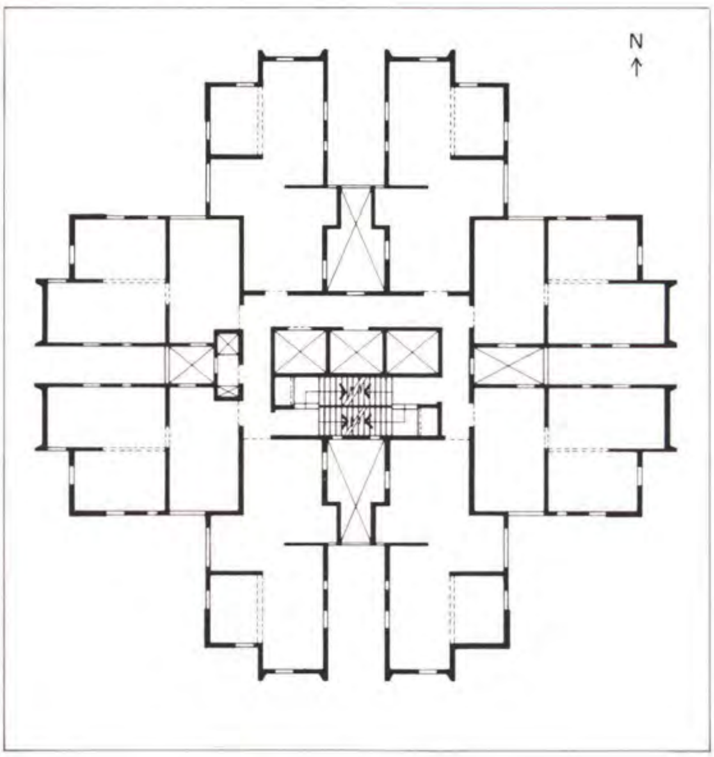

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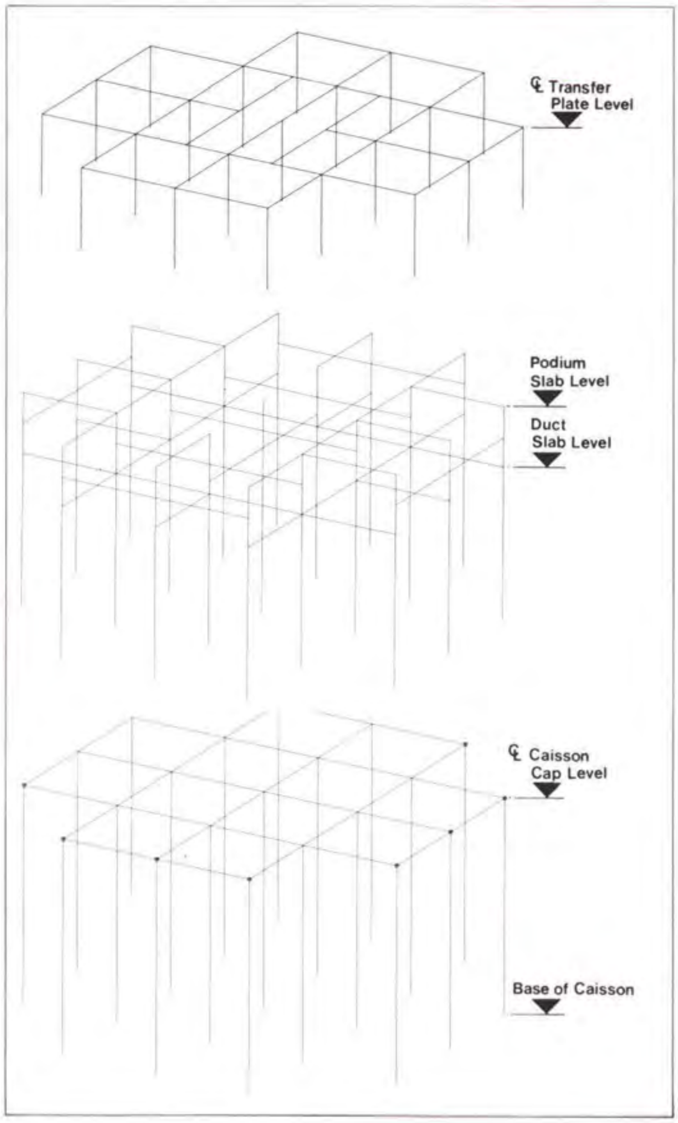


Production stage

Defining the problem

The difficulty in the analysis of the residential blocks arises from the complex behaviour of the shear walls caused by their irregular plan shapes and the arrangement of the window and door openings. It is not possible to calculate accurately the degree of coupling between the walls by any simple technique. The analysis is further complicated because the blocks are supported by the relatively flexible transfer plate and depot structure, the deformations of which will induce additional shear forces and bending moments in the lower storeys.

Analysis models

Initially the intention was to analyze a three-dimensional computer model which would include the depot structure, the transfer plate and the 30 storeys of walls and floors. However, although the blocks are essentially symmetrical about both axes, which allows the model to be reduced to one quadrant in plan, the problem was still too large to be analyzed in a single stage. It was therefore decided to carry out the analysis in three stages.

Stage 1

A three-dimensional model (Fig. 5) representing the 30 storeys of walls and beams above transfer plate was analyzed first. This model was fully fixed at transfer plate level and was subjected to vertical dead and live loads and wind loads in two directions.

The purpose of this stage was to provide details of the behaviour of the structure at high level, remote from the effects of transfer plate deformations and to provide loading data for application to the stage 2 model.

Stage 2

A three-dimensional model (Fig. 6) was produced representing the depot structure, transfer plate and 15 storeys of walls and beams. Again vertical and wind loading was applied. Member forces were abstracted from the wall elements at the 16th floor of the 30-storey model and applied to the top of the stage 2 model.

Stage 3

In the stage 2 model the transfer plate members were stiffened by the structure above so that spandrel beams helped to transfer loads to the columns. It is not reasonable, however, to rely on this contribution during the early construction stages when the transfer plate has been built and depropped and the first few storeys of walls have been constructed but have not matured. A third model was therefore analyzed in which the stage 2 model was modified to remove the structural contribution of the residential block. This model was loaded with the self-weight of the transfer plate plus the equivalent of the self-weight of four storeys of walls and slabs.

Modelling details

Advantage was taken of the symmetrical plan arrangement of the load-bearing walls by modelling only one quarter of the block and choosing suitable restraints at the two axes of symmetry. These restraints vary for each type of loading and hence three analyses were required for each of the stage 1 and 2 models. In these models each rectangular wall section was represented by a vertical beam element at the section centroid (Fig. 7). At storey height intervals these elements were connected by horizontal stiff arms which also connected to beam elements representing the spandrel and lintel beams. To limit the size of the problem a number of horizontal stiff arms were omitted, and the length of the spandrel beams modelled were increased. Beam properties were adjusted in order to model the correct effective stiffness of the beam-wall arrangements.

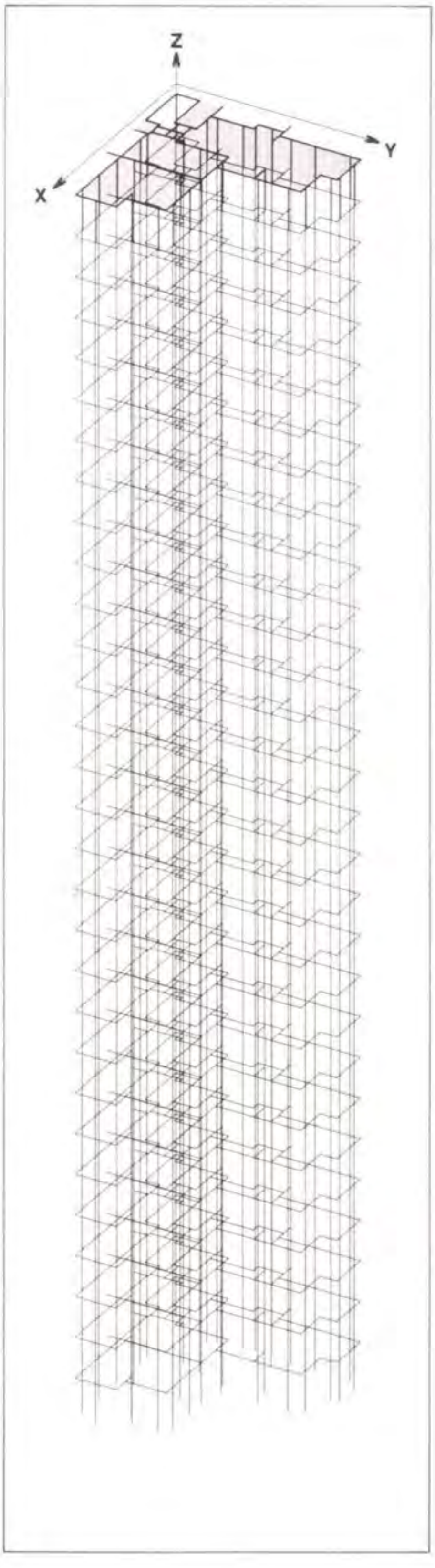
The floor slabs were assumed to act as horizontal diaphragms and this effect was simulated by specifying equal horizontal displacements of the nodes at each floor level.

Fig. 7 shows relevant element numbers for a typical floor. This single-storey model is referred to as the 'chassis' model from which the 15-storey and the 30-storey models were generated.

In the 15-storey models, the transfer plate was represented by a grillage of beams (Fig. 8). The effects of axial and shear deformations of all elements were included but torsional stiffnesses were not generally taken into account except in certain selected members.

All loads were applied directly to nodes as point loads and moments where appropriate.

Separate analyses were carried out for each of the four basic block types.



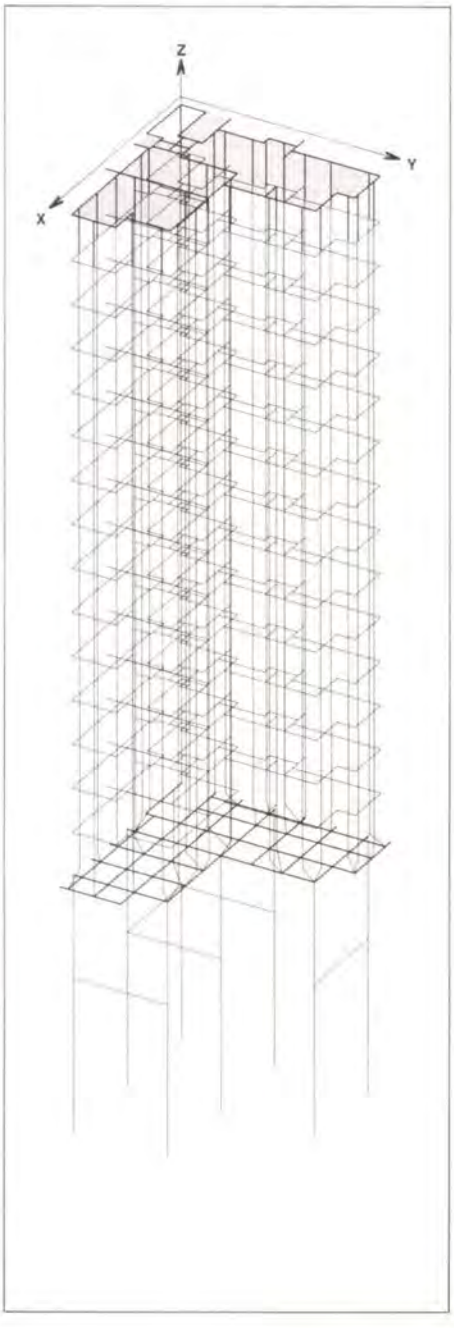
Behaviour of the structure

Effect of coupling

Spandrel and lintel beams are required to transfer shear forces across wall sections under wind loading so reducing bending moments in the individual walls. The efficiency of a beam providing coupling is governed by the stiffness of the connecting beam relative to the stiffnesses of the connected walls. Fig. 9 shows shear force plots for elements numbers 25 and 52 indicated on Fig. 7. Element 25 is a relatively stiff spandrel beam connecting flexible wall elements and the plot is almost linear, indicating that the walls are effectively acting together as a single cantilever. Element 52 is, in contrast, a relatively flexible lintel beam, in which the peak shear force occurs at about the 8th floor and the shear force distribution is similar to that normally associated with coupling beams.

Fig. 5
Computer model – 30-storey

Fig. 6
Computer model – 15-storey



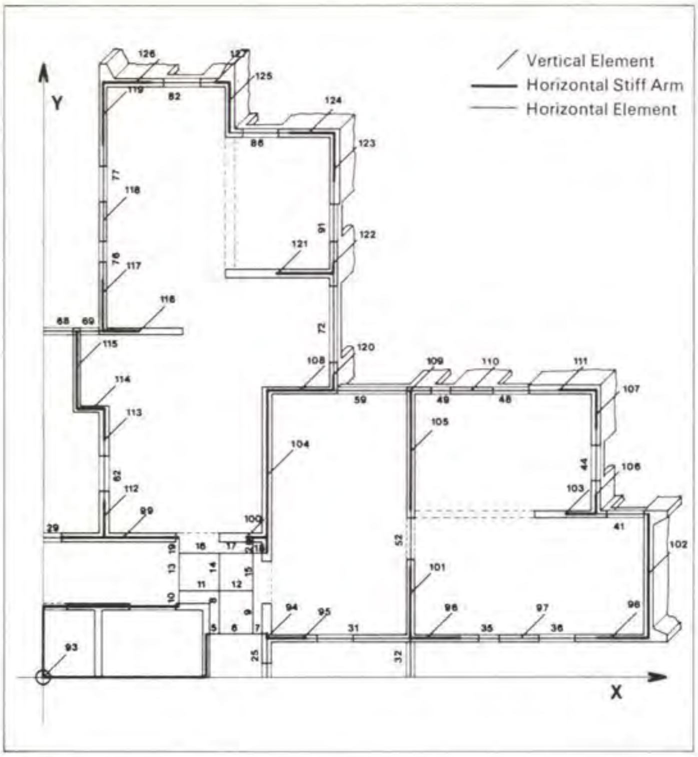


Fig. 7
Typical floor modelling

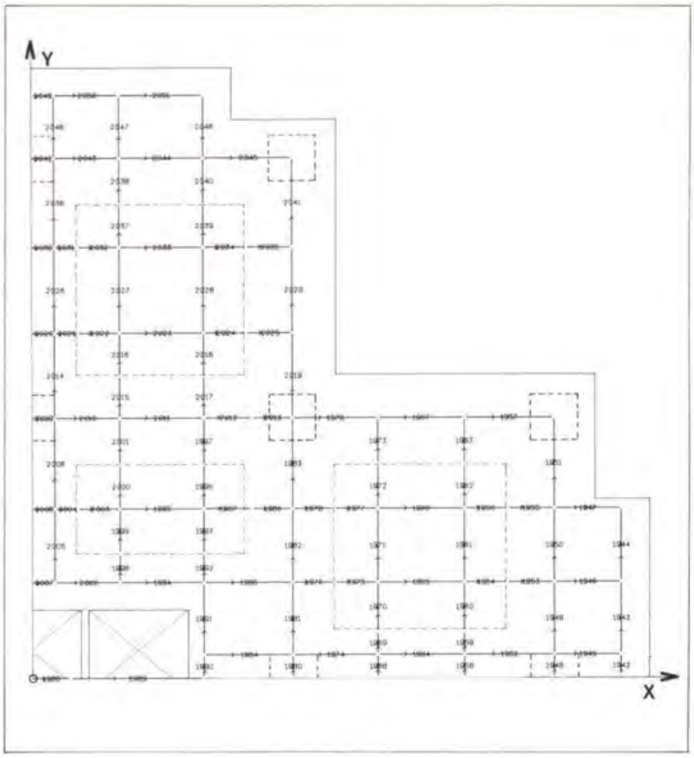


Fig. 8
Transfer plate modelling

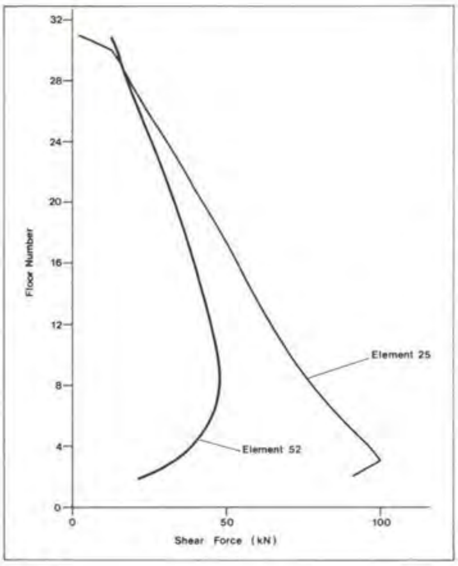
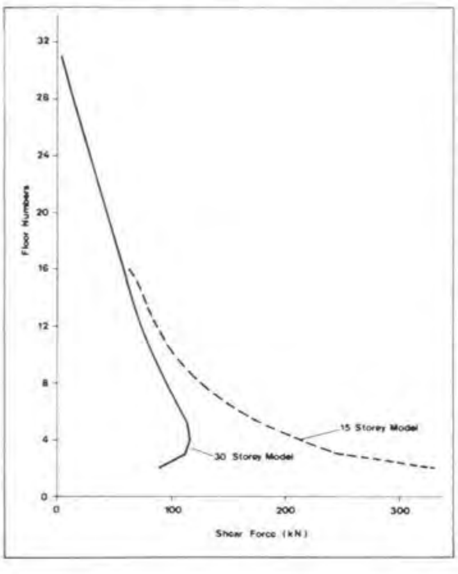


Fig. 9
Shear force distribution – chassis elements 25 and 52

Fig. 10
Shear force distribution – chassis element 44



Degree of coupling

The degree of coupling under wind loading can be expressed in terms of the ratio between the actual shear transferred across an axis of symmetry and that which would be transferred with full coupling. The latter force can be expressed as

$$P = \frac{MAL}{I}$$ where M = total wind moment

A = area of walls in one half of the block

L = distance to the centroid of the walls in one half of the block from the axis of symmetry

I = total inertia of the block assuming full coupling.

On this basis, coupling was found to be approximately 80% efficient in the east-west (x-axis) direction and 70% efficient in the north-south (y-axis) direction.

Transfer plate flexibility

In the 30-storey model axial stresses in the walls due to vertical loading are very uniform at about 4.5 N/mm^2 at first floor level. In the 15-storey model this increases to about 7.0 N/mm^2 in the walls close to the column supports as a result of the flexibility of the transfer plate. In addition the rotation of the transfer plate induces local bending in the lower storeys. The forces in the beam and wall elements under wind loading are also affected by the deformations of the transfer plate. Fig. 10 demonstrates the effect on the shear force distribution for chassis element 44.

Computing aspects

The computer analysis program used was PAFEC 75. There were approximately 3,800 elements and 2,600 nodes required for the 30-storey models and 2,100 elements and 1,400 nodes required for the 15-storey models. In order to save time and reduce the possibility of error in both data preparation and interpretation of the results, purpose-written computer programs were used to generate the data automatically and to post-process and present the results in a comprehensible form.

Data preparation

The input data for the 30 and 15-storey models was generated from the data for the single-storey chassis model by a special computer program. This program also generated the necessary vertical loading data.

Another program was written to extract the analysis results from the required level of the 30-storey model and generate loading data for application to the top of the 15-storey model.

Post-processing and presentation of results

The version of PAFEC 75 used by the firm has been modified so that the results of the analysis can be stored on disk in the computer. This enabled the results from the separate analyses for vertical and wind loading in the two directions to be merged and the necessary load combinations generated.

For the design of the spandrel and lintel beams a program was written to generate shear force and bending moment envelopes for combinations of dead load live load and wind loads acting in the directions of the major axes and at 45°. Allowance was made for live load reduction and permissible overstress under wind loading and corrections made for the spandrels which had been modelled with modified spans as mentioned above. The results were presented graphically as shown in Fig. 11.

Similar envelopes were generated for the transfer plate members and these were again presented graphically as shown in Fig. 12.

For the design of the walls themselves it was necessary to calculate the resultant vertical stresses at critical sections under the various load combinations from the results for the individual axial forces and bending moments in the vertical elements. Where composite walls were modelled by one or more elements (e.g. elements 100, 104, 108 and 120 in Fig. 7) it was necessary to combine the forces and moments and apply them to the combined section. These calculations were carried out using yet another program and the results were again presented in graphical form in terms of the ratio of actual to allowable stress (Fig. 13). These plots indicate where the steel percentage can be reduced or alternatively where grade 40 concrete is required.

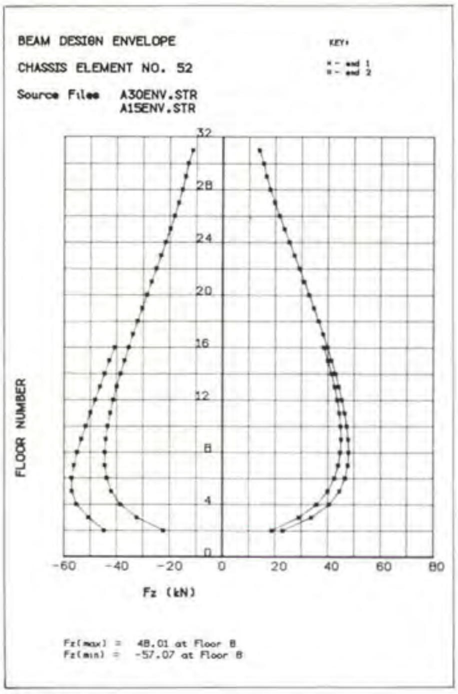


Fig. 11
Element forces plot – shear force

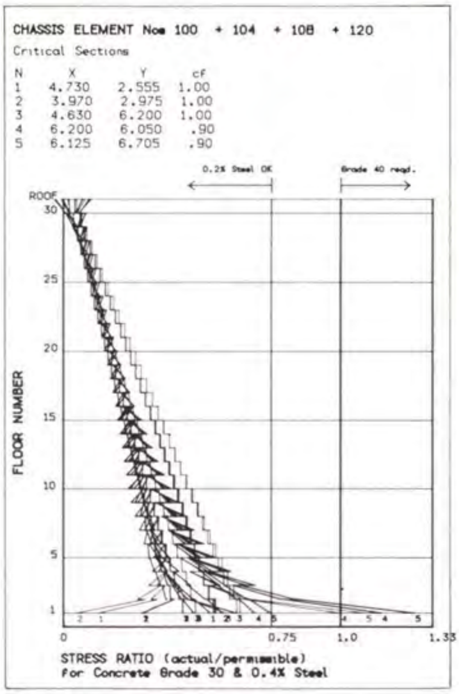


Fig. 13
Wall stresses plot

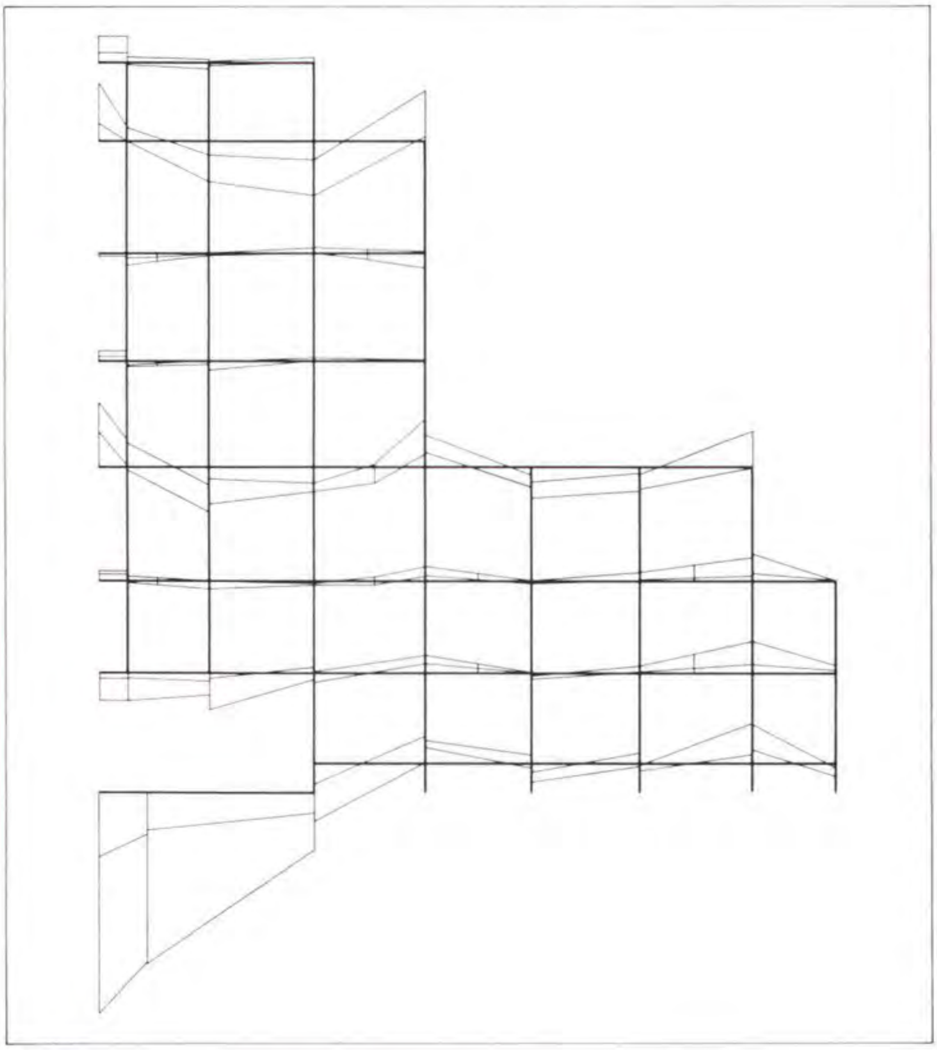


Fig. 12
Transfer plate bending moment envelope (E-W Beams)

Comparison between analyses

The plots described above include results for both the 15-storey and the 30-storey models. Substructure deformations were expected to affect only the bottom few storeys of walls and beams but some of the spandrel plots (Fig. 9) show significant differences in results between the two models at 16th floor level.

To some extent these differences will be due to the inaccuracy of the modelling. However, the results obtained, using the two models, exhibit sufficient convergence for them to be used with confidence for design purposes.

The element forces from the 30-storey model are compatible with those from the preliminary analysis taking account of the revised loading, while the results for the 15-storey model confirmed the necessity of increasing the wall thicknesses to allow for the effects of the deformation of the transfer plate.

The column and foundation loads obtained from the analysis of the 15-storey model have been compared with those obtained from the depot analysis and there is close correlation between the results.

Element design

The structure was generally designed in accordance with the BOO regulations. Additional checks for shear and vertical tensile stresses were also made to *CP110*.

Walls

It was found that compression reinforcement in the walls could be avoided altogether, provided that grade 40 concrete was used for the first lift of walls. Significant tensile stresses as a result of bending in the individual walls only occur in the lower storeys and these were catered for by the provision of 0.4% vertical reinforcement with additional trimming bars at the ends of the walls.

The shear forces in the individual walls are generally small except in some walls at first floor level. In these cases it was necessary to check the principal stresses at various positions and these were found to be acceptable.

Spandrel beams

Several of the spandrel beams are highly stressed in the lower storeys and heavy reinforcement is required. The maximum shear stress is approximately 2.5 N/mm^2 under working loads.

Transfer plate

The transfer plate was designed for the forces obtained from the combined results of the stage 2 and 3 analyses together with some additional calculations necessary because of complexities in the lift core area which are not included in the computer model. The reinforcement, however, is not generally very heavy and the maximum shear stress in the grillage members does not exceed 1.4 N/mm^2 under working loads.

Reinforcement quantities

Approximately 14,500 tonnes of reinforcement are required for the residential blocks, transfer plates and columns above the podium deck. This is equivalent to 68 kg/m^2 of gross floor area.

A breakdown into the various structural elements is as follows:

Slabs	32%
Walls and spandrels	49%
Transfer plates	16%
Columns	3%

The rates for reinforcement weight per unit area of each structural element are:

Slabs	20.5 kg/m^2
Walls and spandrels	23.4 kg/m^2
Transfer plates	255.0 kg/m^2

Acknowledgements

The special programs for the data preparation and post processing of the analysis results were written by Paul Cross.

Credits

Architect:
Choa, Ko and Partners in association with Lee and Zee Associates

Client:
Mass Transit Railway Corporation of Hong Kong

Developer:
Luk Yeung Sun Chuen Joint Venture

Brick vault and dome construction

Michael Noyce

Mud-brick vault and dome systems have been used in countries such as Egypt and Iran for centuries. Their use grew out of necessity in hot dry semi-arid regions where spanning materials such as timber and reeds became more and more scarce as the population grew. One of the earliest examples of this form of construction still in existence is the granary of Rameses in Egypt built about 3,500 years ago.

Traditional development

The stability of mud roofs relies on the fact that they are built as pure compression structures. Traditional vaults follow the shape of an inverted catenary. It is possible that the ancient builders developed the shape by suspending a rope between the springing points of the vault and then inverting the profile. Alternatively, they may just have developed a feel for the right shape, based on experience or trial and error.

Hassan Fathy in the late '40s revived the art of building mud brick roofs without the use of formwork when he designed his Gourna village.

'We are fortunate in being compelled to use mud brick for large-scale rural housing; poverty forces us to use mud brick and to adopt the vault and dome for roofing, while the natural weakness of mud limits the size of vault and dome.

All our buildings must consist of the same elements, slightly varied in shape and size, arranged in different combinations, but all to the human scale, all recognizably of a kind and making harmony with one another.

The situation imposes its own solution, which is – perhaps fortunately, perhaps inevitably – a beautiful one.'—(Hassan Fathy in *Architecture for the Poor.*)

Over the last 10 years Arups' Zimbabwe office has been involved in the design of a number of brick roofs (see Appendix A).

Building materials such as steel and concrete are available in urban areas and have been for many years. However, in the projects listed below, most of which have been built in rural areas, the conditions have been right to make either burnt or cement bricks a viable alternative compared with conventional methods. Mud bricks were never seriously considered because they could not withstand the heavy rains unless they were sealed.

Vaulted roofs

The following assumptions have been made for designing the vaults:

- The centre line of the vault and the line of thrust under dead load are coincident (Figs. 1a and 1b).
- The bricks are incapable of withstanding tensile stresses. Mortar only serves to create a voussoir arch and any tensile strength is ignored. (This means that tensile stresses caused by point loads when multiplied by a factor of safety must not exceed the dead load compression stresses).
- Individual bricks are prevented from sliding out by the frictional resistance due to the axial force.
- Axial forces are low and the vault does not deform significantly under dead load.
- The springing points are fixed.
- In order to collapse the portal comprising the support walls and vault in a single system (Fig. 1c) or an individual vault in the case of a series of vaults, four plastic hinges must be developed (Fig. 1d).

The validity of the assumptions depend on the nature of the materials and the configuration of the structure. Using the above assumptions, the amount of structural calculation required is minimal and most problems can be solved by suspending a chain between two fixed points and noting the shape. The real skill comes in allowing the structural requirements to enrich the architecture.

Domed roofs

The dome must be restrained horizontally at the springing point. This can be done by providing buttresses or a ring tension member. An easy way of achieving this is to embed strands of wire in the brickwork.

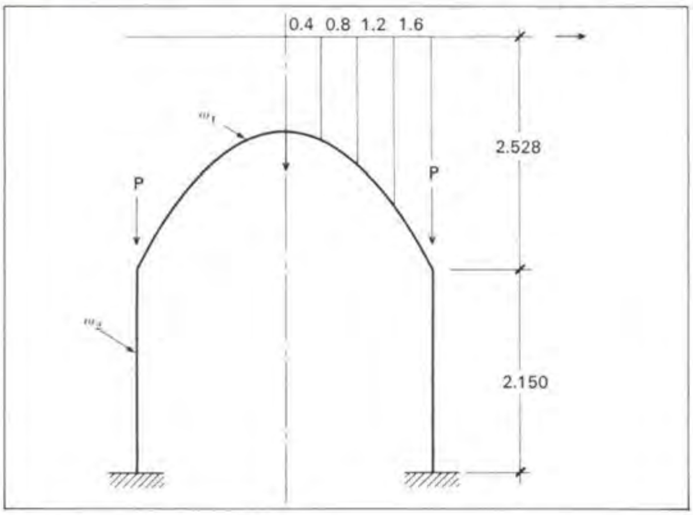


Fig. 1a
Typical cross-section

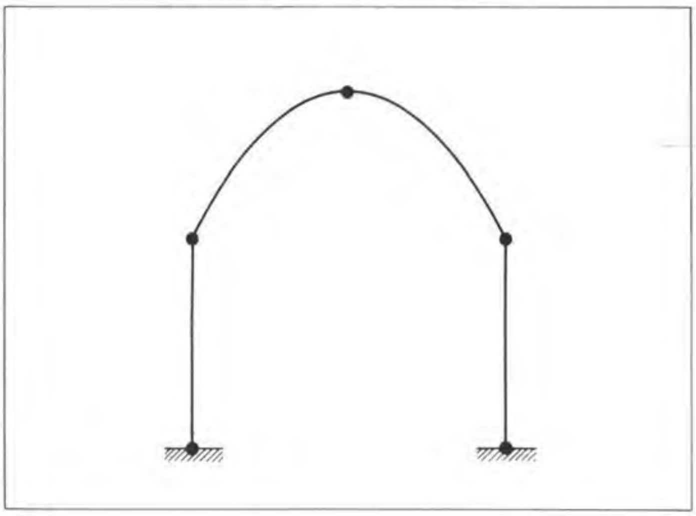
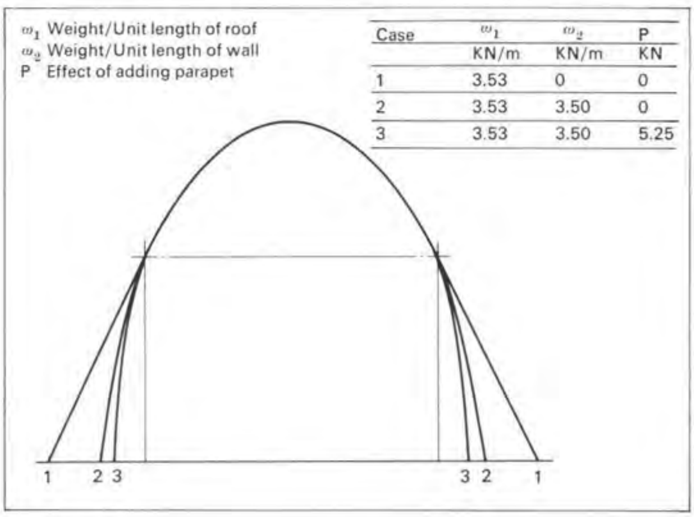


Fig. 1c
Collapse of a portal frame



Case	ω_1	ω_2	P
	KN/m	KN/m	KN
1	3.53	0	0
2	3.53	3.50	0
3	3.53	3.50	5.25

Fig. 1b
Line of thrust under various dead load conditions

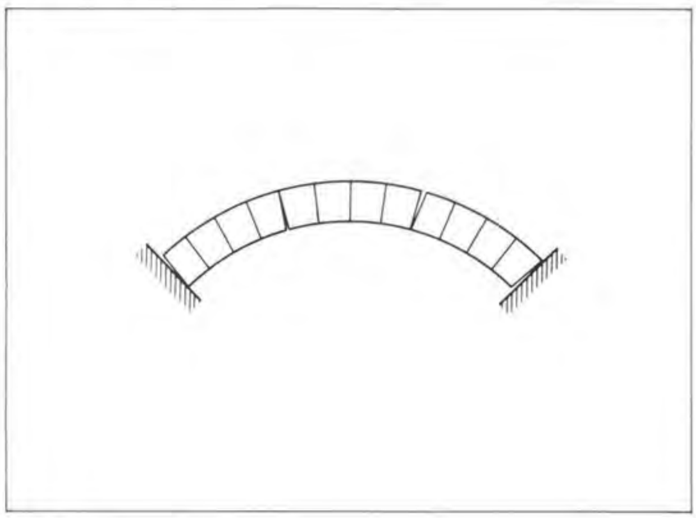


Fig. 1d
Collapse of a voussoir arch

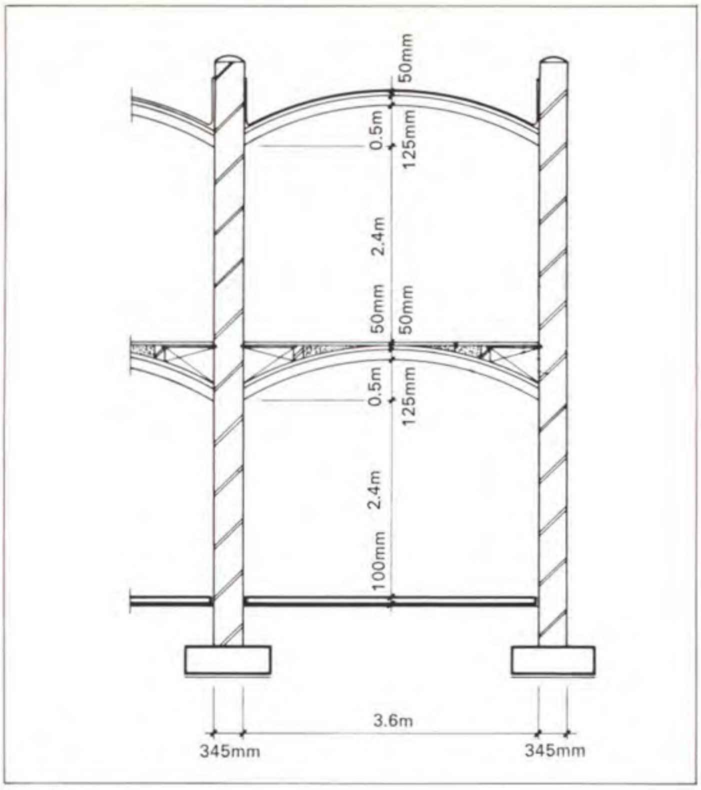


Fig. 2
Basic unit Chobe Safari Lodge

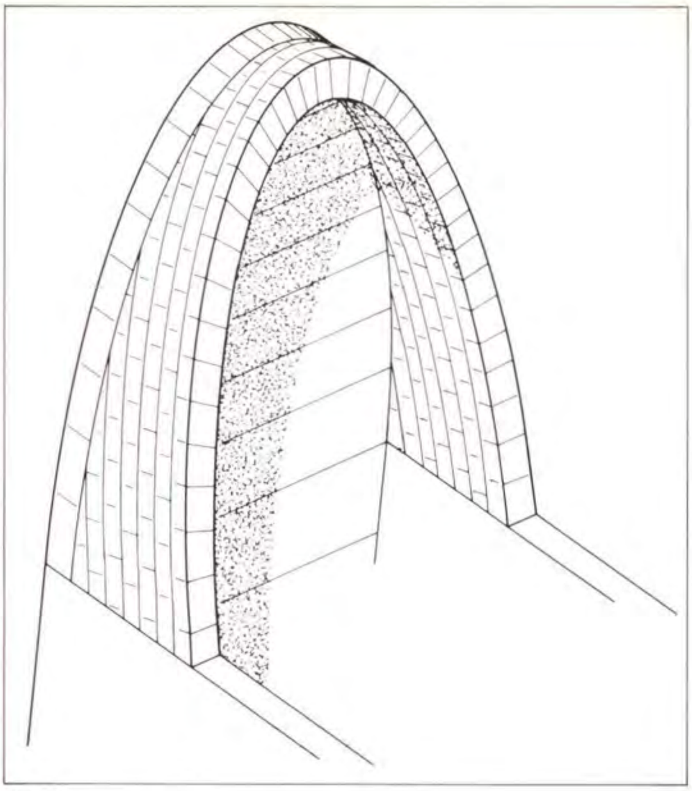


Fig. 3
Brick vault and dome construction

Thermal properties

Thermal storage by the bricks provides a damping effect on external temperature variations. This effect can easily be felt in practice although we have never taken actual readings over a 24-hour cycle.

Chobe Safari Lodge

In 1970, Mallows, Louw, Hoffe & Partners, Architects and Planners, were commissioned to design the Chobe Safari Lodge in the Chobe Game Park, Botswana, about 90km from Victoria Falls, Zimbabwe. Bill Birrer was project architect and Ove Arup and Partners were structural engineers.

Only a dirt road connected the site with the nearest rail head at Victoria Falls. The inhabitants of the area build grass-roofed huts for homes, but had little or no experience in reinforced concrete structures. Our engineering geologist, Joe de Beer, was the first member of Arups to visit the site. He engaged a number of local people to dig a trench across the site while he went game viewing. After a day he returned, looked at the trench and made a few notes. Then he instructed his team to fill the trench. All their worst beliefs about crazy foreigners were confirmed.

However, the crazy foreigners came back to organize the building. Bill Birrer realized how difficult it would be to train sufficient skilled artisans to build a conventional structure. There was no crushed stone in the area and the local alluvial Kalahari sand was unsuitable for concrete. When mixed with river sand in equal quantities, Kalahari sand can be used for sand cement bricks (4:4:1) with a crushing strength of 7 MPa. Therefore, Bill Birrer decided to design the Lodge around the use of local skills and the locally-made bricks. The result was to minimize the need for transported materials which may be subject to delays as well as increases in price.

The basic unit for the chalets and hotel wing is shown in Fig. 2 – 345mm brick cross-walls support prefabricated hollow clay block arches. This method of construction is illustrated below. The span is 3.6m and the rise is 500mm. Light steel reinforcing bars were placed between the hollow pots to augment the moment capacity due to axial forces alone. With a larger rise this steel could have been omitted, but would have increased the height of all the buildings.

Chobe Game Park is famous for large herds of elephant which can often be seen grazing on the flood places near the site. These, together with the fish eagles with their wild cry and the carmine bee-eaters who live in holes in the river bank amongst a host of other animals and birds, give one a beautiful feeling of unspoilt Africa. Because the structure literally grew out of the ground it appears completely at home with the surroundings.

Fig. 4a
Chobe, Botswana: prefabricated units
(Photo: Ove Arup & Partners, Zimbabwe)

Fig. 4b
Cullinans: prefabricated units
(Photo: Ove Arup & Partners, Zimbabwe)

Total brick structures

The Chobe project gave rise to the idea that this type of construction could be used for rural housing in Zimbabwe as it has been in various parts of the world. Bill Birrer decided to experiment with various methods of construction and we were happy to be taken on board for the exercise.

Three methods of constructing brick vaults are described, along with projects on which they have been used:

(1) Construction of vaults and domes without the use of centring (Fig. 3).

This method of construction is fully illustrated in *Architecture for the Poor*. For the arches the end walls are built up to their full height. Then the shape of the arch is marked on the wall. The arch is constructed by first building out the bricks at the base and then proceeding upwards to form a triangle. The inclined faces of the arches give support to succeeding courses until the arch is completed.

Domes may be constructed in a similar way. Neither the bricks nor the mortar require any special attention although a mortar containing river sand is better as it requires less water to make it workable. So far as I know the secret of success is to lay the bricks quickly and not to move them once they have been placed. A number of bricklayers I have watched have been able to master the technique at their first attempt. The part where the tangent to the domes makes an angle of less than 15° with the horizontal is the only really difficult part and it is often easier to provide a shutter for the remaining opening which is usually around 750mm.

With the help of an unskilled labourer I constructed a dome in my back yard. We struggled for a long time because we were not used to placing bricks and many fell down. I think that one of the reasons that they stick, when they do, is that the bricks, being porous, suck water from the mortar and a surface tension is developed. This is of course destroyed if you move the brick.

This method of construction is completely pure in that it requires no foreign materials but it is rather time-consuming. It is unlikely that it could be used on a commercial project for vaults.

(2) Construction using preformed brick arches (Experimental Masonry Houses Project, Chobe, Cullinan's Lodge)

A variety of bricks have been used for this type of construction ranging from hollow blocks to bricks with a hole through the middle. Fig. 4 illustrates how these planks are made. Once the brick planks have been made they are inverted and placed on the structure.

(3) Construction using centring (Monis Mukuyu Winery). This method of construction has proved the most successful on larger projects. Bricks are laid on the shuttering and mortared up. The shuttering is then withdrawn.

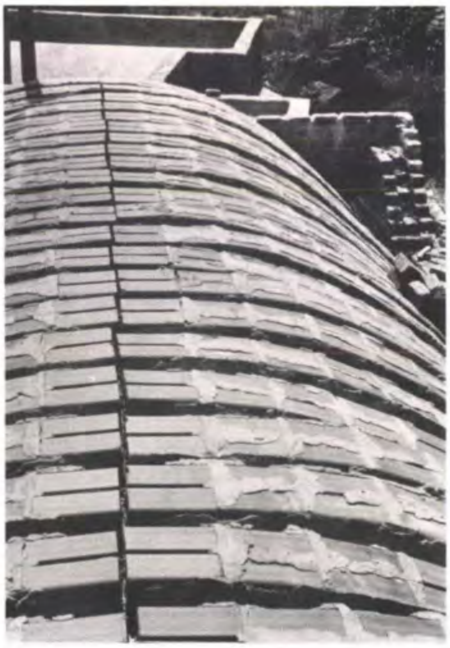


Fig. 4c
Cullinans: 4.5m span lounge
(Photo: Ove Arup & Partners, Zimbabwe)

Fig. 4d
Cullinans: 4.5m lounge
(Photo: Ove Arup & Partners, Zimbabwe)

Fig. 5a
Complete low-cost two-bedroom house without parapets: 3m span (Photo: Ove Arup & Partners, Zimbabwe)

Fig. 5b
Fathy's experimental vault structures
(Photo: Ove Arup & Partners, Zimbabwe)

Fig. 5c
Experimental house: 4.24m diameter vault and dome
(Photo: Ove Arup & Partners, Zimbabwe)

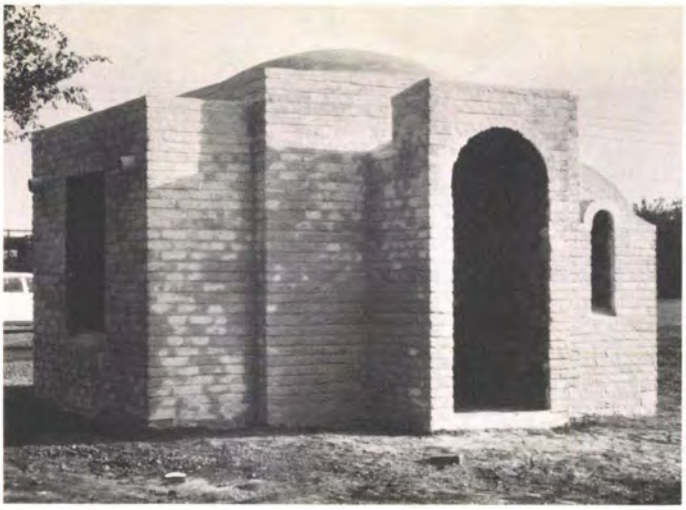


Fig. 5d
Experimental house : 4.29m diameter vault and dome
(Photo : Ove Arup & Partners, Zimbabwe)

Fig. 5f
Low-cost housing : fabricating the brick vault ribs, in two halves, on brick moulds

Fig. 5e
Low-cost housing : dome and vault
(Photo : Ove Arup & Partners, Zimbabwe)

Fig. 6b
Monis Winery : step in roof
(Photo : Ove Arup & Partners, Zimbabwe)

Fig. 6a
Monis Winery : 5m clear span
(Photo : Ove Arup & Partners, Zimbabwe)

Fig. 6c-d
Monis Winery
(Photo : Ove Arup & Partners, Zimbabwe)

Fig. 6e
Monis Winery
(Photo : Ove Arup & Partners, Zimbabwe)

Fig. 7
Chobe, Botswana
(Photo : Ove Arup & Partners, Zimbabwe)

Case histories:
Experimental masonry houses

A prototype house was designed and used on a number of projects, e.g. staff house for the Union Lime Corporation. The objective was to evolve a form of construction which could be handled by any family of average skill that would involve no plant or tools beyond the trowel, shovel and wheelbarrow. Apart from electrical work, no skilled labour is required at any stage. The 3m maximum span vaults are constructed using preformed brick planks. A glass fibre reinforced plaster waterproofs the roof.

Cullinans Lodge

Catenary arches were formed using hollow clay blocks. No reinforcement was used other than the wire in prefabricated arches for the 3.0m and 4.5m spans. The roof was waterproofed by covering the brick arches with a river sand cement screed and then painting the surface with a cement-based paint.

Monis Mukuyu Winery

There were three main reasons for using brick vaults:

(a) The building was to look and feel like a winery. It was to be used to advertise the product and attract visitors.

(b) Local farmers use bricks extensively for farm buildings and a nearby farmer agreed to produce bricks for the winery at ZD 14/1000 (i.e. just less than £10 sterling/1000).

(c) Mukuyu is about 120km from Salisbury. It is in a summer rainfall area, where the grapes are picked at the height of the hot season and therefore a structure with a high thermal storage capacity that would not respond immediately to the mid-day heat was desirable.

Brick vaults met all three requirements. The structure consists of a series of brick vaults supported by brick cross-walls which are corbelled out at the top to receive the vaults. The cross-walls are at 6.0m centres and the clear span between corbelling is 5.0m.

The building which is 3700m² in area was built for ZD105/m² (i.e. £70 sterling/m²) in 1978. This price includes the complete structure and the waterproofing. The construction period was five months and the peak labour force 140. In the latter stages commercial bricks had to be purchased as the grapes were ripening and the farmer's brick field could not keep pace.

Waterproofing

Various types of waterproofing have been used which include painting with a waterproof paint, plastering with a waterproof compound or covering the vaults with asbestos sheeting. The latter, which was the one used on Mukuyu Winery, has proved most successful and has the additional advantage that it provides an insulating medium.

Conclusion

The question arises: does brick construction for roofs have any relevance in our present society? It may well be argued that the Mukuyu Winery is a one-off situation and that one cannot expect to do many more structures of this type. However, in the low-cost housing field there must be scope, providing the ideas are presented and implemented in the right way. It is obviously not the answer to all housing needs but it does provide a means whereby a family can literally grow their own home using only basic skills and materials. It also affords great scope for imaginative architecture and personal involvement.

APPENDIX A:
Brick structures designed by Ove Arup & Partners, Zimbabwe

Project	Date Built	Description	Client	Architect	Value Z$
Chobe Safari Lodge	1970	Hotel	Southern Sun	Mallows, Louw, Hoffe & Ptnrs.	900,000
Cullinans Lodge	1975	Private Home		Mallows, Louw, Hoffe & Ptnrs.	
House Farrall		Private House		Tony Wales-Smith	
Torwood House	1976	3-bedroom Staff House	Rhod. Iron and Steel Co.	Roy Densem & Partners	
Experimental Masonry House	1977	Staff House	Union Lime Corp.	Mallows, Louw, Hoffe & Ptnrs.	
Mukuyu Winery	1978	3700m² Winery	Monis Wineries	Mallows, Louw, Hoffe & Ptnrs.	390,000

MOSS in consultancy: home and abroad

Keith Law
Jonathan Norris

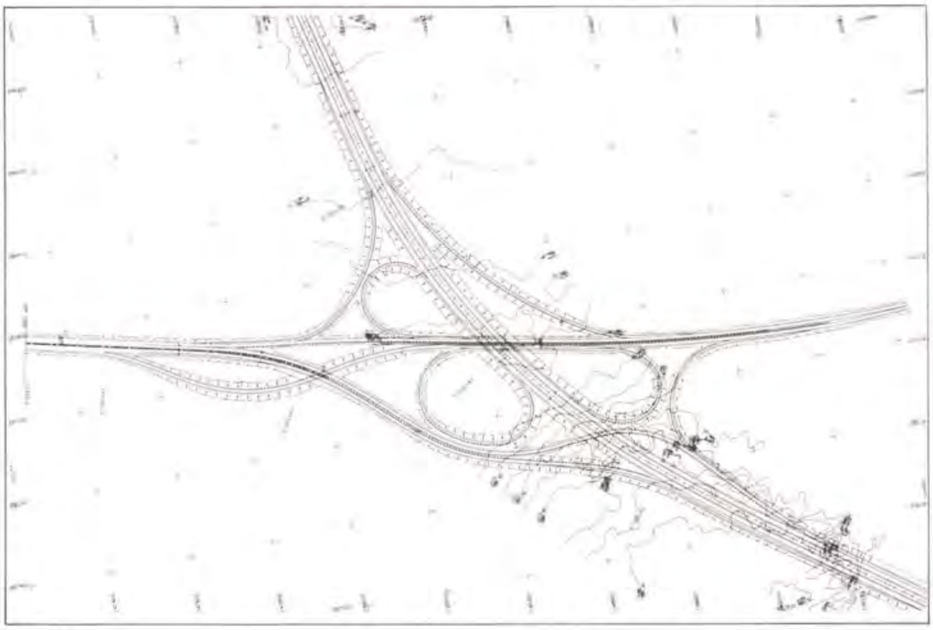


Fig. 1
Thumamah interchange : basic computer plot

Introduction

The role of the computer within the organization of the large consulting engineering practice is, we suspect, fundamentally different from that within the large local and public authority, where it is often the work and efficiency of the treasurer's department which dictate the choice and usage of the particular computer equipment.

Because of their traditional connections with large-scale and advanced engineering projects, large consultancy practices, such as Arups, have found the computer to be necessary for the efficient analysis and production of much of their work, in our case since the 1960s. We are lucky, however, in that the choice of computer has been dictated solely by the nature of the engineering tasks which it has to perform.

From our particular highway engineering aspect, our first computer work was with the Elliot suite of highway programs on the Elliot 4120 computer that we had in the late 1960s. Despite its quirks and limitations this was a good suite of programs and even gave us some very respectable perspectives after some effort. The Elliot was superseded by an IBM 1130 linked to an outside computer running the BIPS suite. During this period most of our highway engineering work was involved with complex urban motorway sections with frequent interchanges and it was not found advantageous to use the computer for much other than horizontal and vertical channel alignments. The IBM machine was replaced by a DEC 10 timesharing system with terminals distributed throughout the firm's offices. By this time our highway engineering work had become very diverse, from complex urban motorways and wholesale site regrading work in Teheran through simple rural road design to local infrastructure of trading and other such sites.

MOSS origins

The MOSS Modelling System has its origins in the attempt to improve and integrate computer systems for highway engineering, including road design, ground modelling and ground surveying and it is useful to describe the problems inherent in previous computer systems to underline the fundamental simplicity of the MOSS approach in unifying and solving these problems and to explain how the system can be used for the solution of problems other than those in highway engineering.

All previous attempts to produce computer aided road design systems automated the traditional manual design procedure. These systems were useful only for highways with simple cross sections and did not satisfactorily deal with the geometrical problems inherent in the design of complex features such as split level-diverging carriageways, junctions and interchanges.

MOSS has developed from a study of the problems of defining earthworks and the computer storage of ground surfaces in the form of digital models. As a result of experience with square grid, random point and triangular models it was found that the ground can best be defined by a combination of feature lines for the definition of irregular or acute ground profiles such as existing roads, railways, etc. and contours or general lines for the recording of ground curvature. These lines or strings are composed of three dimensional co-ordinates and form the digital model of the ground surface.

It became apparent that the designed earthworks and surfaces could be described in identical manner to the existing ground surface.

Further investigation showed that the concept could be simplified because the angular nature of earthworks requires only road feature lines to define channels, kerbs, backs of verges, embankment toes, etc. Road feature lines are similar to ground feature lines but are generated by the designer and are stored as strings of three dimensional co-ordinates. Because a global co-ordinate system is used it is simple to generate the features of the highway because they have a known relationship with the line defining the road alignment. Thus the engineer is creating the ground model of the finished earthworks. Because both the road and ground models are dealt with in the same way the ground model can be updated with the new construction. This facility is useful where schemes are to be constructed in several stages.

Thus a simple concept has evolved which makes it possible to store both ground and highway models in the same way. The system can operate on both types of models with the same program logic, for instance, the method of editing or plotting road or ground strings is the same.

It is important to note that several application areas, i.e. bridge geometry, surveying and highway design which were previously considered as independent, have been united by the development of a common storage concept based on spatial co-ordinates. Thus it is possible that a variety of information can be processed by a single system with common files and processing options such as plotting and editing. It is also possible to compare and combine information from different sources.

The attributes of MOSS for the consultant

For ourselves in the Civil Engineering Division the right machine and the right suite of programs arrived at nearly the same time in the mid 1970s. MOSS we feel is still the right suite of programs for our work in two main respects.

Firstly, it has the flexibility to tackle any of the wide range of jobs that we are called on to tackle at home and abroad, whether they be enormous desert expressways with dual carriageways on differing alignments, urban motorways with frequent interchanges, new railways, site regrading or networks of local roads.

Secondly, it has a high standard and flexibility of plotted output, suitable for both design and production drawings of all types of schemes and for all types of clients.

These attributes lead to the position where the engineers and technicians in the highway engineering group, having become fully conversant with just the one suite of programs and knowing the strengths and, let it be said, the fallibilities also of some of its options and minor options, are able to tackle, week in and week out, the layout design of such varied work in the most efficient manner with few of the dud runs which always seem to arise with unfamiliar programs when there is shortfall between the claims of the user manual and actuality. In times of high office rentals, immense variability in quantity and type of workload and, not least, statutory difficulties in responding quickly to staffing requirements, such flexibility and efficiency is most welcome and is indeed necessary for survival. Some of our clients, mainly overseas, insist on the most hair-raising of project completion dates, with penalties for late delivery. For these projects full computerized production is not an option but a necessity. At the same time, most of the clients with whom we deal at the highest level are themselves senior civil engineers by tradition and, as such, have very definite ideas of the format and nomenclature that shall be used on the drawings to be produced under the agreement. We have found MOSS to be quite adaptable in this respect but, for the same reason, have not thought it worthwhile, for example, to adapt MOSS to plot element alignment parameters on plan or profile because every client seems to wish them presented in a completely different way. Ever present, too, is the traditional difference between European and American training and terminology.

Computer organization

Our highway design commitments currently warrant the implementation and support of MOSS on both our PRIME 400 in Riyadh and, principally, on the DEC 10 system in London.

Whilst virtually all of the Arups' highway design employs MOSS, it is one of many engineering and building services programs that have to conform to certain stringent operating conditions. Probably the most significant of all these conditions is that of core size, which at peak hours of usage is restricted to 43K words, inclusive of system routines. Although the computer has a virtual memory operating system, the loss in efficiency resulted in the non-virtual partitioned memory being preferred. Such a constraint imposes two conflicting problems. The first is the design and linking of a heavily overlaid program whereby routines and their associated files are manipulated as efficiently as possible. The second is that of minimizing central processor time in handling these sectors of program. An optimum balance has therefore to be derived.

To obtain such a structure it is firstly essential to reduce the supplied source file into as many files as routines and thereby an overlay structure based on a root containing essential routines which reside in core at all times. Other routines related to specific options are then called into core by the overlay handler as required. It is only on execution that the efficiency of the overlay design can be assessed.

User support

User support is provided by the Computer Group in four main areas:

1 Guidance in the use of MOSS

The very magnitude of MOSS as a design package, both graphically and analytically, is in many instances awesome for the inexperienced user. In some instances the use of the computer is itself a new frontier to be breached. Despite the readability of the MOSS manual, invariably the user has to justify the use of a program to meet his particular requirement and to that end there can be no substitute for the guidance of an experienced user.

2 Software support

This essentially revolves around the problems encountered by the user, be they associated with the program or computer system. In the productive environment of the Highway Group it is essential that, in the event of problems developing, they can be rapidly resolved as effectively as possible. MOSS, like all computer programs, can, under certain adverse data conditions, or indeed file corruption be reasonably expected to produce both program and system errors.

It is a credit to the Consortium that the program can stand up to the rigorous use to which our current version is put. It is not at all unusual for model files of the order of 1.5 m. characters or more to be handled with confidence; or put another way, about a third of the size of the whole MOSS package.

We try to resolve any problems associated with the code as quickly as possible, or if not, at least identify, document and avoid them in the interests of production. Whilst the creation of an overlaid program of this size is not an easy undertaking the resultant 'file per routine' convention lends itself to easy modification, recompiling and linking.

3 Software enhancement

From time to time it has been considered advantageous, in view of the quantities of data handled, to make certain refinements to both input and output. For example, if one considers the sheer volume of ground data generated by digitization of a strip of aerial photography 100km long with a width up to 500m, there is really only one practical way of inputting that data into DIGIT and that is by means of a program that will read and reformat the digitized data automatically.

Another modification that is used extensively is of the format of the cross-section output, whereby both proposed and existing data are produced on a single page of output (see Fig 5). In conjunction with the standard nomenclature diagram this becomes a very readable document.

4 Administration

With large model files and road contracts extending several hundreds of kilometres and intersections covering up to 36ha, file organization and nomenclature is of paramount importance.

The close monitoring and reporting on the use of computer resources helps to keep projects within budget and strict adherence to established computer security procedures ensures continuity even in the event of a major disruption.

The use of MOSS in preliminary and detail design

As examples here are three quite different schemes on which we have used MOSS in differing ways, which highlight its use as either a design aid or as a fundamental part of an overall design and drawing production system for a major project.

Firstly, a small scheme set in the far north west corner of Scotland where we were commissioned to design a bridge and approach roads to replace the Kylestrome ferry at Kylesku. The topography is of a severely indented coastline with sea lochs and steeply undulating igneous outcrops. A preliminary 1:2500 aerial survey of the approaches was made and digitized and three possible routes were identified. All involved rock cuts and steep and curving alignments. The phasing of curves and the fit with the topography were essential on this new, highly scenic road. A prime necessity also was to ensure that the new road did not affect the beauty of the scene from Kylestrome itself. In this respect it would have been very useful to have had the perspective option that we believe is now becoming available on MOSS. The three preliminary routes were modelled simply and quantities and cross-section at selected critical locations were compared. Finally, after selection of one of the routes by the client, a detailed aerial survey was made at 1:500 scale and digitized; detailed road design was completed, including plans and profiles and at-grade junctions with the existing road. Obviously, on a scheme in terrain such as this, comparison of alternatives and detail design by hand methods would have been extremely laborious, or modelling of the existing ground, by any other method than string contours, probably very inaccurate and misleading.

The second scheme is a project we have for the design of a new highway and railway crossing of the River Lagan in Belfast, together with their approaches. Some extremely complex interrelated alignment design was called for, weaving slip road structures through and under other structures whilst maintaining adequate clearances to existing buildings and the less flexible new railway we were designing alongside. Integrated with the design were new railway stations with their own design parameters to be observed, whilst elsewhere were problems of phased construction by the client on earthworks over very bad substrata. In order to be absolutely sure of minimum clearance at particularly critical points, ground survey co-ordination was carried out and hand calculation of minimum clearances made. The use of MOSS for calculation of both horizontal and vertical alignments on this project was extremely helpful, particularly in the facilities of section plotting and of superimposed profiles to check alignment interrelationships throughout.

The third project is, by contrast, immense. It is the design of, in total, 650km of dual three-lane, grade-separated expressway across Saudi Arabia. 250km lie west of Riyadh, the capital, towards Jeddah, and the remaining 400km run eastwards between Riyadh and Damman on the Arabian Gulf, of which about the first 20km in Riyadh are of the most complex urban nature.

Grade separated interchanges occur at intervals along the expressway, from the simple, desert access, partial clover-leaf layouts to the most complex direct link layouts (see Fig. 1) that were required near to the capital. It is difficult in a paper of this length to describe the whole of the background and enormous content of the work that we were required to perform, including the setting up and operation of MOSS and a PRIME 400 computer in our Riyadh office. The first requisite, after the reconnaissance survey stages (see Fig. 2), was to plan the production of drawings and standardize work throughout the team after agreement of standard details with the client's engineers. Such items as standard acceleration and deceleration lane and nose details were adopted, using standard exit and entry radii derivations from the adjacent expressway centreline alignment. Survey output has to be standardized. The west side project was essentially the widening, overlaying and dualling of an existing lower standard road which passes through various types of topography, including hilly igneous rock (see Fig. 3), flat pan and high wind blown sand dune desert with frequent settlements along its length. Because of the need for accurate levelling of the existing road for minimum overlay design, ground survey methods were used giving very nearly direct digitization of longitudinal strings within a corridor of 200 to 300m. On the east side

Fig. 2
Reconnaissance survey camp
(Photo: Keith Law)

Fig. 3
Existing road through wadi in igneous rock terrain
(Photo: Keith Law)

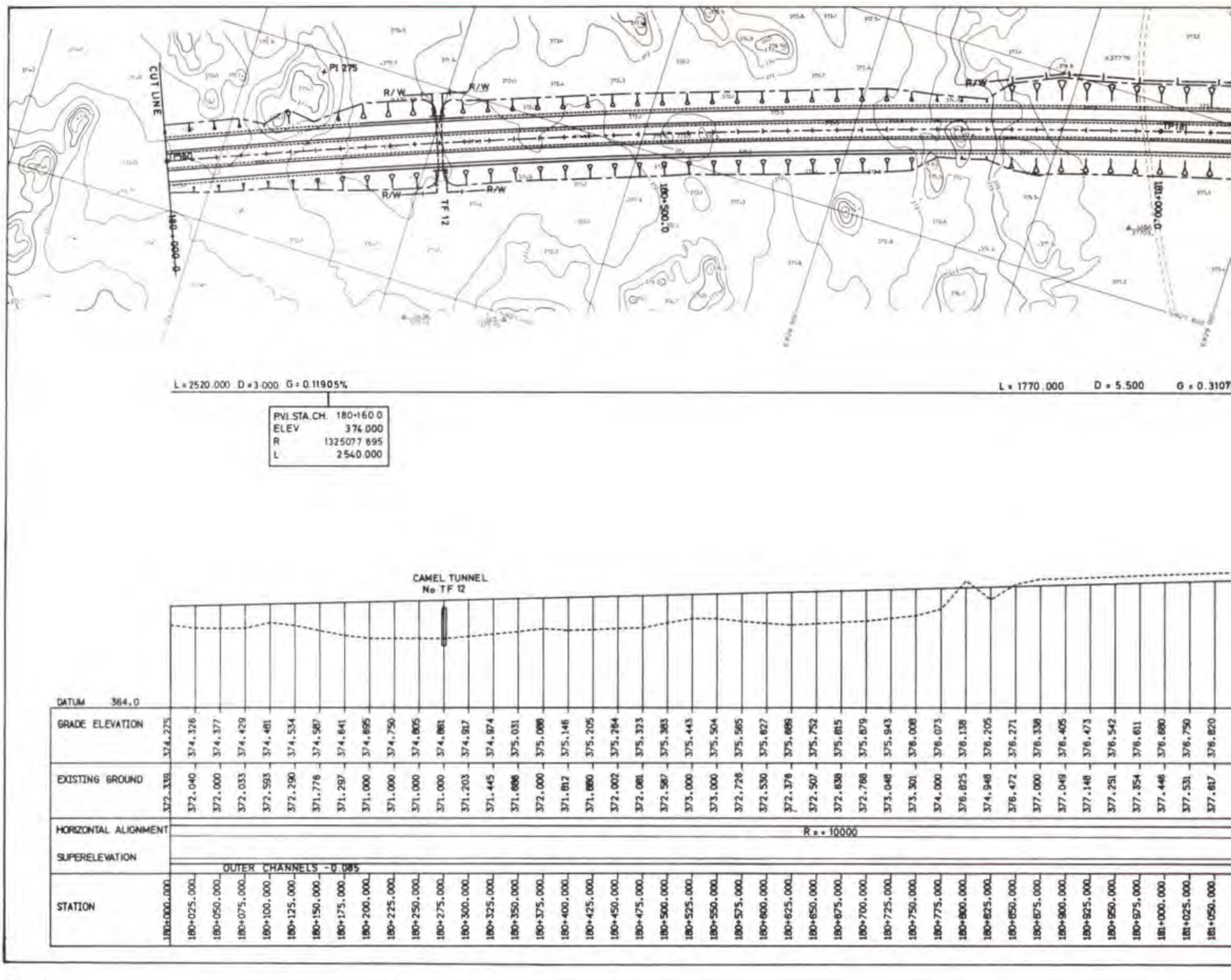


Fig. 4
Typical computer plan and profile plot, after flat bed printing with survey plot

of Riyadh our route lay across country through virgin desert and across the northern part of the largest oilfield in the world, and the supply pipes from it. On the east side aerial photography was used throughout. Digitization was carried out using the survey pencil plots so that computer design could continue whilst fair drawing of surveys proceeded. All computer plotting is done in reverse, by the way, so that stencilling of parameters on the opposite side of the film may be carried out without erasure or smudging problems. This also leads to clearer plan reproduction as after the combined computer plan and profile plots are produced (see Fig. 4) they are flatbed-printed in register with the fair drawn survey plots to produce combined negatives. Reduced and bound sets of final contract drawings and documents were required to be produced also, as were plotted cross-sections every 100m and printed cross-sections every 25m throughout. A standard MOSS nomenclature system was produced and adhered to rigidly throughout the design process on this and every other project. This allows the printed cross-sections produced by the MACRO option that we developed to be easily understood by both designer and contractor. Examples of printed and plotted cross-section output are also shown (Figs. 5 and 6).

RIYADH-DAMMAM -- CONTRACT K -- EXPRESSWAY

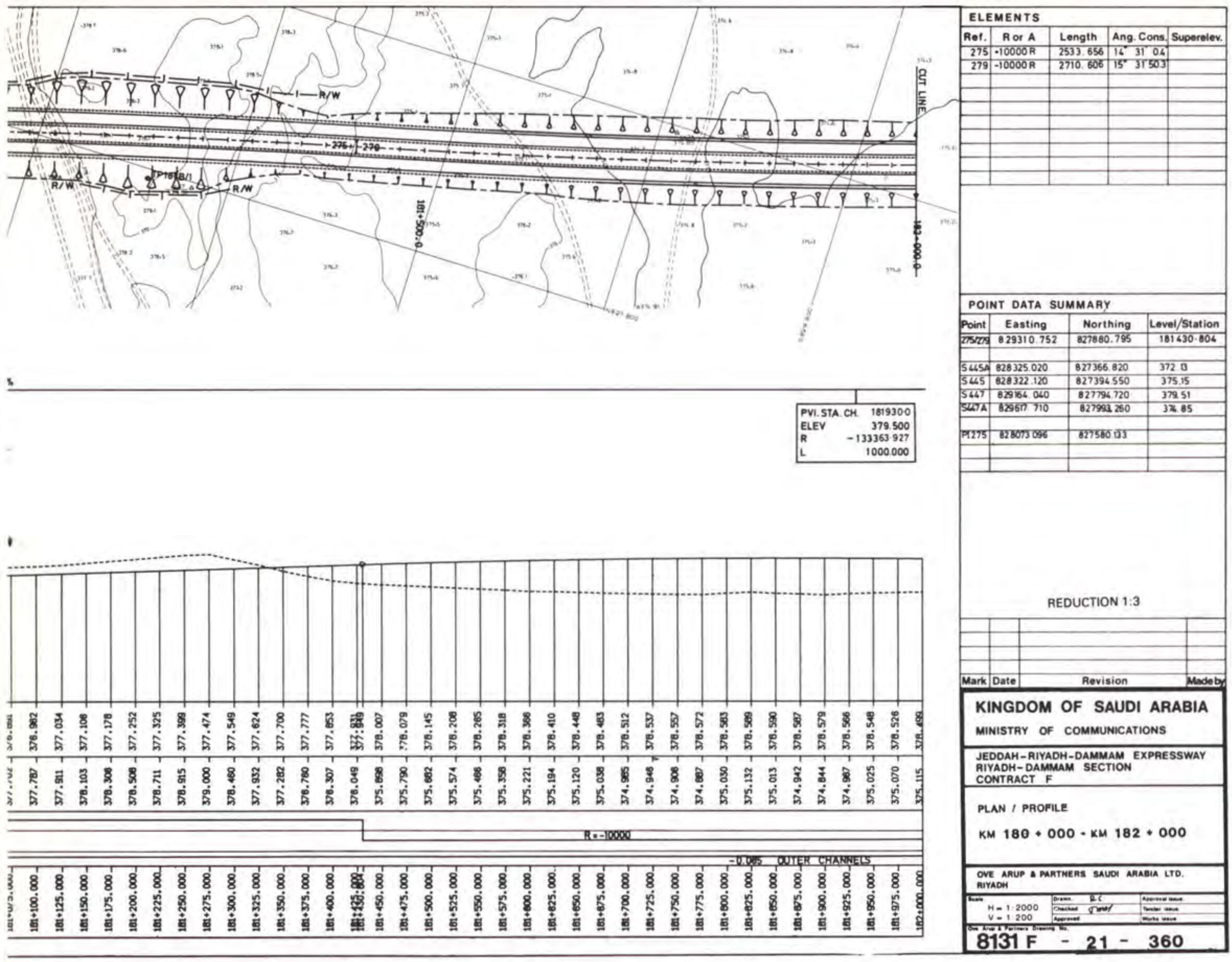
CROSS SECTION INFORMATION AT STATION 7+200.000

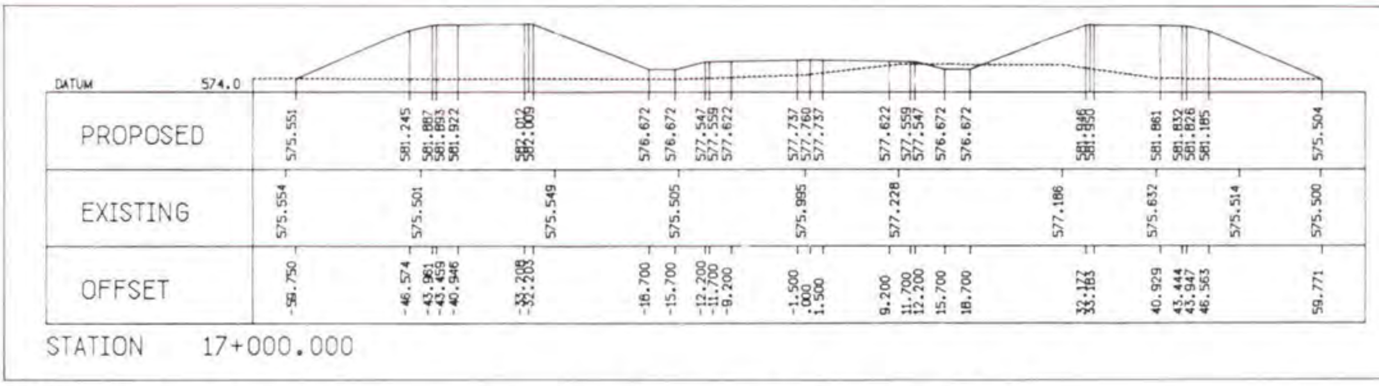
OFFSET	EXISTING	PROPOSED	LABEL
-84.717	613.663		
-70.000		613.800	IAA1
-63.852	613.800		
-58.000		616.866	VAA1
-49.000	614.000		
-41.999		617.266	KAA1
-34.500		617.199	KBA1
-34.000		617.191	JAA1
-33.319	614.019		
-23.500		617.033	MCK1
-23.000		617.025	KE11
-22.999		617.225	KF11
-19.637	614.374		
-15.460		617.375	WA1M
-14.351		609.613	WB1M
-13.351		609.563	KG1M
-13.350		609.363	KH1M
-12.850		609.370	RAAM
-4.072	616.000		
-1.500		609.540	RMAM
0.000		609.563	MCKM
1.500		609.540	RPAM
2.133	616.879		
12.850		609.370	RZAM
13.350		609.363	KT1M
13.351		609.563	KU1M
14.351		609.613	WY1M
15.460		617.375	WZ1M
22.999		617.225	KV12
23.000		617.025	KW12
23.500		617.033	MCK2
28.450	616.741		
34.000		617.191	JZA2
34.500		617.199	KZA2
34.501		617.399	KZZ2
35.221	616.623		
42.001		617.366	VZA2
43.827		616.909	IZA2
46.548	617.000		
55.301	617.292		

CROSS SECTION INFORMATION AT STATION 9+800.00

OFFSET	EXISTING	PROPOSED	LABEL
-78.346	605.304		
-63.629	605.439		
-60.932		605.364	IAA1
-58.000		604.386	VAA1
-48.488	605.017		
-41.999		604.786	KAA1
-36.500		604.749	KBA1
-34.000		604.711	JAA1
-33.411	605.131		
-23.500		604.554	MCK1
-23.000		604.547	KCE1
-22.500		604.497	KDE1
-18.657	607.123		
-15.350		604.738	NAEM
-12.850		604.800	RAAM
-3.122	604.000		
-1.500		604.970	RMAM
0.000		604.993	MCKM
1.500		604.970	RPAM
3.620	604.295		
12.850		604.800	RZAM
15.350		604.738	NZEM
22.500		604.497	KXE2
23.000		604.547	KYE2
23.500		604.554	MCK2
29.931	604.230		
34.000		604.711	JZA2
36.450	604.694		
39.000		604.786	KZA2
39.001		604.986	KZZ2
42.001		604.886	VZA2
43.521		604.507	IZA2
47.202	604.409		
56.920	604.182		

Fig. 5
Example of printed cross-section output





MOSS and the young engineer

In tackling all the above types of work with one computing system, the young engineer becomes extremely familiar with just what MOSS can and cannot do for him and becomes extremely efficient in the process. The amount of work that can be produced by comparatively few engineers and drafts-men in a small amount of office space is surprising. We must stress a resulting danger, though, that we have tried very hard to avoid. This is that the young engineer must not become completely absorbed in his MOSS modelling, seated all day at the computer terminal preparing his data files for the coming night's cheap batch processing. It is so easy for him after some months training to have become *only* a very skilled MOSS driver, of high value to his employer in terms of drawing output but not maturing as an all-round civil or even highway engineer, nor getting adequate professional job satisfaction. The proper balance between adequate training and MOSS design work must be reached and maintained at all times – and it has to be recognized that this will most probably cost the firm real money.

Future developments

Our work so far has been produced using MOSS 3 and that edition must stay on our system to allow possible future revision of the models we have produced and have stored on magnetic tape. We have mounted MOSS 4 and look forward to using the MACRO option of that edition. Contouring and perspective options are facilities that we particularly look forward to having, as large-scale site redevelopment and regrading will figure largely, we think, in possible future work abroad. Similarly, the modelling of various services and pipe networks within total infrastructure design is experience that we must develop. And then shouldn't we all be including bridges and other structures in our total layout modelling? We now include retaining walls in our urban work but further development and refinement is needed.

Fig. 6
Example of plotted cross-section output

MOSS in consultancy: home and abroad

That was the title of this paper. MOSS, though it has its detractors and deficiencies, has allowed Arups to go ahead earning foreign currency for the country in the face of very stern competition and arduous conditions abroad, when the highway opportunities for consultants at home have been very lean indeed. For that at least we are grateful and hope that we shall have ample opportunity to further disseminate the resulting experience so that all may gain from it.

Editor's note
This article is based on a paper presented to the 2nd International MOSS Conference, Bournemouth, 22-24 October 1980.

Waterford Glass Ltd.

Douglas Baxter

The Irish practice's association with Waterford Glass Ltd. began in 1970 when we were asked to look at a problem concerning the stability of oil tanks at the Kilbarry factory.

Soon after this we were engaged as consulting engineers for three major projects; the Stage 4 extension and office block at Kilbarry, and the first phase of Dungarvan Crystal, to be built on a new site south of Dungarvan, a coastal town in County Waterford some 30 miles from Waterford City.

The design for these projects began in early 1970 and the contracts were let in the autumn of the same year.

Stage 4 of the Kilbarry Factory was a repeat, with modifications, of the factory begun in Kilbarry in 1966. The tremendous demand for traditional hand-cut lead crystal had brought Waterford Glass Ltd. to the fore in industrial expansion in Ireland.

The extension consisted of a furnace house and service area for the third production line (K3) and a new production line including furnace house, service area, blank store, cutting shops and backing area for K4, a total area of 7,400 m^2.

Extension of the site westwards to give space at the same level for the new production line required a deep excavation and, with a basement area under much of the furnace house floor, there were many artesian springs which caused dewatering problems.

To protect the brick linings to furnace ducts' a sump 3m deep below basement level, equipped with electric pumps actuated by electrode switches, was necessary. As the bottom level of the sump was some 15m below original ground level, the pumps had to work continuously during long periods of wet weather.

The new factory development at Dungarvan began on a green field site and was basically similar to the Stage 4 extension.

1

Fig. 1
Waterford Glass Office Block (Photo : Harry Sowden)

Fig. 2
Showroom inside Office Block (Photo : Harry Sowden)

2

3


4


Fig. 3
Waterford Glass Lightingware Factory
(Photo: Harry Sowden)

Fig. 4
Waterford Glass Lightingware Factory
(Photo: Douglas Baxter)

Fig. 5
Surveillance monitors: Lightingware Factory
(Photo: Harry Sowden)

5


6a


6c


6b


6d


Fig. 6a-d
The glass making process
(6a Photo: Harry Sowden)
(6b to 6d Photos: Terry Murphy)

Poor subsoil conditions with lenses of sand occurring within the glacial tilts led to groundwater problems, particularly in the sump construction where dewatering equipment had to be installed to draw down the groundwater level temporarily. In addition, sheet piling had to be driven to stabilize the deep excavation.

At the same time as these works were under construction, the Waterford Glass office block was also being built. This building is situated on a site sloping towards the Cork Road at Kilbarry and is a three-storey structure over a semi-basement in which the showrooms are situated. The total floor area is 3,700m^2.

In 1974–75 a second stage of the Dungarvan Crystal factory was built, this being a repeat of the initial stage.

On all the foregoing works the architects were O'Neill Flanagan and Partners, a Waterford firm with an extensive practice in Dublin, and with whom we are currently involved on a number of interesting projects.

In September 1977 Waterford Glass expanded again within the Kilbarry site and we were asked to be project leaders on the construction of a small extension comprising a decanter shop and warehouse, totalling about 4,200 m^2. Apart from the mechanical and electrical services works, which were supervised by Waterford Glass Ltd., we were the sole consultants on this project.

In early 1978, during the final stages of this work, we were asked to investigate and report on two new sites for a further development.

Investigations proved the more favourable

Fig. 7
Interior of Lightingware Factory (Photo: Douglas Baxter)

site to be on the Cork Road owned by the Irish Development Association as part of their western extension. Accordingly a 9 ha site was purchased and the first phase of the development planned with Ove Arup & Partners leading the design team.
This factory is slightly different in structural form and usage from the previous factories. While portal frames were again used for the furnace house, the height to eaves level was reduced and the pitch of the roof dropped, giving economy in materials and a reduced volume to make temperature control less expensive. In the lamp shop and blank store areas, twin skin insulated profiled steel cladding was used to improve the 'U' value and this cladding was used also for wall cladding above door opening level, (2.1 m). *Forticrete* masonry blockwork was used and the building detailed to suit modular blockwork.

Summary of Waterford Glass projects

Date	Project	Area (m^2)	Main contractor
1970-72	Kilbarry factory Stage 4 Extension	7,400	John Jones Ltd. Dublin
1970-72	Dungarvan Crystal Phase 1	6,100	P. J. Hegarty & Son Ltd. Cork
1970-72	Kilbarry Office Block	3,700	John Sisk & Son Ltd. Cork
1974-75	Dungarvan Crystal Phase 2	6,100	Sitecast Ltd. Midleton, Co. Cork
1977-78	Kilbarry factory Stage 5	4,200	Sitecast Ltd. Midleton, Co. Cork
1978-80	Butlerstown Lightingware factory, Waterford Phase 1	7,900	John Sisk & Son Ltd., Cork

The first of the two furnace houses was commissioned at the end of March 1980 and production is concentrated mostly on cut glass lightingware bases and globes, a new product for the group.

So almost 200 years after glass blowing was originally commenced in Waterford by the Penrose Brothers in 1782, a thriving lead crystal industry is the city's main employer of about 3,000 persons, occupying some 37,000 m^2 of factory and office space, making Waterford Glass Ltd., the world's largest producer of high quality, hand-cut, lead crystal.

Credits
Client:
Waterford Glass Ltd.
Consulting architects:
O'Neill, Flanagan & Partners
Mechanical, electrical consultants:
J. V. Tierney and Co. Ltd.
Quantity surveyor:
Austin Reddy & Co. Ltd.

RIBA Gold Medal 1981

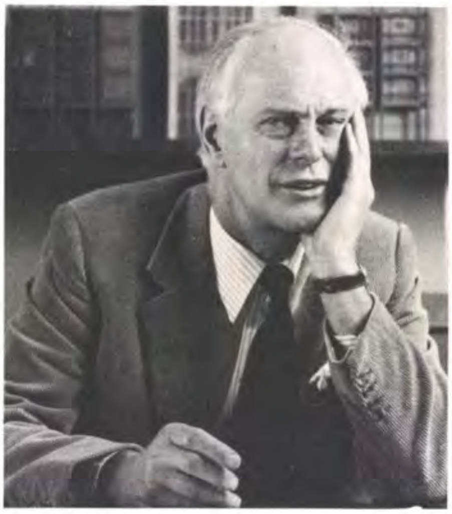
Philip Dowson, Partner of Arup Associates, has been awarded this year's Royal Gold Medal for Architecture. This is the second time that the RIBA Gold Medal has been given to a member of the Arup organization (the previous recipient was Ove Arup himself, in 1966).

The Medal was instituted in 1884 by Queen Victoria and is conferred annually by the Sovereign on 'some distinguished architect or group of architects, for work of high merit, or on some distinguished person or persons whose work has promoted either directly or indirectly the advancement of architecture'.

The RIBA's citation states: 'Sir Philip Dowson's outstanding contribution to architecture has rested on his reassertion of the intellectual basis of the subject and a deep concern for the needs of those who use his buildings.

He has set new standards in industrial architecture with the IBM offices at Havant and has done the same for office development with the Central Electricity Generating Board Regional Headquarters at Bristol and the Lloyds Administrative Headquarters at Chatham.'

A formal presentation will take place at the RIBA on 16 June 1981.



Sir Philip Dowson
(Photo: John Donat)

1 IBM, Havant
(Photo: Colin Westwood)

2 CEGB West Region HQ, Bristol
(Photo: Crispin Boyle Photography)

3 Lloyds, Chatham
(Photo: Henk Snoek)

4 Leckhampton House,
Corpus Christi College, Cambridge
(Photo: Colin Westwood)

5 Truman Ltd., Office Block, London
(Photo: John Donat)

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