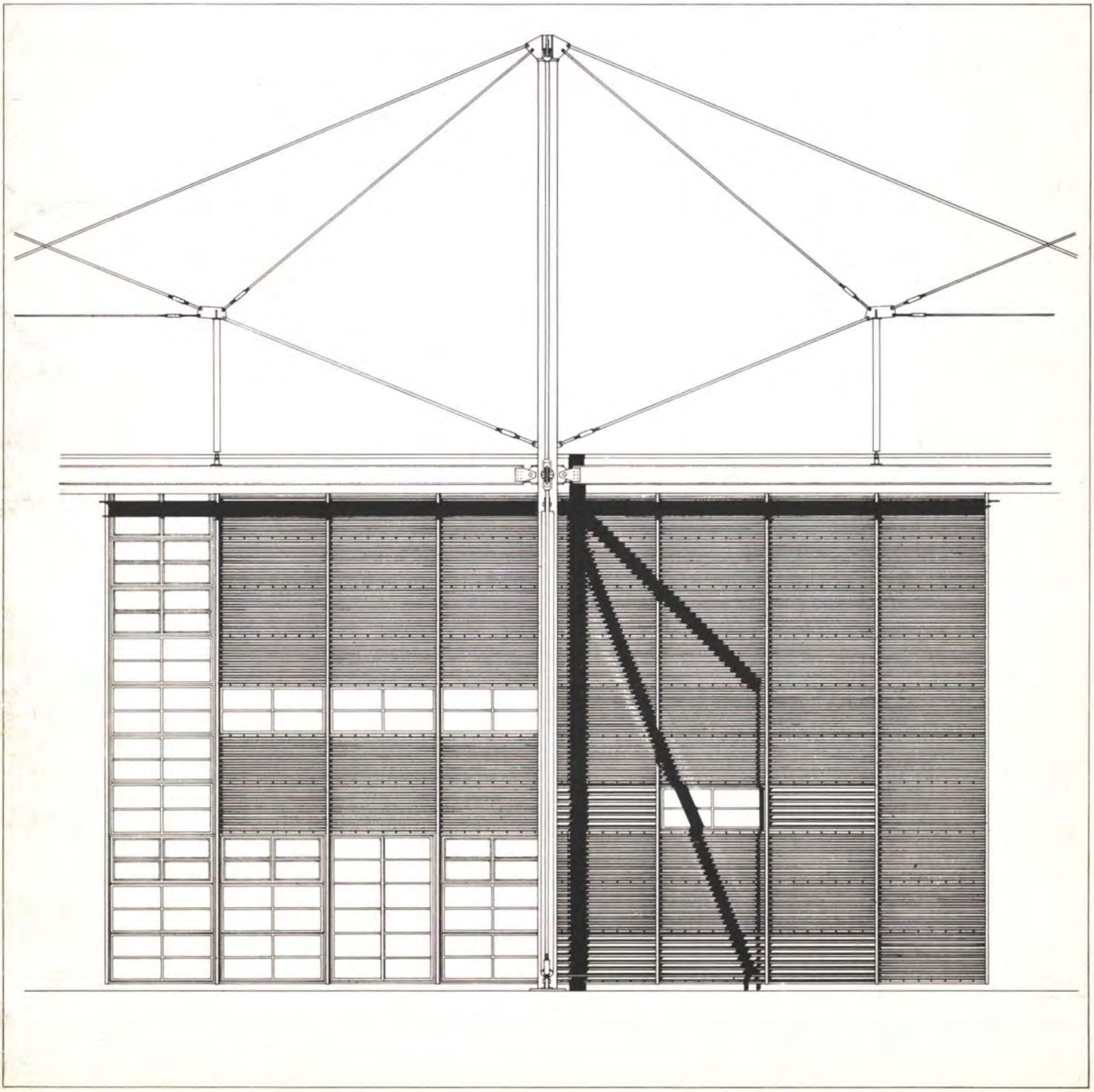
THE ARUP JOURNAL

Brian Foster
I/AH

SEPTEMBER 1981



THE ARUP JOURNAL

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Contents

Front and back cover: Elevations of Fleetguard, Quimper (reproduced by courtesy of the architects)

Discourse at the Royal Gold Medal Presentation

Philip Dowson

Mr. President, thank you for conferring on me this evening the great honour of the Queen's Gold Medal.

Thank you too, Philip*, for your very generous introduction and for the kindness of both you and Sherban Cantacuzino in supporting me this evening. The last time I stood on this rostrum was in 1966 when we had both taken part in the series 'An architect's approach to architecture'. It was in the same year that Ove Arup received his Gold Medal. So this evening for me is also something of an anniversary. To speak on this occasion and do justice to the great honour bestowed is difficult, and in this I shall need your forbearance. But the Gold Medal, however, does give me the opportunity of being able first to express in public, my personal feelings of deep gratitude to all my partners and colleagues. It has been my uncommon good fortune to work, in the words of this Institute's Journal, with such 'splendid captains'. Standing here this evening they stand with me. To have been able to share with them, our joint work together, carries for me personally its own very special reward.

There can be several views on the way our practice started – but on one there is no doubt. The formation of Arup Associates as a parallel partnership to Ove Arup and Partners in 1963 was a courageous venture particularly on the part of Ove himself, for the decision was taken in the face of very understandable anxieties, on the part of some of his oldest friends and colleagues. You will understand my feelings, therefore, in being able this evening to repay him, in a sense, with the same coin.

I joined Ove Arup and Partners in 1953 and the architectural practice was really born out of wedlock in 1958 when I was commissioned to do some work by Somerville College. This required a reassessment of what we should do in the future, either separately or together.

By then a close working relationship had developed between Ronald Hobbs, Derek Sugden and myself. Together we had designed some industrial buildings and become close colleagues, which we have remained ever since. In the event, the infant was formally christened Arup Associates in 1963. In 1970 Peter Foggo became the second architectural partner, and together and sharing the same aims, we have slowly evolved and developed our present practice and design methods, which now combine seven disciplines, with partners in five of them.

I have spent my working life closely associated with different professions, and with ideas that try to reconcile in practice some of the many conflicting interests. But I don't want to pursue that subject this evening. Collaboration has become a jaded topic, self-evident and charged with truism as it is, and on which too much has probably already been written. In any case, it was covered splendidly by Ove Arup in his own Gold Medal address when he spoke at length and with eloquence on this whole subject, which he has spent his life practising. Suffice it to say that, given the attitudes at the time I left the Architectural Association it seemed quite natural to join a consulting engineering practice which was so closely associated with architecture.

In the immediate post-War era there was in the AA, what I can only describe as an atmosphere of heady ferment. We all felt ourselves the inheritors of the pioneers and visionaries of the Modern Movement, and with a new world to reconstruct. The three years I spent there were intoxicating, very special, and formative for me. It was at the AA that I first met and got to know Ronald Jenkins, who was a remarkable man – and to whom I am much indebted. Subsequently Ove offered me a job for six months – a six months that has now stretched to almost 30 years. In joining them directly from the AA I moved into a firm whose roots, through Ove himself, went straight back to the '20s and to the Modern Movement, and it was perhaps rather to the work of the '20s that I naturally turned.

When I search my memory, I think that the first time I probably became aware of the new architecture was as a 15 year old schoolboy in the late '30s. The clarity of those haunting white images against pine trees; a kind of immaculate conception – white for virtue, evergreen for fidelity – may have awakened something. The images still haunt. However, they never quite seemed to me to belong to the real world. They have remained an idealized view, hovering somewhere between aspirations and dreams.

My father was an engineer, and taught me to use tools when I was still a child so I grew up making things. To take an inanimate material and change it under your hands into something usable, which you can feel a part of, is an intensely exciting experience, which

*Sir Philip Powell

made me aware that the 'thinking hand' as well as the discerning eye is an integral part of any apprenticeship that seeks excellence – the Head, the Heart and the Hand. I knew whatever I did in the future I should always want to make things.

When I went back to Cambridge after the War, I changed from the engineering course on which I had already embarked and turned to architecture, and perhaps ever since I have been trying to ride two horses at once.

In the William Morris and Baker controversy over the Forth Bridge – 'There would never be' declared Morris 'an architecture of iron – the supreme specimen of all ugliness, the Forth Bridge', and Baker's reply, concerning harmony, 'You will search in vain for a moulded capping or cornice throughout the whole work – the leading lines of the structure convey an idea of strength and stability and this in such a structure seems to be at once the truest and highest art' – in this controversy is expressed an inherent difficulty between art and science, by two great men. In the underlying argument my heart leads me to Morris and my head to Baker.

Fortunately, we mostly live with a happy misconception of what others might think of us, and when I read my citation, I was a little troubled. 'An intellectual basis'? – Yes. But architecture has also always been for me a very sensual extension to our lives – sensual in the fullest meaning of the word. About buildings, I have always felt promiscuous. 'My favourite colour is many colours', as Gropius said as a child. For fine architecture, regardless of time or style, has its own song to sing, and the older I get the closer I feel in fellowship, *particularly* to those nameless artists and craftsmen who are our ancient predecessors, and a sense of wonder at the way with which they strove to communicate *all* to which they aspired, *all* that was in them to give in imagination, to permanent concepts in an impermanent world. In our own period of rapid change it is difficult to think in terms of extended time. Yet about a work of architecture there is a timeless quality that endures. 'Every art', said Geoffrey Scott, 'Every art that finds a penetrating pathway to the mind and whose foundations are profoundly set, must needs have a precedent and parallel, ancestors and heirs.'

During the last 30 years we have moved from that period of post-War optimism and confidence to one of questioning and confusion, with the architectural compass slowly rotating in its binnacle.

Speculations

This evening, before showing a few slides, I wanted to dwell for a moment or two, on some thoughts and conjectures and speculate a little. And this is where I start to get into some difficulty. My trouble is that when I write down something of this nature and look at it, it never seems quite true without endless qualification, and that then renders it more or less meaningless.

So these personal thoughts and particular speculations, I am aware, are full of loose ends, but for better or worse they are ones that have engaged us closely in recent years. During the last decade we have been asked to design several large office buildings with working communities of over 1,000 people. As one would imagine, these have complicated briefs and raise deep and troubling questions of scale and context, site and so on, and above all, of unity and coherence. Stated simply, I suppose the question is 'How to get to grips with the scale of large organizations and to clothe them in civilized surroundings'. These have also emphasized the importance of the notion of limits as an 'idea', and which we are trying to understand better – energy is a simple example. 'The self-embracing systems of nature which never fail to recognise measure and limitation', in Schumacher's words.

Architecture is unique in that it is an art that we inhabit. The roof over our heads is the first security. To experience and explore, and inhabit this space in one's mind's eye, is really to conceive of light as a material that can give it definition and that can enrich it. But what is *inexplicable*, is the power that it has to move us, and to create a mood consonant with its purpose.

Human scale

In these large buildings to which I have referred we wanted the inhabitants to possess them, and be able to use them in the spirit in which they were designed so they can make them their own. This requires, amongst the many other things, a scale with human references to which they can respond, and in this respect, I have always felt keenly the need of reassurance within buildings – and there are many aspects to it. But, at the simplest level for example, the hand is an integral part of our intuitive sense, and indeed I believe, a medium for some of our deepest feelings. It is no surprise that one of the first instinctive gestures of reassurance is to touch and feel. The first mouldings, worn smooth, within the west door of any great pilgrim church bear witness to this. So for me, whatever other qualities a building aims to possess and communicate, and at whatever level – *let* it welcome and reassure, if it is not to alienate people and become unloved.

In thinking about this problem, I have always been fascinated by large, mediaeval institutional buildings which, in spite of their size and many building types, were able in so many ways to maintain a very human scale, with marvellously diverse and structured spaces. They seemed so eloquently to be able to express their purpose, intensity of use, and appropriate mood.

One of the secrets perhaps is that within them there is what I have sometimes referred to as a kind of invisible armature' with a shape of its own – a matrix that includes circulation – and which links all the parts and spaces together in a coherent way. Here *memory* is particularly important. We all experience buildings in memory, and in this way we are helped to understand them and locate ourselves within them. One can only *wonder* at the achievement of the monastic tradition in this respect (quite apart *from all the many others*), which allowed so happily for movement, congregation, reflection and withdrawal. What I have referred to as the 'invisible armature' I have always seen as the element which can prevent the 'part' becoming severed from the 'whole', and so the individual from a sense of belonging. These extraordinary buildings recognized and reflected, of course, a very great deal more as well – indeed, at times the very *soul* of their society – and their magic continues to seed the imagination of successive generations. In the monastery at La Tourette, which is for me Le Corbusier's masterpiece, there is a side chapel with a path that rises between altar tables finally up to a cross – a visual metaphor perhaps for the road to Calvary – but unforgettable – where, in the hands of a great architect, visible shape is given to spiritual aspirations.

In thinking and speculating a little about all this and in particular about scale and reassurance, I have taken these buildings as an example simply to illustrate a number of points that for me are important. We have tried to learn from some of these examples and approach our own large schemes with these lessons in mind. We have also tried to wrest from their complicated requirements, appropriate systems that have their own inner logic, and that can order a wide variety of activities and spaces, and can apply them at a human scale. We have sought systems which have an embracing geometry that can be seen and understood as a whole, a structure that is inborn, as it were, authentic, and indivisible within the total concept, which contains the physical requirements, the services and so on, but which also helps the formal and informal relationships that should naturally flow from the human needs of the building.

Looking at it another way, I would like ideally to feel that when the work is complete, it can be cut in half and have its whole anatomy laid open to reveal a consistency between a clear physical organization of its parts and of the smallest detail; as also between the architectural ideas and their execution.

These are pious hopes, I know. Hope though lives eternal.

But there is no good in over-simplifying to make matters manageable – Procrustes' Bed leaves a mutilated body. So too the destructive and artificial divisions between associated specialists who, when chopping problems into pieces invariably create an entirely new set of ambiguities – which, in my experience, at best leads to the construction of a mere analysis, rather than a synthesis – a comprehensive design – an embracing architecture with an authority that is derived from all the sources that can nourish it, where there is a reconciliation – an architecture at peace with itself – which is calm in expression, when rich in ideas.

Having said I wouldn't, I now can't avoid touching on the subject of integrated working – but I'll only touch on it.

Integration

The many disciplines involved in the search for a comprehensive design lead also, I believe, to the simultaneous pursuit of individual freedom within collective action if talent is to flourish. I realise this might appear quite incompatible, and I grant you it is most difficult, and should scotch any notion that integrated practice between imaginative and strong personalities is easy – I can assure you it is not – and at times I might be forgiven for feeling that the ship has rather too much sail set. But for me, I know there is a need for many minds to conflict especially during the early stages of a design; for disciplines to act on one another to release ideas, and for there to be engagement, particularly at the boundaries of adjacent disciplines, where these overlap. It is so often from within these overlapping areas that something worthwhile will develop – what I once lightly referred to as 'perimeters of abrasion'.

The quest for meaning, coherence, and humanity in a design, for the recognition of forms, that in *some strange way* seem to meet *deep-seated* needs within us, leads unerringly to that private 'blank sheet' of paper. To face that 'white sheet' of paper, is to inhabit a kind of limbo, and I think of Paul Klee writing of a reverse pilgrimage in *search* almost of a lost innocence, for the sight of that inner eye – the eye of the artist. It is rather a frightening limbo where anything is possible, free from all associational pressures, and from which one might never escape. Gradually, dredging from one's sub-conscious, ideas and patterns may begin to emerge and take shape and become recognizable; drawing from the abstract, *first a 'conceptual reality'* and then *slowly a physical one*, through the process of search and discovery.

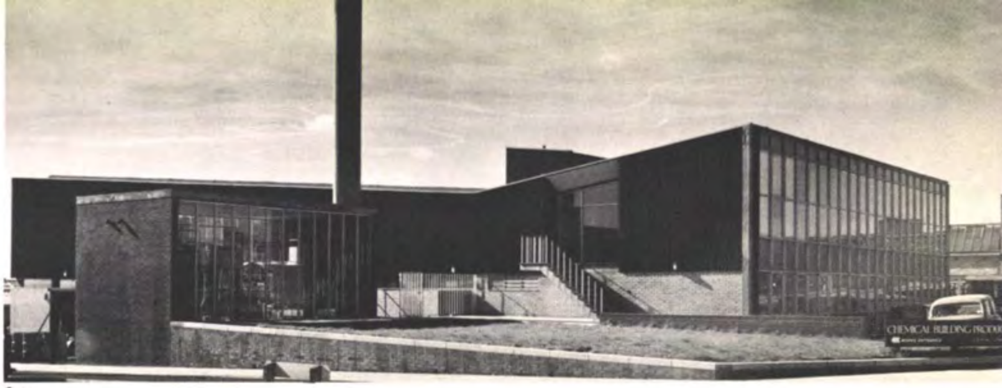
Cold rationalism has no place for me. It is the intuitive response to subjective human needs, beyond reason, that I believe must help find a place for 'value in a world of fact'. But I see design as always having an intellectual spine, if it is to be architecture, from which to draw that internal order, at once unique and personal to itself – where the *feeling* of a whole work can be fully *sensed*, whilst the *thinking* can be both seen and understood.

SOME OF ARUP ASSOCIATES COMPLETED WORK

Fig. 1
Chemical Building Products Ltd. (1955) *

Fig. 2
CIBA Duxford, Araldite Plant. (1958)

*Date of completion follows job title



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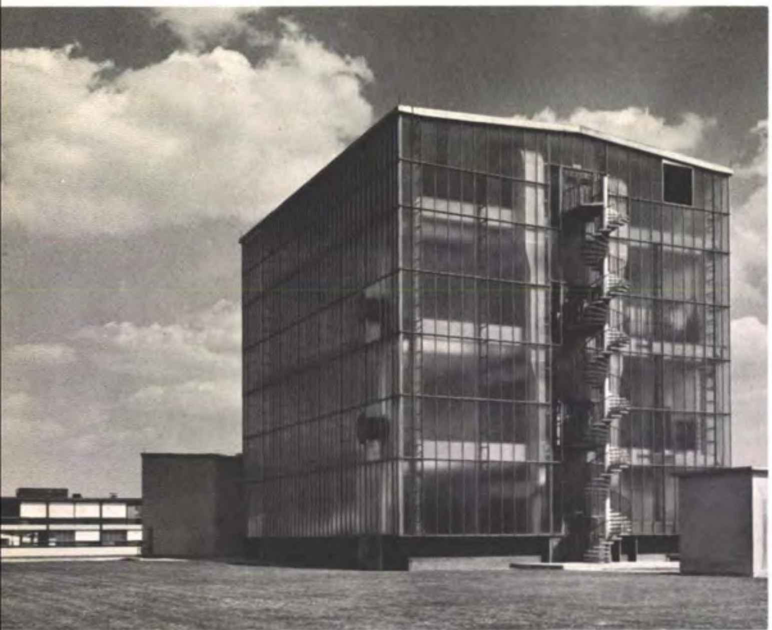

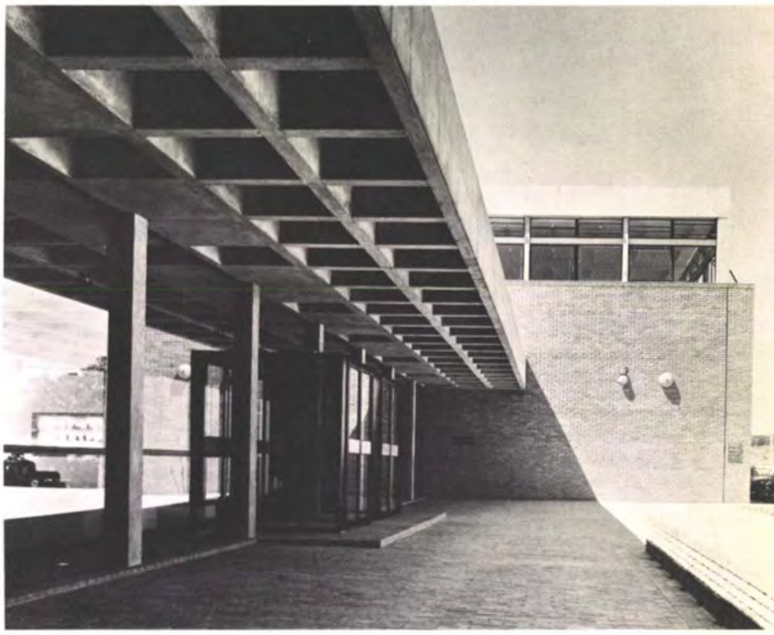

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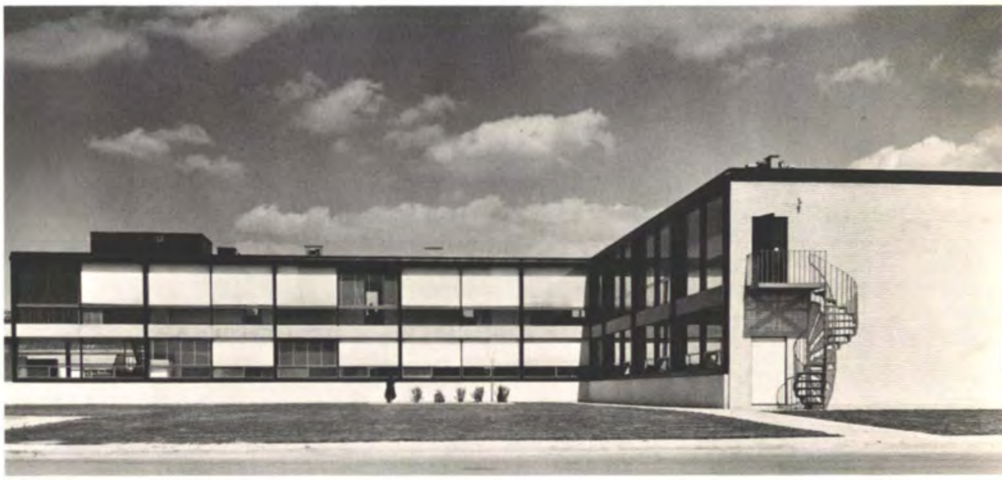
Fig. 3
CIBA Duxford
Research Laboratories. (1959)

Fig. 4
SKF Laboratories Ltd. (1961)

Fig. 5
Evode Ltd., Varnish kitchen. (1963)



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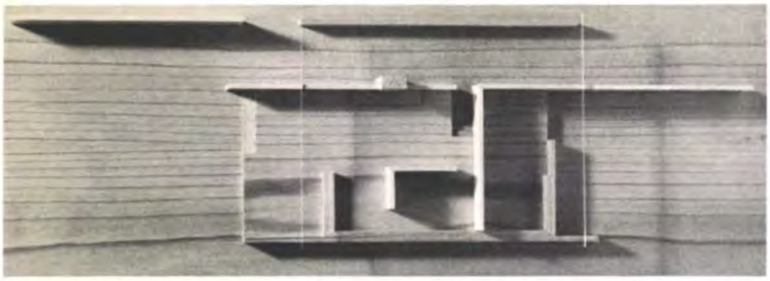

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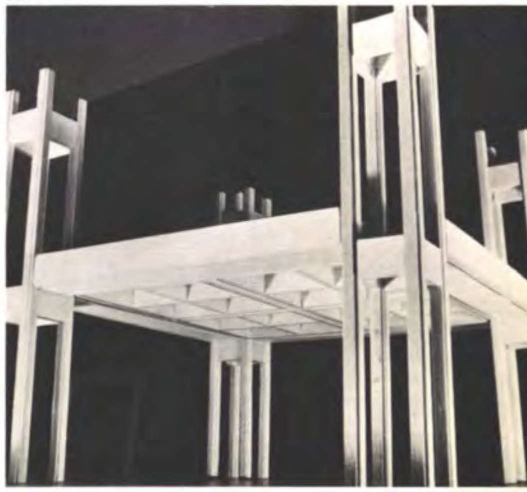

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Figs. 6-7
Williams House, Long Wall
and model (1964)

Fig. 8
Corpus Christi,
Leckhampton House (1964)

Fig. 9
Point Royal Flats, Bracknell (1964)

Figs. 10-11
Birmingham University
Mining and Metallurgy
building and model (1966)

Fig. 12
Snape, The Maltings concert hall (1967)

Fig. 13
House for Jack Zunz (1969)

Fig. 14
IBM Havant,
Systems Assembly Building (1970)

Fig. 15
Oxford Mail & Times (1971)

Fig. 16
Players Factory (1971)

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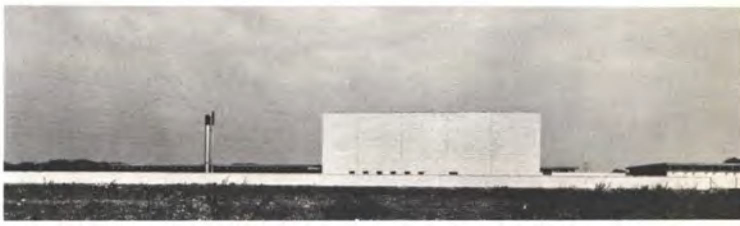

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Figs. 17-19
St. Johns College, Oxford (1976)

Fig. 20
Truman's offices, Brick Lane (1976)

Figs. 21-22
Gateway House
Wiggins Teape Headquarters (1976)

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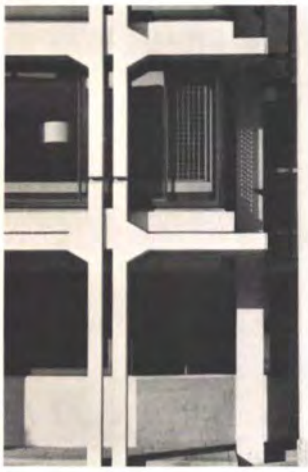

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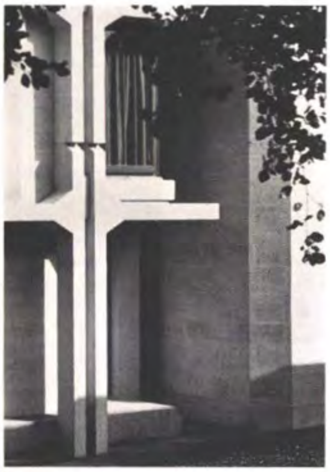

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23△ 24

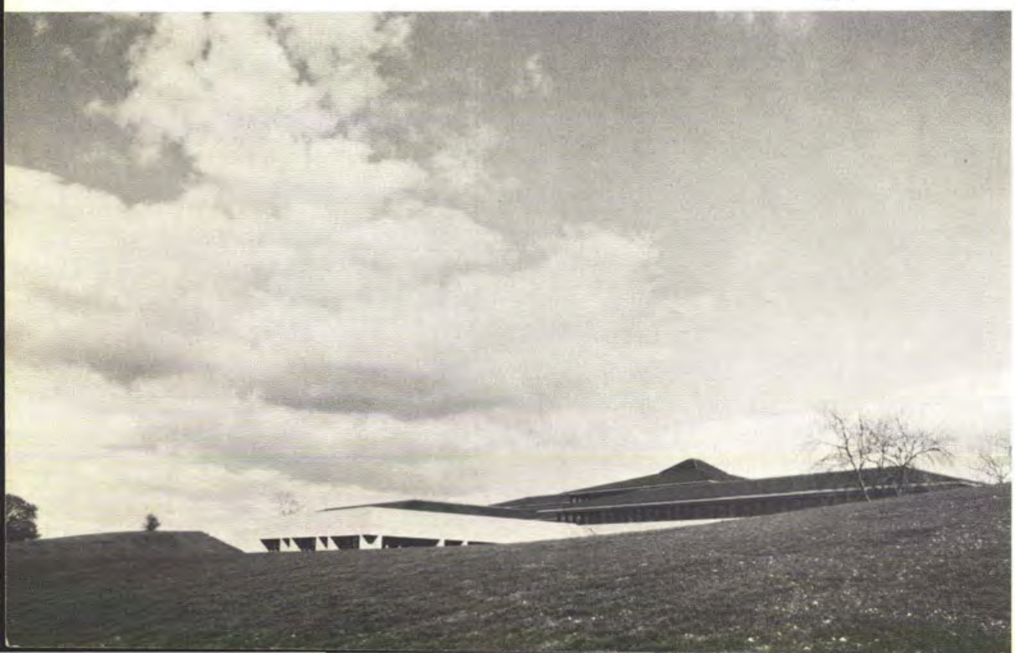
25△ 26▽

Fig. 23
Dock Support Buildings, Portsmouth Dockyard (1977)

Figs. 24-26
Lloyd's Headquarters, Chatham

27▽

Figs. 27-28
CEGB offices – and task light on one of the desks (1978)



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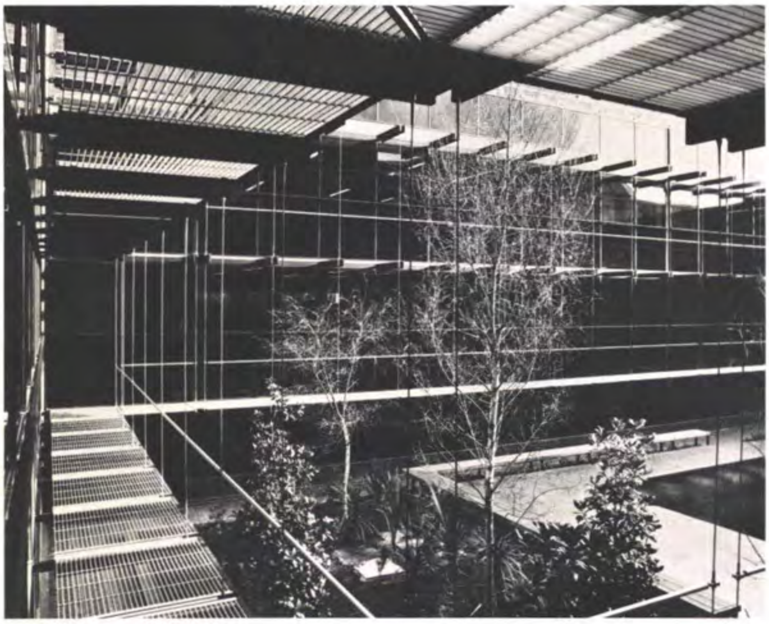
Figs. 29-30
CEGB offices : a corner of the building – and detail of handrail (1978)



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Figs. 31-33
IBM Havant, Phase 6 (1979)

Fig. 34
Trebor factory (1980)

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15: Brecht-Einzig Ltd.
16: Honeyman
20: Trevor Walker
1-6, 8-10, 13, 14: Colin Westwood

(During the discourse some slides were shown):

Long Wall (Figs. 6-7)
This is a little house which was designed in 1964. A small house is always a fascinating subject and seems to combine all the problems in microcosm. In this case I show them to illustrate a particular point. The heavy brick base, with radiating walls, locates the building on the site and in the landscape, and has a light enclosing structure in timber over only part of it. The two construction processes – heavy base and light umbrella – emphasize an architectural idea. The first establishes a secure base for a visual step-ladder to the horizon – foreground, middle distance and far distance. The second encloses the immediate space with the hearth built at the psychological centre of gravity.

Mining and Metallurgy (Figs. 10-11)
The Mining and Metallurgy building marked a watershed in our practice. It was the first really large laboratory building we designed. At the time it was also a fairly radical solution for a building full of services – however, it taught us a great deal and has had a considerable influence on the later work of our office.

Wiggins Teape (Figs. 20-21)
The design of the offices for Wiggins Teape, developed by Peter Foggo, with its stepped and planted terraces and molecular organization, drew from the experience that we had had in the integration of the structure with the services in laboratory and industrial buildings.

Lloyd's and CEGB (Figs. 24-26, 27-30)
The administrative headquarters for Lloyd's, Chatham and the South West Regional Headquarters for CEGB, Bristol belong, in a sense, to the same family. Both are large with working communities of over a thousand people. Each seeks to establish a relationship with the landscape which becomes a direct extension of the buildings themselves. Stepped roofs and silhouettes are designed to conform with their contours and in the case of Lloyd's, also form a terminal building to the quarter-mile long 18th-century dockyard roperies on the edge of the Medway.

As a whole they aim to have an inner and coordinating system of the kind that I have been discussing. As with the Mining and Metallurgy building, it is built up of a series of carefully scaled structured spaces.

The sense of definition that each of these gives can also suggest and encourage groupings of people and we intend them to do so.

CEGB
The Tavistock Institute helped CEGB initially in analyzing their organization so that their new building would do its best to reflect its inherent social structure. Approximately one third is offices, one third laboratories and one third is industry. A street runs through the building which includes activities that are shared in common.

And in thinking of limiting notions, and particularly energy, we tried to design the building so that as far as possible, it would temper its own environment.

Snape (Fig. 12)
I can't mention Snape without the name of Derek Sugden who gave his heart to it. But at Snape, with its glorious marshland setting and splendid range of existing malt houses, we determined together to leave the site, if not actually unseen, then at least leaving only the gentlest of traces. Internally, of course it is a different matter. The marsh and the experience of walking in from that wide landscape of reeds and water, required an interior that would recognize this particular quality, with a sympathetic robustness and simplicity that you might expect to find in such surroundings.

St. Johns (Figs. 17-19)
St. Johns and Corpus, Leckhampton are two members of the same family with 10 years between them, both are college buildings for undergraduates and graduates, and include one or two flats. I remember Henry Moore standing where his splendid sculpture was to be placed, and musing that he could never be an architect, adding 'How can you bear to let anyone make that for you', underlining the difficulty in having to work with and through so many people. But therein also lies stimulus and opportunity.

We wanted the rooms, which for a student are his home, to become in the President's words, 'A world within a world', for these rooms to have a sense of generosity as well as an implied enclosure; to be able to enlarge the sensual horizon, within the very limited spaces of the rooms themselves, and to make them feel an established part of the whole college. There are sliding windows so that in fine weather the rooms can become a balcony but within an encompassing frame. The timber sun screens fulfil a number of functions. They provide increased privacy between adjacent rooms and double-up as room dividers between bedrooms and studies in the sets. The natural randomness of these screens is also an important element in the elevations of the new quadrangle, and together with blinds help to provide variety in use, and particularly of course at night.

Curiosity and search was part of the game, and only by moving through the building did we want it to become slowly revealed.

Leaving the slides and returning to some reflections:

Looking back at the work of our office, which spans over 25 years – and it is a humbling experience designing buildings – I am always surprised at its variety; though others often tell me that it is still recognizable. So perhaps there is a common current that does run through it, in spite of its diversity. I hope though that in the better examples there is a certain quality that draws from this country, and I like to feel that perhaps St. Johns, for instance, is an Oxford building and infused with something of the spirit of that university, and the collegiate tradition.

Whither the practice next? – I can't say – except that the enthusiasm that exists within it is infectious.

Mr. President, thank you, and through you, the Institute. This is the greatest honour that could have been paid me, coming, as it does, from my architectural colleagues, and if I might be allowed to quote Luke – and here's the rub: 'For unto whomsoever much is given, of him shall be much required:' – but it gets worse – 'and to whom men have committed much, of him they shall ask the more'.

For any recipient of this Gold Medal, therein lies a problem. Frank Lloyd Wright remarked once that architecture was for grey-heads – I hope that is true. For her Muse remains as absorbing, tantalizing, frustrating, demanding, but as seductive and elusive as ever – and certainly, whilst the architectural libido still runs, she offers no release.

Fleetguard, Quimper

John Thornton

Architects:
Richard Rogers & Partners

Introduction

Fleetguard, a wholly owned subsidiary of Cummins Engine Company, is the largest manufacturer of heavy duty engine filters in the United States. In 1978 Ove Arup & Partners were appointed with Richard Rogers and Northcroft Neighbour and Nicholson to design a factory which would also act as the headquarters of Fleetguard, Europe.

Fig. 1
Map of France

The factory is on a sloping site in a rural area of rolling hills and small woods a few kilometres from Quimper which is in the south west of Brittany, France. The project is funded by the City of Quimper with Fleetguard having the option to purchase the building after five years.

Overall concept

Experience has shown Fleetguard that flexibility of future extension is essential and this has been one of the major concerns in the design. The building has to be capable of extension, both architecturally and structurally, in small units on all four sides. Richard Rogers felt that a symmetrical external structure based on a square bay gave a basis on which expansion could take place while retaining a logic to the external appearance. It gave scale and grain and minimized the clad volume which reduced the visual impact on the rural site. He also wanted the structure to be as visually light as possible and this suggested a tensile structure.

In order to justify the increased complexity of such a structure, compared with a 'conventional structure', we decided that the quantity of steel used should be less. This self-imposed criterion led, on a number of occasions, to the rejection of a technically possible solution and forced us to look for greater efficiency.

Roof structure

The building consists of an assembly of 18m square bays. Initially there were to have been 28 bays arranged 7 x 4, but cost cutting reduced this to 25 which was an early justification of the design (Fig. 2).

The roof, which is a composite panel system on steel beams, is suspended on a 6m grid by tubular steel hangers from an arrangement of rods. The rods are attached to the tops of tubular steel columns which are arranged on the 18m grid. The columns are 17.25m tall and at the 9m level, where they pass through the roof, they are connected to it (Figs. 3 & 4).

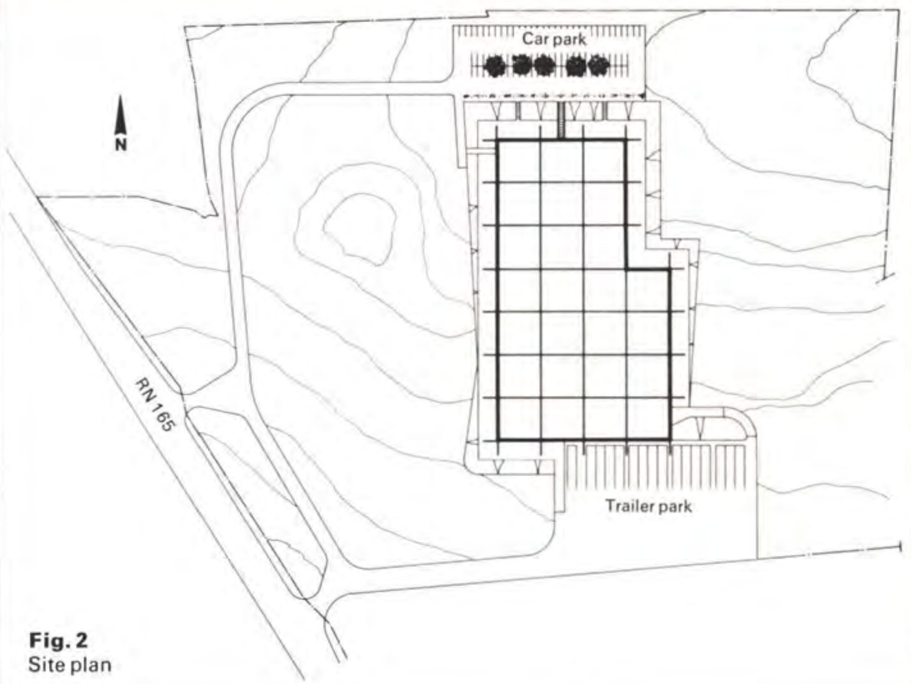

Fig. 2
Site plan

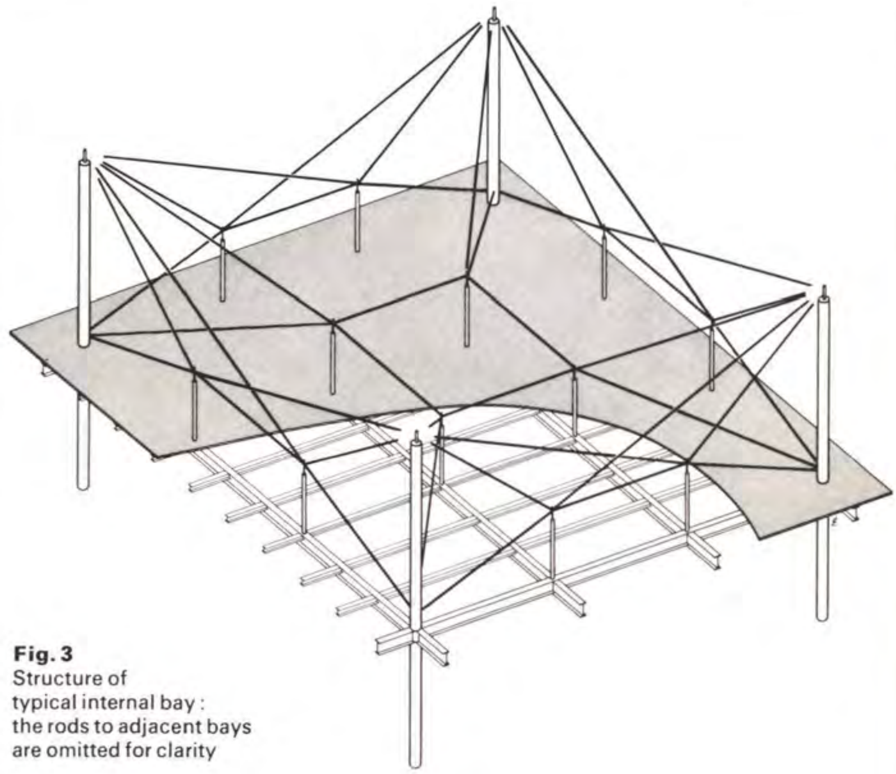

Fig. 3
Structure of typical internal bay: the rods to adjacent bays are omitted for clarity

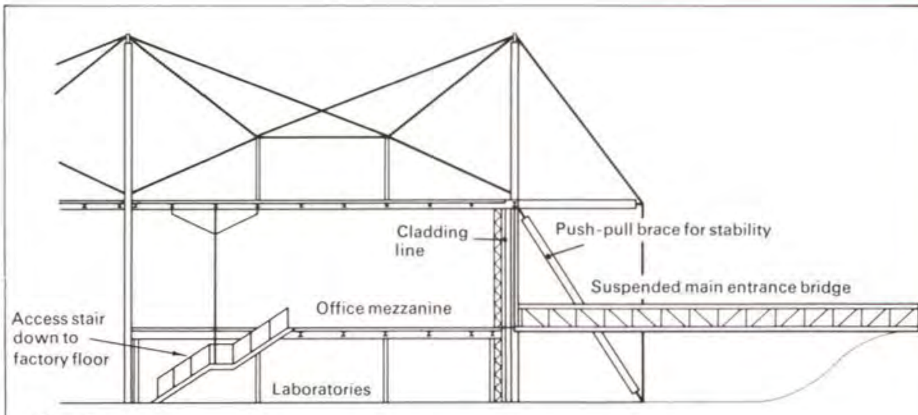

Fig. 4
Section through the central bay of north elevation showing the main structural features

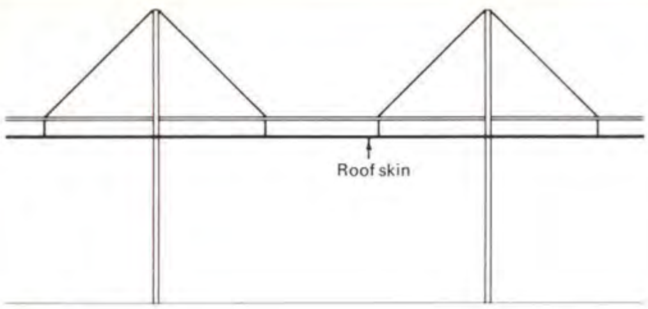

Fig. 5
The first
structural scheme

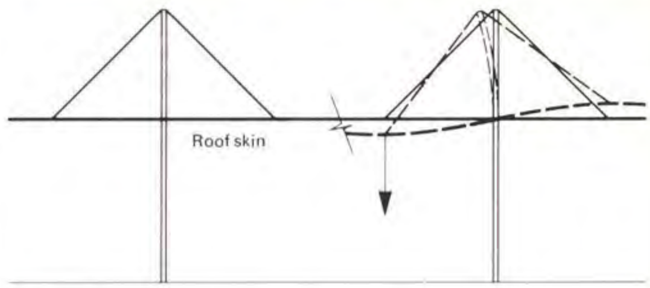

Fig. 6
The second structural scheme
showing the effect of unbalanced loading

Air handling units and a cooling tower are suspended from the tops of the hangers and the roof must be capable of supporting 8 tonne ovens hung underneath.

The roof structure is the most important feature of the building design and it can best be described by explaining its development.

Initially the roof was to be suspended from a horizontal array of tubes 1m above, and this array, in turn, suspended by cables from the column heads (Fig. 5). This emphasized the separation of the building enclosure from the tension/compression elements and ensured that the hangers always penetrated the roof skin at right angles, which made waterproofing easy. There was duplication of structure in this scheme which was uneconomic, and so we looked at suspending the roof directly and exposing only the tension elements (Fig. 6). However, both the systems described above performed badly under out-of-balance loadings between one bay and the next. The requirement to suspend ovens did not help.

The system is highly interactive and there are a number of factors involved but, to simplify, the problem is that when load is applied to the roof on one side of the column without being balanced by an equal load on the other, the forces in the rods are unequal and the column is pulled over. This has the effect of lifting one set of beams and allowing the other to sink (Fig. 6). This movement carries on until the bending forces in the beams and column are sufficient to balance the loads. The entire reason for the suspended roof is that the beams should only span 6m and carry the weight of the roof alone. To make these beams then have to carry larger loads over effectively larger spans is incorrect. Also, apart from the bending over the 6m span and some unavoidable secondary bending, the intention of the structure is that forces should be carried in tension or compression and so substantial bending is contradictory. Apart from these philosophical objections there was another, more mundane.

Because the beam forces are largely controlled by deflections of the columns and cables, the more the sections are increased to carry the forces, the more forces they attract. Eventually the system can be made to work but it is uneconomic and the sections look too bulky.

The solution to this problem lay in developing a system whereby the deflections of the structure in one bay were not transmitted into the adjacent bays. This was done by tying each column head back to the adjacent column at roof level. The force-inducing deflections were then almost entirely controlled by the axial stiffness of the cable system. As part of this arrangement it was also possible to arrange for wind uplift forces to be taken by the tension structure rather than by adding dead weight or increasing beam stiffness. There are thus three load-carrying systems. One system carries downward loads, the second carries upward loads and the third carries out-of-balance loads (Fig. 7). This extra complexity of structure was something we had tried to avoid because of possible complications in assembly, but we recognized that it was essential for economy and by careful planning and detailing there were no problems during construction.

One result of this system is that, because the tension elements are effectively continuous over the whole roof, it is not possible to incorporate an expansion joint. The structure has been designed to absorb the stresses due to thermal expansion of eight bays and, when the building is extended beyond this, a non-standard expansion bay will be introduced.

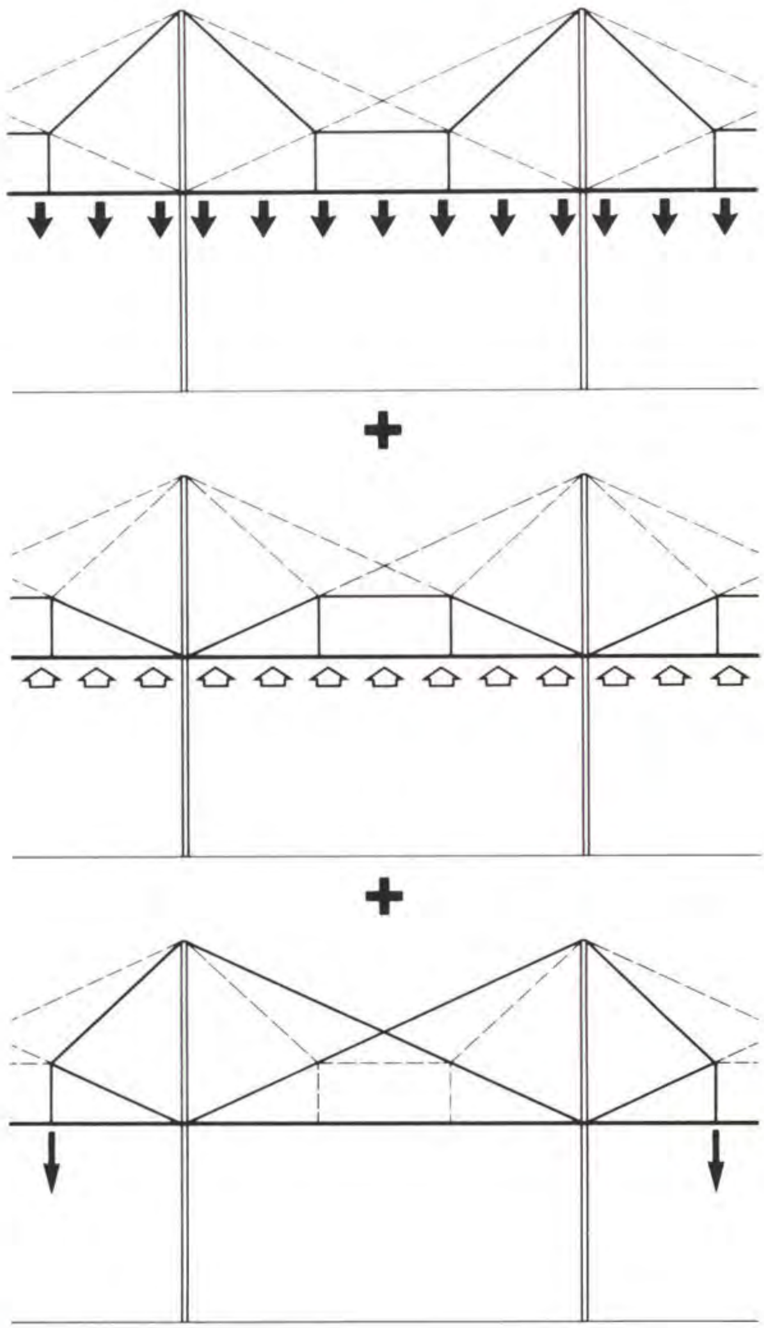

Fig. 7
The three primary load carrying systems
within the overall roof structure

8

Although the system was originally conceived as cable-supported, rods were chosen when it was found that stiffness was more important than strength. The stresses were low enough to permit the use of rods rather than cables and the reduced axial stiffness of cable was a penalty. Rods are cheaper than cables and can be painted and re-painted, whereas the economic corrosion protection of cables has yet to be solved.

When deciding how to restrain the perimeter columns we considered taking a rod directly from the column head down to the ground. However, a sloping rod causes considerable horizontal anchorage forces, and movement of the anchorages must be strictly controlled to avoid deflection of the roof. Unless the angle between the rod and the column is quite large the forces generated in the rod column and anchorage are large and also, with a small angle, small strains in the rod cause large deflections. On a sloping site the anchorages vary in distance from the column and the rod lengths vary. Finally, using a reasonable angle sterilizes a large part of the site. Faced with these disadvantages, we chose to take the rod down to the anchorage vertically by passing it over a boom and accepting the penalty of horizontal forces transmitted through the structure (Fig. 4).

The connections between the 18m grid beams, which can carry substantial axial force, and the columns, were originally to have been bolted. However, by using pinned connections we eliminated the large support moments in the beams and solved the problem of how to detail a connection which could accept either an I beam or a tubular boom.

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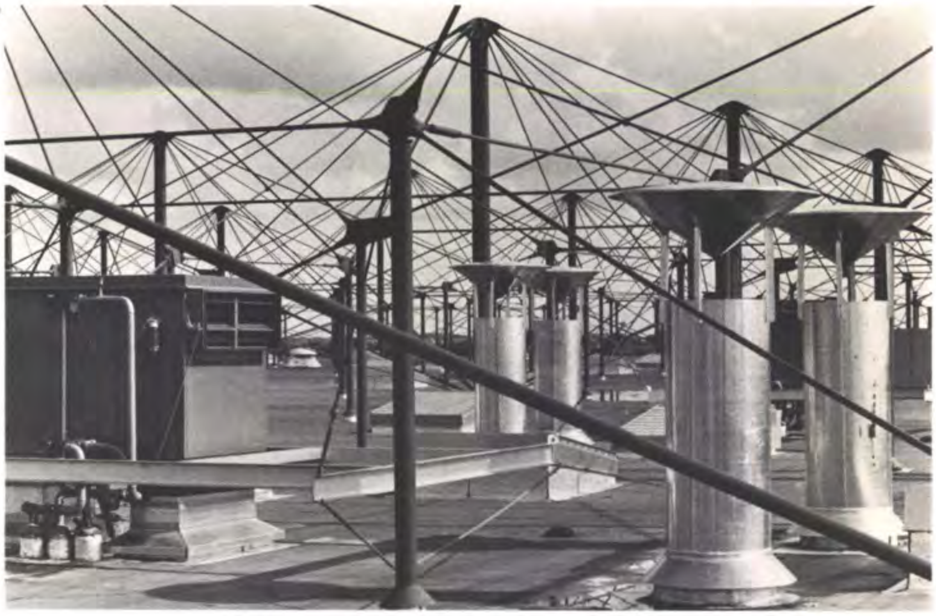

Fig. 8
View from south east

Fig. 9
Roof scape with flues and suspended air handling units

Fig. 10
Main entrance bridge

10

Making the forks

The rods were to have been connected by proprietary forks welded to the ends. However, shortly after contract signature the steelwork contractor, Chagnas, discovered that these were not so readily available as their supplier had led us to believe. Inevitably this took place at Christmas. Faced with a tight programme, Chagnas decided that if they could not buy them they would make them and proceeded to do this by flame cutting, grinding, drilling and turning. This was surprisingly quick and cheap and gave a more attractive profile than originally envisaged. The forks were welded to the rods and all the rods were load-tested. This proved a wise decision since some of the rods failed because the wrong steel had been supplied.

Originally the structure was designed so that the centre lines of all members intersected. However this meant that around each column, eight rods would penetrate the roof at an angle. By connecting the rods to the columns immediately above the roof and accepting a small amount of bending in the column, this waterproofing problem was eliminated. The structure thus penetrates the roof on 6m centres only and the penetrations consist of tubular elements. A conical shroud is welded to these and the waterproofing dressed up underneath. The number of structural penetrations is not significant compared with the number of services penetrations.

We recognized that there was a danger, with an unconventional structure, that the tenders submitted would be high and a considerable amount of thought went into the design so that the structure would be easy to fabricate and assemble. Assembly procedures were worked out and the structure carefully explained to tenderers.

The structure is designed so that the bulk of it consists of elements which require very little fabrication and are joined simply. The single complex operation is on the column at roof level. At this point four beams and eight rods are connected to the column and all three elements may carry large loads. The fabrication involves notching a 9m section of tube and inserting a spider assembly which projects through the notches to provide the connections. After this a second section of tube is welded on.

Site connections are either bolted or pinned and the major structural connections which have to be made in the air are pinned.

The structure is not pre-tensioned, only made taut. The minimum of adjustment necessary to achieve this is provided. The principle is that the position of the top of each hanger is defined by the two rods coming down to it but that this position is not important. All that is then necessary is to provide adjustment to the rods connecting the hanger tops to each other and to the columns. The level of the roof is adjusted by the connection between the hanger and the roof.

The deflection of the rods under the appropriate load was calculated and, by comparing the position of the rod to a string line, the adjustment can be controlled sufficiently accurately. The columns are erected with the rods attached.

The adjustment is provided by welding left and right hand threaded sections to the rods and connecting them with an internally threaded circular bar which is notched for a spanner at one end. The tie-downs are also adjustable.

All of the structural connections necessary for extension can be made before removal of the cladding. The same column and beam details are used throughout except for the addition of a plate for the push-pull brace and an extra plate on the top of the perimeter columns, and so the addition or substitution of elements necessary for extension is simple. Loads from the additional structure can be transferred to the existing column before removal of the tie-down, thus ensuring equilibrium.

Wall structure

The external walls are set inside the perimeter column line. The structure to the roof passes through the wall and is exposed on the perimeter. The walls are made of two skins of profiled steel sheet with insulation fixed on vertical lightweight steel trusses at 2m centres. The top of the wall is held in an inverted U detail which permits the roof to deflect vertically and allows relative horizontal thermal movement to take place.

The inverted U forms the base to a window which runs as a thin band around the perimeter at high level. As well as separating the walls from the roof visually and lighting the interior, this provides a zone for the structure to penetrate the wall in a way which makes explicit the relationship between internal and external structure. This window is particularly effective at night. Wind forces from the walls are taken by horizontal trusses around the perimeter. These trusses are bolted up under the main roof steelwork in 18m sections which may be removed for re-use when the building is extended. The trusses transfer the wind forces to the main column lines where they are taken out on external raking tubes. These push-pulls are provided on two adjacent sides only, to allow for free thermal expansion.

Mezzanine

The three bays on the north face of the building are those in which extension is least likely to take place and house the energy centre, offices and laboratories. The offices occupy two bays and are on a mezzanine floor. There is a partial mezzanine on the energy centre. The mezzanine structures are similar to the roof but are supported by steel columns on a nominal 6m grid. The mezzanines are completely independent of the main structure and are designed for easy extension (Fig. 4).

The level of the ground slab is determined by the constraints imposed by the shape and contours of the site, the access position specified by the highway authority and the truck loading requirements. The result of this is that the building is cut into the hillside on the north side and so the office mezzanine is at ground level. The excavated face is set well back from the building and the main entrance to the building, which is on the office mezzanine, is approached over a 16m tubular steel bridge suspended from the perimeter roof beam at its inboard end. Access to the factory floor from the offices is via a tubular steel staircase. To keep this as light as possible it is suspended, at half landing, by rods from the roof (Fig. 4).

Foundations

The site is underlain by granite. Luckily the earthworks involved cut rather than fill because, while the local contractors are used to excavating granite, good fill is in short supply and expensive. Because most of the foundations are on or close to the granite, the only problem is holding the building down under wind loads. In the case of the columns this is done with heavy pad foundations. For the anchorages to the perimeter column tie-downs the contractors were given a choice between mass concrete, a concrete box filled

Fig. 11
Corner structures

Fig. 12
Column head details. The rings are for use during maintenance.

Fig. 13
Boom end detail

Fig. 14
Column detail at roof level

with rock and ground anchors. They preferred to dig a big hole and fill it with concrete.

The floor slab, which is 150mm thick, has to withstand high racking loads and has been designed as a structural element. We proposed to construct our slab with reinforcement in the bottom and both sawn and free contraction joints according to the C and CA method. However, SOCOTEC, the checking bureau, while agreeing that ground slab design is a controversial subject, insisted that there should be no free joints and that the steel should be in the middle. A compromise was reached with steel in both middle and bottom.

Services

The services installation is planned for ease of extension. Space has been provided in the energy centre for an additional transformer and gas-fired boilers. From the energy centre a primary services route runs along the main aisle immediately adjacent to the office/laboratory wall. This route can be extended. Secondary routes to the factory branch off on every second column line and the adjacent bays are served by spurs from these. The routes carry electrical supplies, low pressure hot water for heater units, compressed air, gas and domestic and cooling water and are all at high level.

Services are co-ordinated on the building grid. Although various bays may have different servicing, the overall patterns and zones of each service are consistent throughout so that the alterations necessary for change in use are easy and the order of the system is maintained.

Originally the building was to have a sprinkler installation and the co-ordination was set up on this basis. When this requirement was lifted during the design stage we decided to retain the zones allocated so that sprinklers could be installed at a later date without reducing the head-room. One interesting aspect of the fire fighting installation is that some hose-reel cupboards are mounted above roof level because Fleetguard expect periodic fires in the oven extracts, caused by resin from the paper used in the filters.

For flexibility of use, heating and ventilation of each bay of the factory areas is provided on an individual basis. In the production area, air from units suspended above the roof is directed down over each of the two

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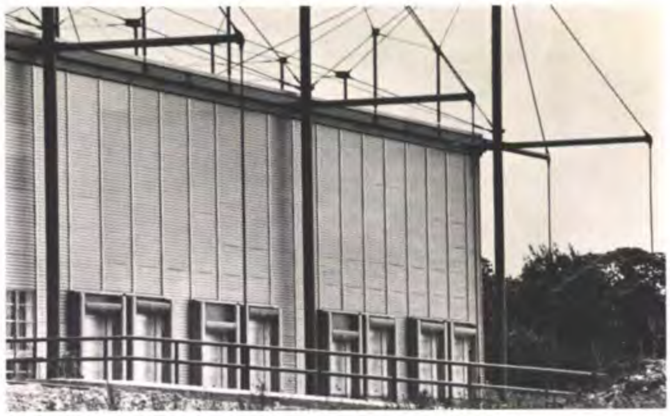

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Fig. 15
Detail of elevation showing one of the many patterns of symmetry of the rods

Fig. 16
Detail of elevation. The glazing arrangement varies in accordance with the use of different sections of the building

Fig. 17
South facade with loading bays

Fig. 18
Interior showing production line bay

(Photos : Ove Arup & Partners)

production lines from ducts running the length of the line and extracted by a single central duct. The storage areas are supplied by smaller recirculating heater/ventilator units with fresh air provision which are suspended directly under the roof.

The office and laboratory areas are heated by skirting radiators and mechanically ventilated by units suspended above the roof with a ducted distribution system serving the zones. The computer room and materials evaluation room are air-conditioned by direct expansion compressor/condenser units suspended above the roof.

The production and storage areas are lit by 'high-bay' type MBF/U luminaires and early involvement in the racking layout options made it possible to establish a lighting grid which relates to both the building and racking grids. For consistency, lighting to the offices, which have a 5.5m ceiling height, is provided by low-bay type MBF/U luminaires fitted with a diffuser. Lighting to the laboratories and canteen area is provided by fluorescent luminaires. Emergency lighting is by fluorescent lamps supplied from a central battery inverter.

Construction

Building in France has been an interesting experience (although any project which involves Americans, Frenchmen, Englishmen, an Israeli and a Scot sitting around one table is bound to be interesting). As a structural engineer a number of things were particularly different.

In France, in order to get your building insured, you need to have the design, including fabrication drawings, checked by an approved bureau. These are commercial organizations who charge a fee. Although we were working to the French steel code, which incidentally is far more theoretical than *BS449*, it seemed that SOCOTEC, who checked our calculations, were more interested in ensuring that the engineering was sound than in adopting a 'deemed-to-satisfy' approach. On a number of occasions they made a valuable contribution to design discussions.

We were very fortunate in our steelwork fabricators, a fairly small private company proud of their local reputation, who took a refreshingly positive attitude to difficulties. They were surprised by the detail given on our drawings and would normally have carried out most of the design and detailing themselves. As seems to be common in France, they had informal links with other contractors, such as cladding specialists, so that as a group they could bid for a wider variety of work.

The factory was built under a French system whereby the work is let as a number of contracts by trade, and overall site management is provided by a 'pilote'. In this case, Fleetguard provided overall project management and the pilote was an employee of the concrete works contractor.

The bulk of the project went to tender in October 1979. Work started on site in October 1979 with the earthworks contract and a letter of intent for the steelwork was issued in November 1979. Handover took place in June 1981.

Credits

Client
Fleetguard (Cummins)
Architect
Richard Rogers and Partners
Quantity Surveyor
Northcroft Neighbour & Nicholson

Agbara Estate: Introduction

Bill Haigh

Site

Agbara Estate is a private development within Ogun State situated approximately 32km west of Lagos on the Badagry Expressway (Fig. 1). The estate is on high ground above the Owo River which forms a natural barrier between it and the low lying swampy land towards Lagos. It derives its name from the small village of Agbara (Fig. 2).

Development

Most of the land in the Agbara area was owned by an important Nigerian businessman called Chief A. O. Lawson. Following the lease of a plot of his land in Agbara to Metal Box Toyo Glass Company for the purpose of building a glass factory, Chief Lawson was encouraged by the factory architects, Godwin & Hopwood, to develop a properly planned model new town on the surrounding land.

Chief Lawson leased the land to Lawson & Company Ltd., who in 1973 commissioned Godwin & Hopwood and chartered surveyors, Knight Frank & Rutley Nigeria, to prepare a feasibility study for the development of approximately 900ha of land into an industrial and residential estate.

The phased development was shown to be viable and as a result a master plan layout was prepared by town planner, Max Lock, and approved by the local planning authorities.

Phase I of the development then proceeded and industrial sites were offered for lease, residential sites sold and, in 1976, a contract let for construction of roads. Ove Arup & Partners Nigeria were appointed as structural engineers by many of the industrialists who set up at Agbara, and four of the following articles describe some of the recent industrial projects in which we have been involved. Arups were also appointed by the developers as civil engineers for the roads and drainage of the estate, and later, in 1979, as services engineers for Phase 2 (see following infrastructure article).

In 1977, an area of approximately 80km² of land was acquired by the Ogun State Government. Lawsons' interest in what had now become known as Agbara Estate was included in this compulsory acquisition. However, the Ogun State Government agreed in due course to lease back to Lawsons part of the original holdings, an area of 454ha, for a term of 99 years. Lawsons & Co. Ltd. later changed its name to Agbara Estates Ltd.

Climate, soil and vegetation

The climate is hot and humid with prevailing breezes from the south west and storms from the north east. Average temperatures are 31°C during the day and 24°C at night. The average annual rainfall is 2.2m.

Geologically Agbara is situated on the southern edge of the coastal plain sands of Nigeria. The land is approximately 15m above sea level, steeply sloping into the river with swampy areas to the east and south, and gently undulating to the north and west. The subsoil conditions are good for building purposes, being generally lateritic sandy clays or clayey sands. The land had been used for farming cocoa, palm oil and cassava.

The vegetation consists predominantly of palm trees, and on the borders of the swamp the estate is heavily wooded with large trees.

Drainage

The drainage is well defined and occurs eastwards into the River Owo. This, in turn, flows southward into the nearby Ologe lagoon which is some 9.6km long and reaches a maximum width of 2.4km.

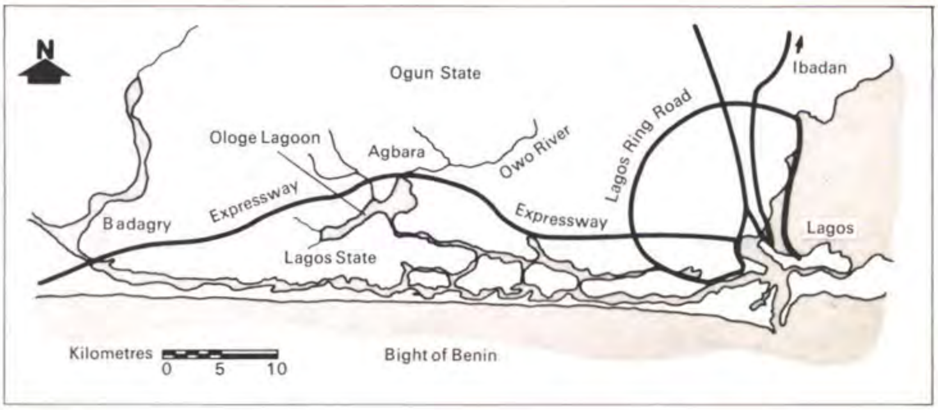


Fig. 1
Location map

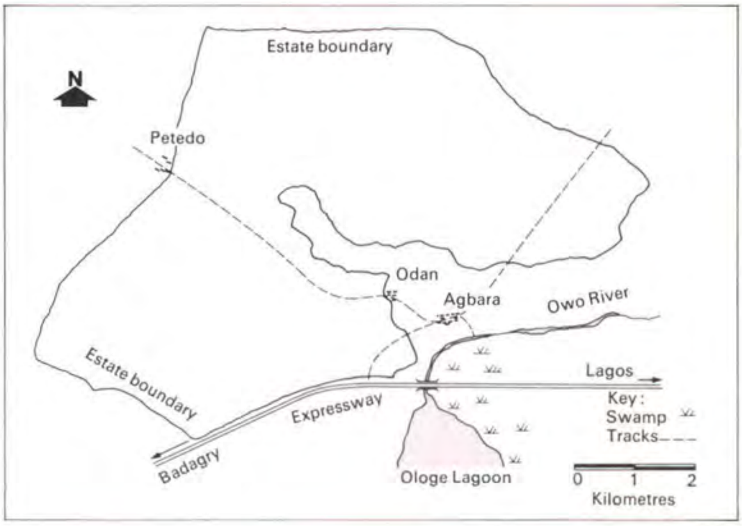


Fig. 2
Agbara land

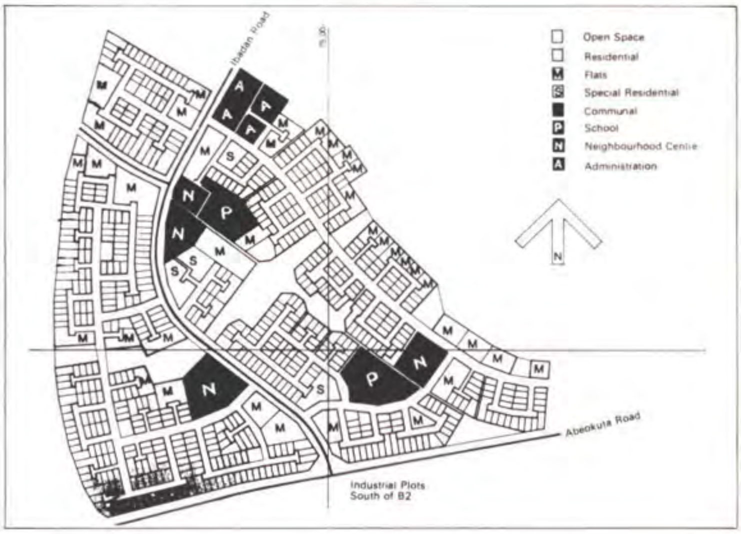


Fig. 3
Part of Agbara Estate residential area

Fig. 4
Interior of Dumex factory

Fig. 5
Metal Box Toyo Glass factory

Fig. 6
Reckitt & Colman factory

(Photos: 4-6, Harry Sowden)

On a regional scale, the Agbara Estate is situated in a relatively small drainage basin which extends some 72km inland. Numerous small rivers and streams flow southward off the so-called Southern Uplands and the majority drain into the Owo River.

Communications

The estate is within 40 minutes of Lagos and within 20 minutes of the border with the Republic of Benin by the Lagos-Badagry expressway. There will soon be a very good link to the north by the new Sokoto Federal highway which bisects the estate on a north/south axis.

Access by water is also feasible through the Badagry creek and Ologe lagoon.

Credits

Freeholder:
Ogun State Government of Nigeria

Leaseholder and developer:
Agbara Estates Ltd.

Architect:
Godwin & Hopwood

Chartered surveyor:
Knight Frank & Rutley

Services engineer:
Phase 1 – McLaren Nigeria Ltd.
Phase 2 – Ove Arup & Partners Nigeria

Quantity surveyor
Tillyard & Partners

Town planner:
Max Lock Group

Acknowledgement

Thanks are given to Mr. J. Godwin, who provided a large part of the information on which the introduction is based.

5

6

Agbara Estate: Infrastructure

Dele Betiku
Chris Bond
Peter Winsor

Road and surface water drainage

In the latter part of 1975, Ove Arup & Partners Nigeria were invited by the estate architects to undertake the design of the roads and associated surface water drainage within Phase 1 of Agbara Estate's development.

In association with the estate architect, it was decided that four types of road were to be constructed to the following finished geometry;

Road Type B:
Local distributor, comprising some 3.6km, with an 8m wide surfaced carriageway and 2m wide shoulders flush with the carriageway

Road Type C:
Feeder road, comprising some 4.2km, with a 6.75m wide surfaced carriageway and 1.5m wide shoulders

Road Type D:
Collector road, comprising some 5.4km, with a 6m wide surfaced carriageway and 1m wide shoulders

Road Type E:
Access road, comprising some 2.2km with a 5.5m wide surfaced carriageway, one 0.5m shoulder and one 1.25m shoulder.

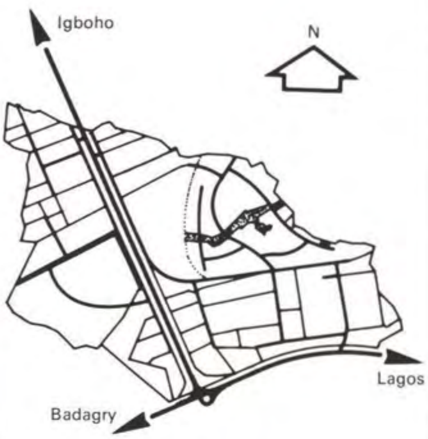


Fig. 7 Key plan, showing:
Federal Roads
Estate Roads Types B & C
Plot and Estate boundaries

Very small-scale earthworks were envisaged, with filling material being won either from cuttings or from borrow pits within the estate.

A prime consideration was that the cost of the road construction should be as low as possible, compatible with operating conditions, although it was anticipated that the pavement would be upgraded at a later date when funds permitted. Accordingly a typical low-cost pavement construction was adopted, consisting of naturally occurring lateritic sub-base and base (each 150mm thick), with a sprayed bitumen seal and surface dressing. Again it was hoped that the pavement materials would be won from borrow pits within the estate. Soil testing had indicated, however, that this locally available material, while suitable for use as sub-base, would not strictly satisfy the specification for base. The specification called for a minimum California Bearing Ratio of 80 but tests, even at 100% modified AASHO, produced values of about 50. Searches were made for acceptable base materials within a reasonable haulage distance, but none were located. Considering again the cost implications and acknowledging that the roads would eventually be structurally upgraded, it was decided to use the estate materials, paying careful attention to selection, on the basis of a low linear shrinkage, and to compaction.

For the Type B, C and D roads, the longitudinal drainage was provided by simple V-shaped ditches alongside the shoulders, or at the toe of the embankment, as appropriate. The ditches are a standard feature of low-cost roads in Nigeria. They serve the dual function of surface water drains to the road cross-section and adjacent areas, and also of the more conventional subsoil drain required to keep any ground water below the pavement construction. This is particularly significant for most naturally occurring lateritic materials, which are susceptible to strength reductions on wetting. Ideally a similar V-shaped ditch

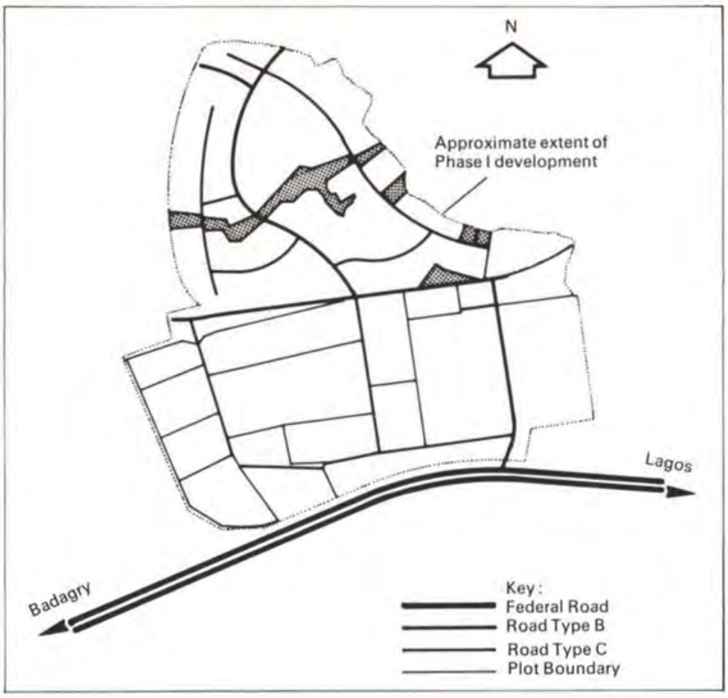


Fig. 8
Phase I: roads layout. Roads Types D & E not shown

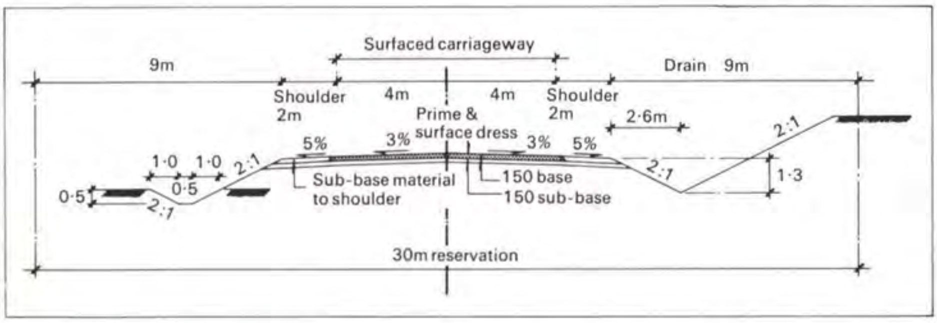


Fig. 9
Typical cross-section of Road Type B

would have been adopted for the Type E roads, but the very small reservation width dictated the use of rectangular lined drains, consisting of an in situ mass concrete base with sandcrete blockwork walls laid partially open-jointed and infilled with mass concrete. Transverse drainage situations could all be adequately catered for by the use of single, double or triple culverts consisting of precast concrete pipes bedded and haunched in mass concrete, with mass concrete headwalls and aprons.

The V-ditch depth and the requirement to have a minimum cover of about 300mm over the culvert often dictated a maximum pipe size of 600mm. Normally, on rural road projects, a minimum size of 900mm diameter is adopted to ease maintenance difficulties. The surface water drainage was concluded with ditches at the low areas outfalling either to a stream just beyond the estate boundary, or to the roadside ditch of an existing Federal road.

A rapid start to construction was required, and tender documents were prepared for issue in December 1975. The bills and tender drawings consisted of a preliminary design based on 1:2,500 photogrammetrically produced mapping, while the final design used on-the-ground survey. At the time of tender, Nigeria was in the process of an extremely rapid development, and it proved very difficult to find a contractor even willing to accept the documents free of charge. Despite all efforts, only two valid tenders were received. The contract for the construction of the Phase I roads was awarded in February 1976 for some N2.2m (then about £1.8 million).

The second phase of the development comprises the design and construction of some 5.2km of roads and associated drainage, sewerage and water supply to the northern industrial area of the estate, upgrading the existing main access off the east-west Lagos-Badagry Expressway as well as the design of a staggered T-Junction with the new south-north Federal Highway to Igboho. Other features of the Phase II development include the survey and design of a 3.5ha parking hardstanding to accommodate some 180 lorries, extensions and upgrading of some Phase I roads, design of the main drainage channel to drain the industrial north area into the swampy stretches outside the estate boundary, and the economic and technical feasibility study of a flyover across the new Federal Highway. Following experience gained from the Phase I development, it was not necessary to undertake an elaborate site investigation. The available foundation and pavement materials have performed well in service in the Phase I development and it was only logical to base our work on this fact.

Planning methodology

There is no defined pattern for the road network within the estate but the roads simply evolved from planning constraints imposed by plot layouts, right of way restrictions, estate boundaries and design standards consistent with the traffic requirements. A number of cul-de-sacs were also necessary to avoid the sterilization and isolation of otherwise economic land. This planning methodology obviously led to severe limitations in the choice of cross-section and drainage arrangement for the roads.

Future work is envisaged to be undertaken by initiating the planning process in reverse, that is, first the roads and then the plots. Design standards for the Phase I B class roads were generally adopted for the Phase II with some modifications. Major improvements include the use of crushed stone base instead of the laterite base and asphaltic concrete surfacing instead of surface dressing. Other features include the provision of raised kerbed footpaths and street lighting. Design standards, and specifications are based on the Federal Republic of Nigeria Works Department Standards and Specification.

Construction work is in progress on the main access at a cost of some N0.44m. (£0.34m. approximately). It is also expected that construction work on the main drainage outfall will commence early in May at a cost of nearly N0.3m. The Phase II industrial road works alone will cost about N4m. (£3m).

We anticipate commissioning for the survey and design of the Phase II and III residential areas in the near future.

Water supply and sewerage

In 1977, the estate services engineers left Nigeria and we took over the supervision of the Phase I water supply and sewage construction which they had designed. We were, in due course, also appointed to undertake the design as well as the supervision of the Phase II water supply and sewage.

Fig. 10a
Agbara Estate infrastructure (Photo: Thorp Modelmakers Ltd.)

As the industrial concerns are responsible for developing their own sources of water, the estate is supplying water only to the domestic users. The ultimate population was assessed at 26,000 with an average daily domestic demand of 4,300m^3/day and a maximum of 1.6 x the average demand.

In the light of evidence obtained from the preliminary subsoil investigation, it was decided to proceed with the construction of two production boreholes. These holes were to be part of an exploratory programme designed to determine the availability of groundwater at Agbara. In addition, they were so located that, if successful, they could be used as the source of supply for Phase I.

There was some concern that the industrial wells were all located within a relatively small area. It was appreciated that there was no easy solution to this, as each user was obviously unwilling to invest money in a borehole which was not on his property. To avoid spoiling the aquifer, the sites recommended for the estate's boreholes were relocated further inland, and hence further away from the industrial plots than was originally suggested.

The results of pumping testing indicated that the two production boreholes were more than capable of producing the anticipated demand of 2,900m^3/day for Phase I of the proposed development. The form of drawdown versus time curves suggested that a recharge boundary exists in the vicinity of the production boreholes (Figs. 11 and 12).

In general it was found that the best water-bearing horizons were encountered between 90m and 150m below ground and that these were relatively clean, medium to coarse-grained sands.

Upon completion, the boreholes were electrically logged for Spontaneous Potential 'SP' and Resistivity 'R' using the manually operated Johnson-Keck DR-74 Electrical Logging System in order to determine the exact location of water-bearing horizons. The results of the electric logging were used as a guide in the final construction of the boreholes and to identify the target depths of the production boreholes.

Observation wells have also been sunk to monitor fluctuations in ground water levels throughout the estate.

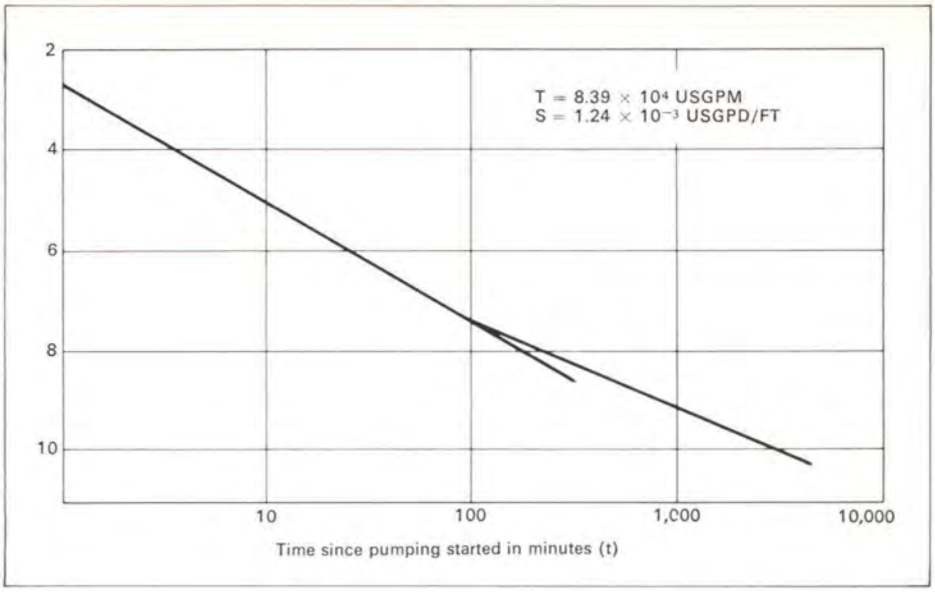


Fig. 11
Time drawdown curve for observation borehole 'A'

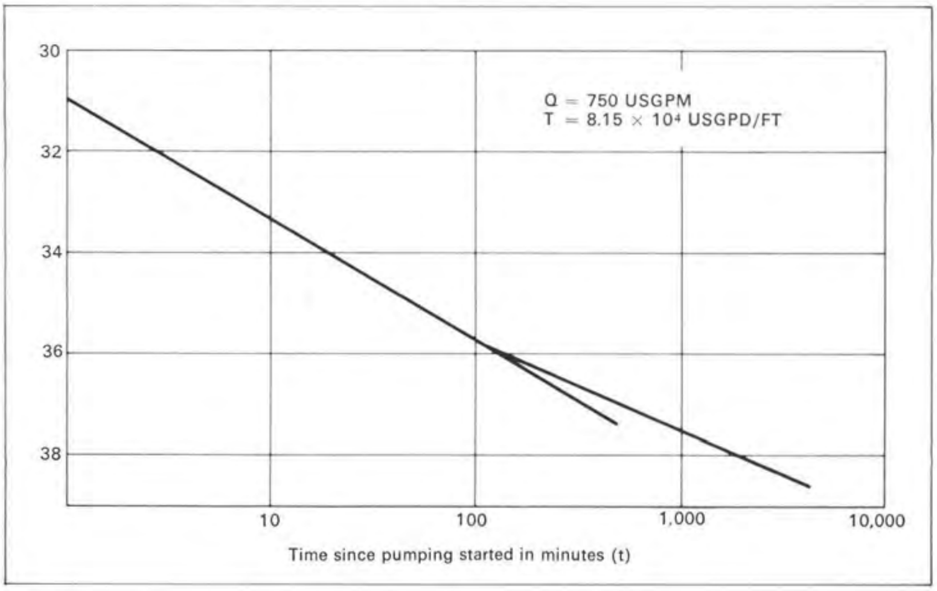
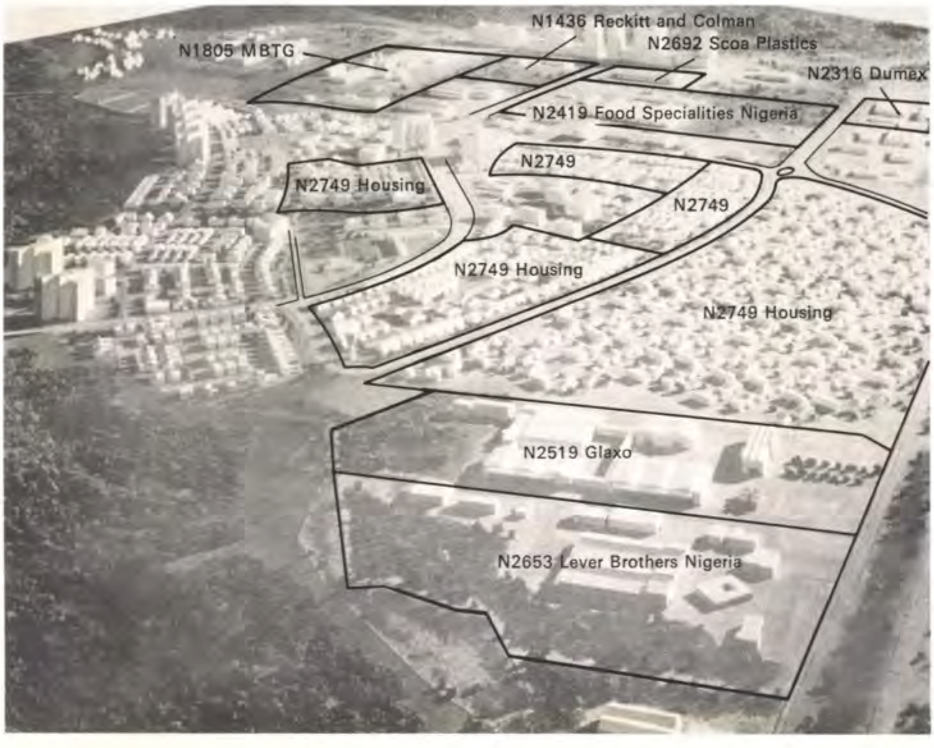


Fig. 12
Time drawdown curve for production borehole 'B'

Fig. 10b
Key to Agbara Estate infrastructure



Further drilling and test pumping is proposed to locate a third well to meet ultimate demand and to determine aquifer characteristics.

Analyses showed the water to be very soft, acidic, and with a high iron concentration.

Various methods of treatment were considered. The one selected uses dolomitic media for automatic ph correction. Iron removal is by aeration in the top dome of the pressure filters from a compressor/receiver, followed by the catalytic action of the dolomitic media. Samples were found to be free of coliform organisms, but chlorine disinfection will be applied.

Because of the corrosive nature of well water, pumping mains to the filtration plant will be laid in asbestos cement.

Three methods were considered for sewage treatment: a sewage lagoon, a package extended aeration plant and an aerated lagoon. A feasibility study was carried out and the aerated lagoon was chosen because of its reasonable land needs and its simplicity of operation.

Estate regulations prohibit the discharge of industrial effluent in which Biochemical Oxygen Demand exceeds 500mg/l. The combined industrial and residential effluent loading on completion of the development is estimated at 8,600m^3/day.

The site allocated was triangular in shape and 2.7ha in area. The layout comprises three cells. The outer walls are formed as earth structures, concrete lined at a 1 :2 gradient. To conserve space, division walls between cells are made of reinforced concrete.

Cells 1 and 2 will each have a detention time of 2.4 days. Four surface aerators are provided in each cell, each aerator powered by a 37.5kw motor.

Cell 3, for settlement and clarification, will have a detention time of 0.8 days.

In operation, sewage entering aeration cell 1 will enter cell 2 by passing over wires set in the division walls and thence to cell 3.

A bypass arrangement allows one cell to be closed for maintenance.

Fig. 13
Sewage lagoon (Photo : Bill Haigh)

Cell 3 incorporates a sludge hopper located immediately after the division wall. Sludge pumps return sludge to cell 1 to reduce sludge wastage.

The resulting effluent should have a Biochemical Oxygen Demand of 35-50mg/l. The flow could have been directed to a stream adjoining the site but, since the stream could not provide a dilution factor of at least 10, disinfection would have been required because it was accessible to the public. It was therefore decided to lay an outfall pipe discharging to the mouth of the Owo River where it enters the lagoon.

Credits

Client:
Agbara Estates Ltd.

Services engineers:
Phase 1 : McLaren Nigeria Ltd.
Phase 2 : Ove Arup & Partners Nigeria

M & E services engineer for electrical distribution:
Oscar Faber Nigeria Ltd.

Main contractor:
James Kilpatrick Nigeria Ltd.

Supply of aerators:
Lightning

Supply of pumps:
Flygt

Agbara Estate: Lever Brothers Nigeria Ltd.

Stephen West
Elu Elumelu

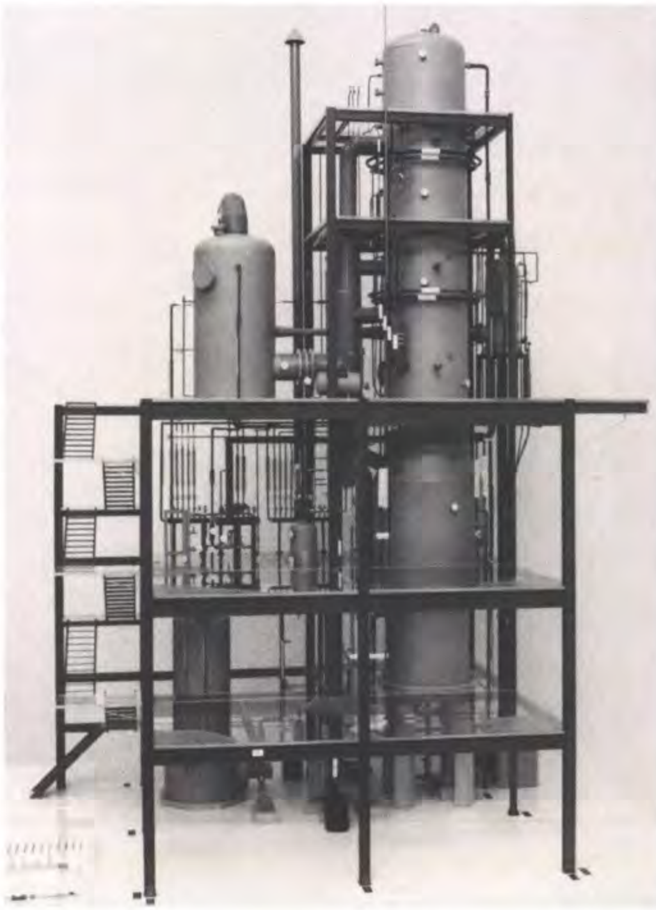


Fig 14.
Model of Lever Brothers refinery (Photo : Unilever, London)

The client

Lever Brothers Nigeria Ltd. are a Unilever company producing a wide range of household products such as soaps, detergents and fats for a fast expanding Nigerian market. In a competitive environment such as Nigeria the importance of self-sufficiency allied to modern production facilities has led Lever Brothers Nigeria to embark upon an expansion programme, part of which is the construction of a new processing complex within the Agbara Industrial Estate. Phase I of this complex is concerned with the production of edible fats, being chiefly margarines, cooking oils and industrial fats. Phase II is planned to double the production of these items and, additionally, to provide sundry foods and drinks.

The construction

The site has an area of 20ha and in Phase I, production, warehousing services and social buildings will cover an area of about 14,000m². Included in the above will be a small refinery where systems for two processes will be installed to handle the locally obtained oils. The building for the refinery will have an area in plan of about 400m² and comprise a four storey high steel-framed structure. Within this framework the refinery and associated equipment will be located, including a 100 tonnes semicontinuous deodorizer and numerous vessels weighing up to 40 tonnes each. The building is essentially industrial but external louvres on three sides provide a uniform appearance, giving sun and rain protection whilst allowing good ventilation.

As hygiene in the food processing industry is paramount, working areas will be tiled, where possible, using oil-resistant materials, and floor coverings in general will be easily washable.

The main processing and packaging areas and storage facilities will be contained within a building, mostly single storey, based upon a

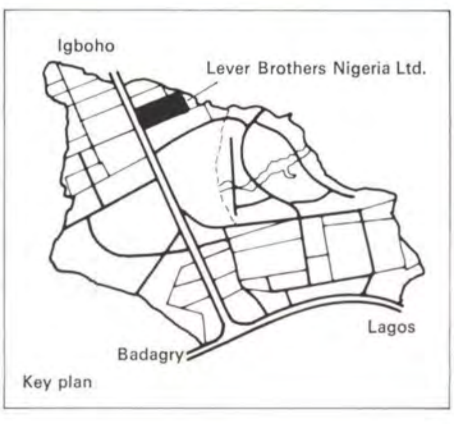


Fig. 15
Erection of refinery steelwork (Photo : Bill Haigh)

Fig. 16
Cruciform column to carry pipe bridge
(Photo: Bill Haigh)

column grid of 18m by 19.8m. Under Phase I an area of about 8,500m^2 is involved. The client was particularly interested in the alternative structural systems available to achieve his requirements for this building. The normally accepted solution is pitched portal, steel frames at 6m centres, with eaves and valley gutters allowing rain water down pipes at 6 or 12m centres. This is sometimes modified so that internal stanchions are at 12m centres with the pitched rafters supported on valley trusses. Rainwater is run off in an underfloor duct with access manholes at regular intervals to facilitate cleaning. In process buildings where hygiene is a primary consideration, stanchions are cased and possibly tiled and the access manholes have to be omitted at least in certain areas.

These considerations led to the notion that if the rainwater gutter were at eaves level then downpipes would only be needed at the building perimeter and access manholes could be eliminated from the internal ground floor areas entirely. We therefore compared the normal steel frame solution with a reinforced concrete frame of gutter beams at eaves level at 19.8m centres supported on columns at 18m centres and trusses at 6m centres spanning 19.8m onto the gutter beams. This solution proved cheaper than the steelwork solution.

The rainwater from the gutter is not taken in downpipes but is allowed to run freely inside 'U' shaped columns. See Fig. 17.

An essential part of the complex is the movement of oils and service connections between the various production buildings and this will be achieved by a high level structural steel pipe bridge, 254m in length, supported on concrete columns of cruciform section. Each column permits the support of four incoming pipe bridges, giving flexibility for future expansion, and the general arrangement at a column head is shown in Fig. 18.

Where possible the architect has based his building layouts on a grid of 900mm, which apart from standardizing architectural and structural dimensions, defines the discipline under which Phase II expansion can occur. This module has been adopted in the use of GKN 9 waffle moulds for suspended floors and roofs throughout all buildings where possible.

The contracts

Lodigiani (Nigeria) Ltd. were awarded the main contract of value N7.5m. (about £6m.) and with a construction period of 18 months. They took over the site in November, 1980 following the completion of a preliminary earthworks contract carried out by Guffanti (Nigeria) Ltd. for the site clearance and topsoil strip. Lodigiani (Nigeria) Ltd. are associated with Lodigiani of Italy, part of the Impregilo consortium. They have recently completed the Ministry of Communications Territorial HQ and an extension to the Senate, both in Lagos. To date the main contractor has completed the majority of his foundation construction and is presently involved in the superstructure and external works, especially the site drainage which had to be operational prior to the wet season, commencing April/May 1981.

Eldorado (Nigeria) Ltd. were awarded the sub-contract for the fabrication, supply and erection of approximately 350 tonnes of structural steelwork. The first delivery of steelwork to site was made at the beginning of March, 1981.

Site supervision

The biggest problem for a resident engineer on a project of this kind is the initial grasp of its content and extent. An RE should become part of the project from the planning period to the design stage. In this way he is able to assess the problems before he moves to site.

Nigeria is a developing country where the standard of available technical manpower is low. This increases the work of the RE on site, having invariably to direct a large part of the contractor's work, especially if the main contractor's supervisors are new to Nigeria and cannot communicate well, therefore relying on the RE to interpret every aspect of the drawings to all categories of workmen. Consequently, although there are normally sufficient men on site, standards tend to be poor and production low.

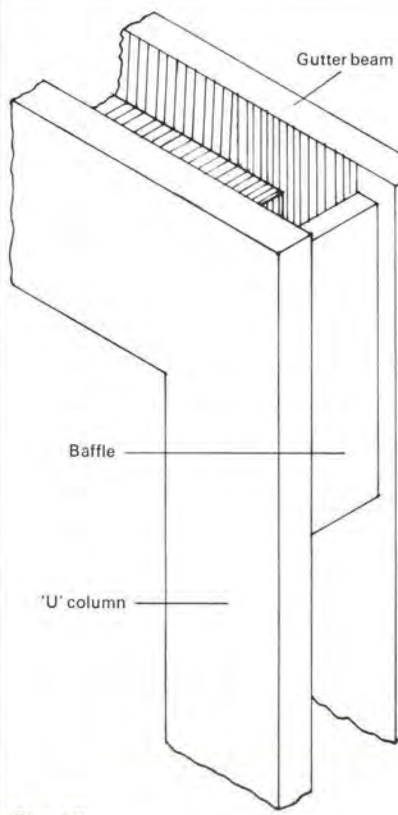


Fig. 17
Gutter water deflected down open 'U' shaped column by concrete baffle

Quality of materials, such as reinforcement, cement and structural steel, is good, but the production of concrete on site needs constant supervision. For example, it is difficult to keep to the same standard of aggregate throughout a project, the source varies and hence the quality of the struck concrete.

The responsibilities of the RE on such a site are far greater under these circumstances than on a similar project located, say, in the UK.

The programme

The programme for the completion of this particular project is closely related to the client's own extensive mechanical and electrical installation, which is being carried out in association with the Engineering Division Projects Group of Unilever Ltd., London. To date Lodigiani have been able to work within the scope of their own expertise but as the programme continues they will be under increasing pressure to maintain Guiseppe Lodigiani's proud claim 'that his contracts are always finished on time'.

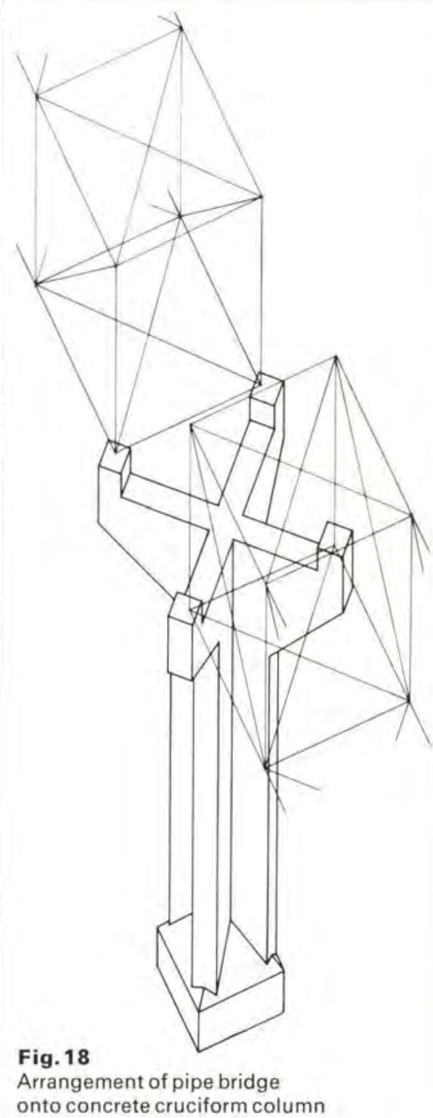


Fig. 18
Arrangement of pipe bridge onto concrete cruciform column

Credits

Client:
Lever Brothers Nigeria Ltd.

Architect:
James Cubitt & Partners Nigeria

Quantity surveyor:
Tillyard & Partners

Plant design:
Engineering Division Projects Group
Unilever, London

Main contractor:
Lodigiani (Nigeria) Ltd.

Structural steelwork contractor:
Eldorado (Nigeria) Ltd.

Agbara Estate: Glaxo Nigeria Ltd.

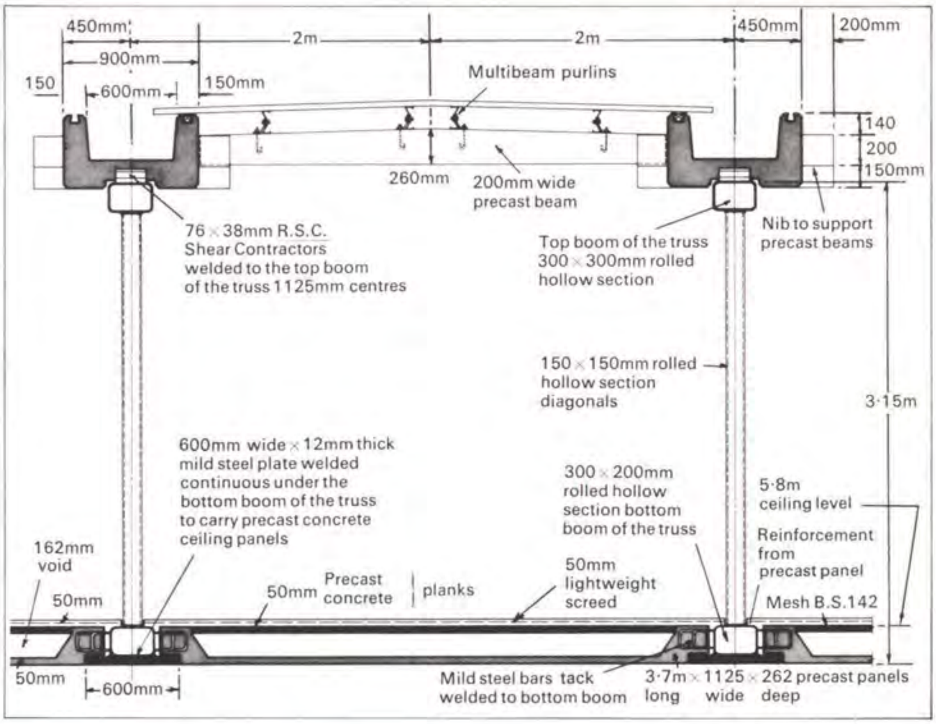
Abul Hossain

Following the successful completion of a new office block for Glaxo Nigeria Ltd. at Apapa, we were commissioned by Glaxo together with architects, Godwin & Hopwood, to carry out the design of a pharmaceutical factory on a 9ha site within the north west industrial zone of the Agbara Estate.

The complex consists of nine separate buildings, the main buildings being Block A – pharmaceutical production (72m x 72m), Block B – raw materials and warehouse (84m x 24m) and Block D – production and foods warehouse (60m x 57m).

The ancillary buildings are for the energy centre, canteen security, solvent store, gatehouse, water storage and fuel storage.

Apart from the production building, canteen, security building and gatehouse, all other buildings are steel-framed structures. Warehouse structures throughout the development have been standardized using a 28m steel frame at 6m centres.



Key plan

Fig. 19
Glaxo Block A: pharmaceutical production building: typical section through roof

Fig. 20
Load test of truss (Photo: Bill Haigh)

Fig. 21
Joint detail in tubular Warren truss (Photo: Bill Haigh)

Intermediate stanchions in the valleys are omitted. A trussed beam spanning 12m between the portal stanchions carries the load from the intermediate rafters. Clearance under the trussed beam is 9m.

The canteen and security building have 15m span reinforced concrete rigid frames at 4m spacing. The horizontal and vertical members of the frame are U-shaped gutter beams and columns, the shape of which is required for rainwater drainage. Precast concrete rafters at 6m centre to centre carry the purlins in the direction parallel to the span of gutter beam.

Lateral stability in the direction parallel to the span of the gutter beam is provided by portal action. Perpendicular to the span of the gutter beam, stability is provided by the precast concrete rafter.

The structure of the production area (Block A) is basically divided into three column-free zones, of 17.5m, 36m and 17.5m spans. The structural form and materials used were dictated by five considerations:

(1) The use of dust free materials and shapes, which would not harbour dust

(2) The requirement of a service floor over the entire production area and the heavy plant loads to be located therein

(3) The high degree of flexibility needed in the vertical and horizontal distribution of services

(4) Low maintenance costs

(5) A balance of the cost equation relating rapid erection to minimum construction costs.

These considerations led to the use of concrete as the material for the structural envelope, namely concrete U-shaped columns and concrete floors to the service void. The form of roof structure chosen as a result of the considerations outlined above is a Warren truss formed of structural steel hollow sections with a U-shaped reinforced concrete gutter over the top boom. (Fig. 19).

The floor to the service void, which also carries plant and ductwork, is supported on the bottom boom of the truss. It consists of precast concrete panels at 1.125m centres, with sealed joints and intermediate service panels which accommodate light fittings and service drops to machinery installations below, all of which must be assembled from within the service void.

This form gives a high degree of flexibility for placing plant and the horizontal distribution of ductwork through the webs of the trusses and also for the vertical distribution of the services between the precast ceiling panels. Lateral stability is derived from the U-profiled top beam which will greatly facilitate erection.

The extensive use of prefabricated elements within the services void is derived from the need to build rapidly. The trusses themselves are designed for fabrication at ground level and then are to be lifted into position on their columns. This means that the roof structure can be fabricated while the contractor is carrying out ground works, i.e. at a very early stage in the construction.

The roof enclosure is then completed with a double skin of metal profiled roof cladding with a sandwich of insulation to reduce radiated heat to acceptable levels within the service void.

The value of the main contract is N9.07m. (about £7.07m.).

Credits

Client:
Glaxo Nigeria Ltd.

Architect:
Godwin & Hopwood

Quantity surveyor:
Roxburgh & Partners

Main contractor:
Cappa & D'Alberto Ltd.

Structural steelwork sub contractor:
Eldorado (Nigeria) Ltd.

M & E services design and construction:
Drake and Scull Nigeria Ltd.

Agbara Estate: Food Specialities (Nigeria) Ltd.

Cheem Shah
Peter Terrell

In July, 1977, Ove Arup & Partners Nigeria were appointed to design and supervise the structural and civil engineering works for a new cereals and beverages manufacturing plant for Food Specialities (Nigeria) Ltd., a branch of the Nestlé company.

The site investigation on the 15ha plot confirmed the typical estate subsoil conditions, with a layer of 300mm thick topsoil overlying compact lateritic reddish brown sandy clay, which varied little with depth. Pad and strip footings were, therefore, the most economical solutions for the foundations, using an allowable bearing pressure of 250kN/m^2 at a depth of 500mm below original ground level.

Considerable earthworks were required to increase the general level of the site. They provided the necessary falls for the site drainage to tie in with the invert levels of the existing Agbara Estate drains.

Contracts

The works were originally split into three separate contracts :– housing for the factory supervisors, earthworks, and the main factory complex. The housing and earthworks contracts were let first, and main contract six months later. Bouygues Nigeria Ltd. won the housing contract of four family houses, bachelor accommodation for four people, a swimming pool and tennis court. The contract was completed at the beginning of 1980.

The earthworks contract was won by Scan Construction, who unfortunately were bogged down by a worse than usual rainy season. In order to catch up on programme, their contract was terminated by mutual agreement, and the earthworks were completed by Cappa & D'Alberto Ltd., who had by this time won the main contract.

The large quantity of fill required over the site was taken from borrow pits on a part of the site to be used for landscaping and planting. The topsoil from the site was used partially to fill the borrow pits, the remainder coming from adjacent sites.

The main factory complex includes two concrete frame production buildings of two and three storeys respectively, a 12,000m^2 warehouse, an energy centre in structural steelwork, an office canteen and amenities buildings of single-storey reinforced concrete construction, covered ways, pipe bridges, oil and water tanks, and gate house.

The two production buildings are constructed using ground bearing slabs at ground floor level, the suspended slabs being in solid reinforced concrete designed to carry an imposed load of 20kN/m^2. These slabs span onto beams in both directions, which in turn span between reinforced concrete columns at 6m centres. The production areas in Block 14 are enclosed by insulated double skin blockwork walls, with insulation provided by a false ceiling at roof level. The system of construction had been developed by the architect to control the temperature and humidity, as the finished product is hygroscopic. The roof consists of welded rolled hollow section trusses spanning 12m between reinforced concrete gutters. The sensiplast steel roof sheets are supported on purlins at 1.2m centres, and have a pitch of only 1%, the roof sheets being able to take up the curvature without being damaged. Sensiplast sheets with an insulated screed on top form the false ceiling. Allowance was made in the steelwork design for a future extension, which is already now being commissioned.

The production buildings are linked to the warehouse by staircases and a goods lift. The warehouse itself is a three-bay pitched portal structure with spans of 24m, the stanchions being at 6m centres longitudinally. The total length of 170m is split into three by full height blockwork walls. The centre portion is to be used as a tin shop which will make cans to serve the two production buildings via overhead conveyors, and the two end portions are distribution warehouses for the finished products. An 8m cantilevered truss runs along the length of the warehouse building providing a covered loading area.

The warehouse and services buildings rely upon natural ventilation to maintain acceptable temperature levels internally. This is achieved in general by the provision of monitor roofs on the ridges, angled towards the direction of the prevailing wind. This tends to create a suction on the downwind side, causing air to be drawn into the building through the low level louvres. The technique is very effective, the internal termperature remaining remarkably cool throughout the day.

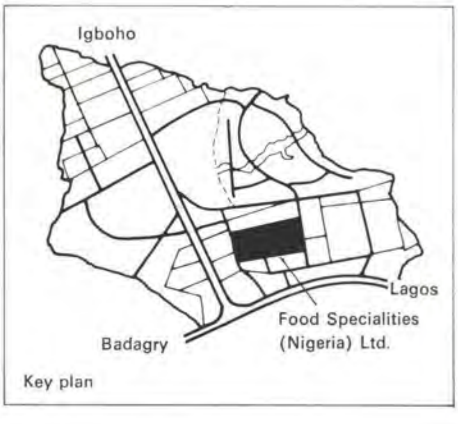
The services building is again of portal frame construction with single spans of 12m, the stanchions being at 6m centres which is the optimum spacing for the available Multibeam purlins. This building will provide energy for the whole factory complex and houses three diesel generators, two boilers, fire fighting equipment and assorted repair and maintenance workshops. The four oil storage tanks are linked directly to the boiler house.

The finish to the concrete floors throughout the working areas is produced using a 20mm thick mono-grano screed. The floor is laid in the normal manner, stopping 20mm down from floor datum level. The concrete is allowed to set for an hour or two, after which time the screed, consisting of crushed granite pea gravel with a small amount of sharp sand to obtain an acceptable workability, is laid and tamped by hand. The water/cement ratio is kept as low as possible. The screed is allowed to set before being trowelled smooth three times during the same day.

Covered walkways, serving also as pipe bridges, connect the services buildings to the manufacturing and amenities buildings.

Fig. 22
Model of Food Specialities (Nigeria) factory (Photo : Nestlé, Switzerland)

Fig. 23
Generator house (Photo : Bill Haigh)



They are of portal frame construction covered by sensiplast roofing sheets which are curved down to provide some protection against driving rain.

A 364,000 l capacity fresh water tank in reinforced concrete, coupled to a cooling tower, provides water to the whole site from deep boreholes nearby. The walls of the tank were cast in one pour, taking approximately seven hours. Solid waste is disposed of by use of an incinerator and scrap store. A network of concrete roads links the various buildings in the complex.

The client's head office provided considerable technical input during the briefing sessions before construction, and Nestlé's involvement is continuing during construction of the project.

Construction sequence

The construction period for the factory complex is approximately 18 months. The installation of the equipment, piping, ducting and machinery is being carried out by the client himself and subcontractors appointed directly by him. This has placed a considerable restriction on the sequence of construction available to the main contractor, who has shown remarkable flexibility when confronted with varying lists of priority areas. The installation of the equipment into services and production areas has been hard on the heels of the building works, and credit is due to all concerned that acrimony has rarely entered into the picture.

The steelwork subcontractor has had to mobilize several trusses on the site, as continuity of erection was impossible due to the construction sequence laid down by the client.

Site meetings are held once a week in order to keep a tight control on the programme. All consultants, subcontractors and the client attend the meetings. Information from the consultants has been fed to the site continuously during the construction period.

The quality of workmanship, especially the concrete works, has been of a very high standard. The contractor prepared fairfaced samples for approval of the consultants. Most of the internal and external concrete is fairfaced, painted internally but not externally.

Steelwork finish

There are as yet very few facilities available for grit blasting the structural steelwork, and hence a fair proportion of it has mill scale adhering to it despite wire brushing. This notwithstanding, the finish in general is very acceptable. It is hoped that in the near future we may be able to specify grit-blasted steelwork without having to accept an exorbitant surcharge.

This particular site has increased our awareness of the necessity to look very carefully at the detailing of connections in steelwork, especially those concerned with monitor roofs and cladding rails. To this end, we have initiated a programme to produce better standard details for those areas that repeat themselves from job to job, combining our expertise with that of steelwork fabricators and architects.

Credits

Client:
Food Specialities Nigeria Ltd. (Nestlé)

Architect:
Godwin & Hopwood

Quantity surveyor:
Roxburgh & Partners

M & E services and plant design:
Nestec, Verey, Switzerland

Main contractor:
Cappa & D'Alberto Ltd.

Structural steelwork subcontractor:
Dorman Long and
Amalgamated Engineering Ltd.

Agbara Estate: Beecham Nigeria Ltd.

Ike Chukwuneke

The Beecham Factory complex owned by Beecham Nigeria Ltd. is located on 8.37ha of land on the Agbara Estate. The complex comprises five major blocks and covers a floor area of about 1.3ha. The first phase of development is shown in Fig. 24.

The main factory block has provision for future expansion. The factory on completion will be producing Lucozade and Ribena health drinks. Initial construction cost is estimated at N8.8m.

The building structures provided are of two types, structural steel and reinforced concrete. Blocks A and C are in structural steel and have certain features in common. These include (1) the provision of monitor ridge ventilation, which serves the additional function of a pressure release gate, (2) the same ridge and eaves heights, and (3) a concrete perimeter beam at 3.5m height. This arrangement ties the building at this level and also makes possible the reduction of the effective length of the stanchion about the minor axis. This results in the use of lighter sections and considerable saving in total tonnage of steel. The foundations are designed as pinned bases.

Block A is a double bay portal frame, 30m span at 6m centres over a length of 168m. Special features in this block include the provision of a high level walkway to carry the services in the first seven bays, and the manufacturing platforms for Lucozade and Ribena. Analysis of the structures for various loading conditions was by conventional methods, but further design checks were performed using Hewlett Packard 9830 frame analysis program AP 109.

Block C, the energy centre, is a single bay 10m span portal frame at 6m centres. There is a provision for a gantry beam to support a two-wheel travelling crane within the generator bays. The gantry beam bracket is cantilevered from the main stanchions by welded connections. This block also houses the vehicle maintenance workshop, CO_2 plant and boiler equipment.

Lateral stability of this block is provided by the reinforced concrete perimeter beam at 3.5m height. The use of links and angle connectors ensures that the stanchions are properly tied to the concrete. Services from Block C are carried via cable and pipes by a Howe truss bridge to the main factory. The pipe bridge is constructed over a length of 88m, with a maximum span of 15m.

Blocks B, D and E are low rise blocks in conventional reinforced concrete. B and D have 200mm. flat roof slabs supported by square columns on a grid of approximately 5m. Block E is initially a single-storey office block with structural provisions for two additional floors at some future date.

Water to be used in the factory is provided by means of a borehole. Treated water will be stored in a 436,000 l Braithwaite tank supported on an 18m high reinforced concrete wall structure. The structure which consists of four concrete walls, 3.5 x 0.4m, with a special geometrical arrangement in plan, is effectively braced at third points of its height. The foundation is a raft with upstand beams, which tie the columns at the ground level.

Soil investigation was carried out by Arups' soils division and the maximum recommended bearing pressure is $150kN/m^2$.

Work on the site started in October, 1980. Effective planning will ensure completion of the project by November, 1981 and the contractor is on programme.

Credits

Client:
Beecham Nigeria Ltd.

Architect:
Godwin & Hopwood

Quantity surveyor:
Roxburgh & Partners

Main contractor:
Cappa & D'Alberto Ltd.

Structural steelwork subcontractor:
Dorman Long and
Amalgamated Engineering Ltd.

Key plan

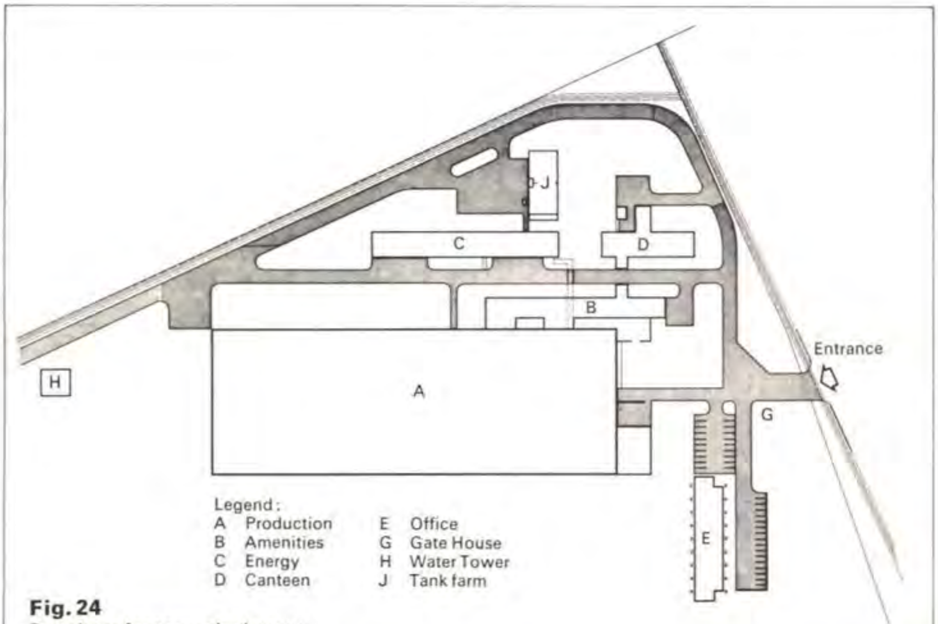


Fig. 24
Beecham factory : site layout

Barbican Arts Centre

Architects:
Chamberlin, Powell & Bon (Barbican)

When Chamberlin, Powell & Bon submitted their first proposals to the Corporation of London for the Barbican Redevelopment Scheme in 1955 they were asked to include new premises for the Guildhall School of Music & Drama. In subsequent proposals for the development the accommodation for the GSMD was expanded to provide facilities for the school which could also be used by visiting companies for the entertainment of the general public. It was, however, eventually recognized that the two requirements were incompatible, in that the facilities best suited to the needs of the school were being compromised by those required for public use, and vice versa. Consequently the Music School has been provided with accommodation designed to suit its specific needs, and in addition facilities for public use have been included, designed, in the case of the concert hall and theatre, to the particular requirements of two well-established companies of high repute, the London Symphony Orchestra and the Royal Shakespeare Company. In addition to the concert hall and theatre, a large library and art gallery, a cinema, generous catering facilities and conference facilities are included as part of the scheme.

Pedestrian precinct

The Barbican Redevelopment area is a pedestrian precinct, pedestrian and vehicular traffic having been segregated by confining pedestrian circulation over most of the area to that of an elevated podium. Because of the gradual slope of the site down from north to south, the podium over North Barbican is 3m above that over the remainder of the site. Both levels, however, intersect at the Arts Centre, which thus forms a natural point at which pedestrians converge. Vehicular access to the centre is provided by means of an underground road, serving the lowest level of foyer and leading to adjacent car parking spaces.

The principal auditoria within the Centre are linked by generous foyers and circulation spaces, some of which are set at the levels of external pedestrian circulation. Although these different facilities can operate independently, there is considerable opportunity provided for the inter-related use of the different functions within the building. For example, the library, containing a large Arts and Music collection, and the art gallery, which are located above and are spatially inter-connected with the various levels of foyer, can be used independently, or can be approached by those members of the public who are also patronizing the concert hall and theatre. There is the potential for a considerable amount of other inter-related activity within the Centre.

In addition to its use for concerts, the Barbican Hall has been equipped for conference use, as has the cinema, both of which are expected to be used in conjunction with adjacent lecture and seminar rooms, and exhibition halls in North Barbican.

Materials

The structure throughout the centre is of reinforced concrete, the principal elements of which are exposed to view. A granite aggregate has been incorporated within the concrete which is exposed by heavy and light tooling of the surface. As a complement to this, 'natural' materials such as timber, bronze, leather, wool (carpets) and brickwork are used for surfaces and components with which users of the building will come into close contact.

Fig. 1
View from Britannic House overlooking Barbican Arts Centre and Barbican redevelopment generally. Conservatory against flytower of Royal Shakespeare Theatre in centre

Fig. 2
Close-up of flytower and conservatory

Guildhall School of Music & Drama

As its name implies, the school consists primarily of two departments, one for music and the other for drama. The music department is provided with a small concert hall capable of seating up to 400, which is surrounded on three levels by 36 acoustically isolated practice studios.

The drama department consists of a theatre equipped with retractable seating which can be set up in a variety of arrangements to suit the particular needs of a production, capable of accommodating an audience of up to 400.

The stage is large with a wide proscenium and flytower. The theatre is supported by the provision of backstage facilities in the form of workshops, paint shops, etc. as well as with dressing rooms. The school also includes a lecture/recital room, a gymnasium, dance studios and rehearsal rooms.

The drama and music departments share a common foyer and bar inter-connected with the foyer of the main Arts Centre.

Theatre

The Barbican Theatre is intended to replace the Royal Shakespeare Company's current use of the Aldwych Theatre in London and has been designed to their specific requirements.

In the design of the Barbican Theatre considerable attention has been given to the provision of good sight lines from every seat in the auditorium and to achieving as close a proximity of all seats to the stage as possible. No seat is further than 20m from the point of command, being a position in the centre of the stage 2.4m behind the front edge of the stage from which an actor can encompass the whole of the auditorium in his peripheral vision.

The volume of the auditorium has been reduced to the minimum possible by:

(1) Excluding all circulation space in the form of gangways from within the auditorium enclosure which would otherwise occupy space better suited to favourably placed seats.

The auditorium is approached by means of stepped foyers from which the seat row is selected, access being obtained by means of a door at the end of each row.

(2) The provision of three balconies containing only two rows, each projecting forward towards the stage thus incurring a reduction rather than an increase in headroom. The balconies also step down towards the stage around the sides of the auditorium.

(3) The design of the main beams which support the roof to the auditorium which are upstanding beams and are therefore external to the volume of the auditorium. Furthermore, these beams, being hollow, provide the means by which the conditioned air is supplied to the auditorium, the vitiated air being extracted via plenum ducts beneath the seats. Most of the air supply and extract ducts are therefore also external to the volume of the auditorium.

A 'double height' flytower is provided to enable the flats within the company's repertoire to be stored at the top of the tower as well as for the intermediate level to serve the current production. The height of the tower is 33.5m from stage to underside of grid, from which are suspended 76 scene bars operated by motorized winches.

The flytower is enclosed externally within a large conservatory. This will be set out as a winter garden and will be used for civic receptions and as a restaurant to supplement the other catering facilities included in the Centre.

Concert hall

The concert hall, which has been provided to accommodate an audience of approximately 2,000, has been designed to the specific requirements of the London Symphony Orchestra, who prescribed that a 'rich' and 'full' quality of sound be produced. To achieve this the Corporation's acoustic consultant, Mr. Hugh Creighton, determined that the volume of the hall be not less than $8.5m^3$ of space per seat. Whilst acoustic considerations are paramount, considerable attention has been given to limiting the distance of the furthest seat from the orchestra, and to the comfort of the audience in the design of the seats by Mr. Robin Day.

The acoustic requirements for music and for the spoken word are incompatible. Consequently although there is no need to amplify the sound emanating from the orchestra, a public address system has been introduced for the benefit of those wishing to use the hall for conferences.

The stage is extremely flexible in use. It is capable of accommodating an orchestra of 110 players and, when the stage is extended forward by some 2.4m a chorus of up to 200 members. Whilst the forestage is fixed (incorporating a piano lift), the rear sections are adjustable in height, being supported on scissor jacks, which when used in conjunction with a number of stage rostra units, are capable of meeting the demands of almost any required configuration. The canopy over the stage is profiled to reflect the sound forward into the auditorium, and conceals film screens, house curtains, production lights, loudspeakers, etc., as well as a maintenance gantry in its 'parked' position. This gantry is designed to travel out across the auditorium on tracks beneath the north/south beams to provide access to the house lights, production lights and perspex spheres which are suspended from the roof over the auditorium. The spheres have been introduced to diffuse the sound which would otherwise be reflected from the sides of the roof beams causing undesirable echoes.

The concert hall is supported by dressing room accommodation, rehearsal rooms, recording rooms, as well as by administrative offices and a performers' bar.

3

4

Cinema

The smallest of the auditoria, the cinema, seats 300 and is equipped with a screen designed to accommodate modern picture ratios including standard and wide screen.

It is also intended to be used as a conference/lecture room and has been equipped with suitable audio visual and simultaneous translation facilities.

Library/art gallery

The library and art gallery are positioned centrally within the Arts Centre as a whole, and accommodated on three floors above the foyers, being visually connected with these.

The library includes a large lending library, an arts library, a children's library and, on a mezzanine floor within the main foyer, a music library.

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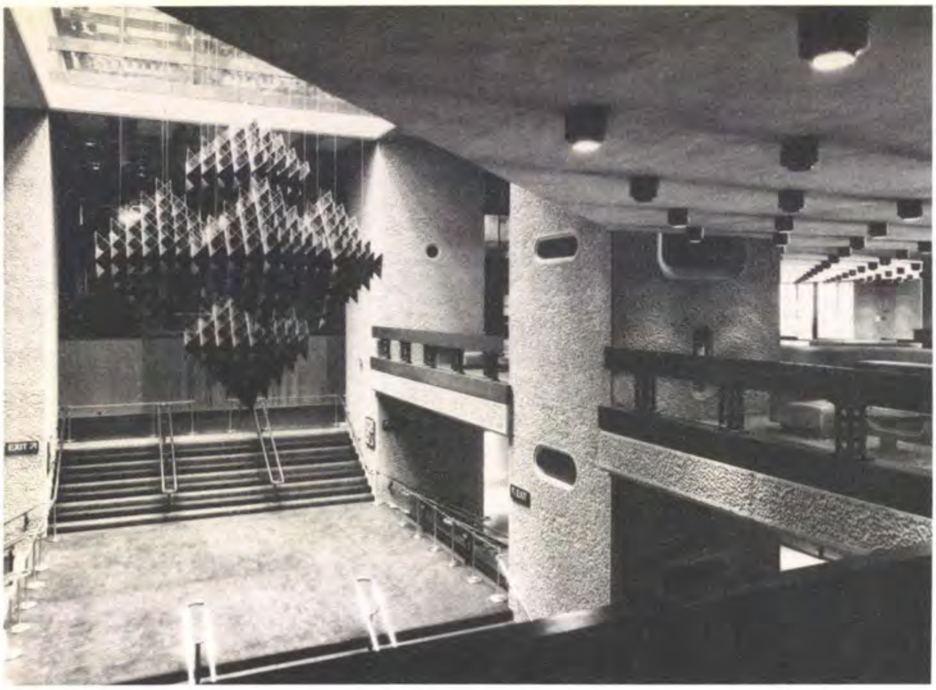


Fig. 3
Interior of concert hall

Fig. 4
Interior of the conservatory

Fig. 5
Main entrance to the Arts Centre

Fig. 6
Artist's impression of the Arts Centre

(Photos : 1-5, John Laing Ltd.)

The art gallery is on two levels, the lowest being on the same as that of the roof to the concert hall which is intended to be used as a sculpture court. The upper level avails itself of controlled roof lighting, and is arranged in a series of separate but interconnected bays of different sizes. The art gallery is to be equipped with a demountable display system to provide as much flexibility as possible in the arrangement of exhibits.

Catering

Various restaurants are arranged as a compact group to the south of the theatre, overlooking the Barbican Lake. A cafeteria is provided adjacent to the lakeside terrace which will also be used as an external extension of this facility. Above this are another three restauants of differing size and standards of service, the highest priced restaurant being at the upper level overlooking St. Giles Church and St. Pauls Cathedral to the south and the Conservatory garden to the north.

All restaurants are interconnected by means of lift and serveries with the kitchens beneath.

Frobisher Crescent

The concert hall roof/sculpture court is enclosed by a semi-circular block which contains conference facilities and which is linked by means of lifts and stairs with the concert hall, which is also to be used as a conference hall. The two lowest floors of this block contain a number of seminar rooms, and two cinema/lecture rooms. The middle two floors will be let as offices and the upper two floors provide accommodation for the City University School of Business Studies.

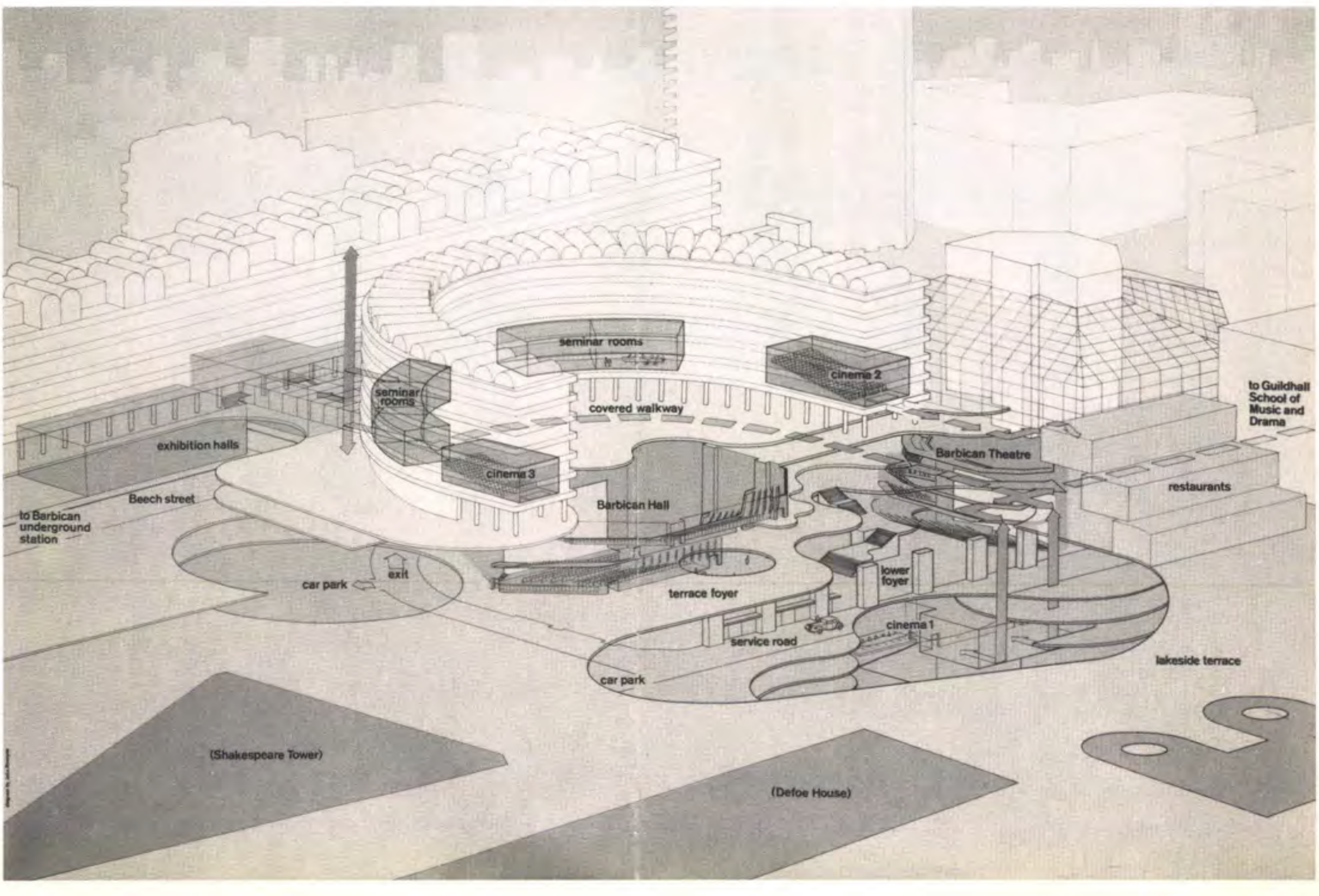
Credits

Client:
The Corporation of London
Architects:
Chamberlin, Powell & Bon (Barbican)
Structural engineers:
Ove Arup & Partners
Services engineers:
Buckle & Partners
Quantity surveyors:
Davis, Belfield & Everest
Acoustic:
Hugh Creighton
Auditorium seating:
Robin Day
Waterproofing:
Arthur Smith
Theatre equipment:
Theatre Projects Consultants Ltd.
Audio visual:
Michael Holden
Main contractor:
John Laing Construction Ltd.

Editor's note

This article is based on material supplied by Chamberlin, Powell & Bon.

6



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