THE ARUP JOURNAL

25TH YEAR

SPRING 1990

THE ARUP JOURNAL

Vol.25 No.1 Spring 1990

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

Editor:
David J. Brown
Art Editor:
Desmond Wyeth FCSD
Deputy Editor:
Caroline Lucas

Contents

Front cover:
Stansted Airport Terminal by Ben Johnson

Back cover:
Afprint textiles (see p.29)
(Photo: Peter Mackinven)

Foreword

Povl Ahm

Chairman
Ove Arup Partnership

Photo: Harry Sowden

The Arup Journal is now beginning its 25th year. It is difficult to believe, since it seems only yesterday that Peter Dunican wrote his 'personal view' on the occasion of 10 years of the *Journal*. At least it seems only yesterday to me. To some of our younger members it may seem like an eternity.

Sadly, Peter is not here to help to celebrate the birthday of what was so definitely his baby. His love for communication and his commitment to this publication was essential for the creation of *The Arup Journal* in the first instance, and for its continued existence and growth over most of its life. Fortunately, he has not been alone in this effort. Rosemary Devine saw *The Arup Journal* through its first difficult years. Then Peter Hoggett took over as Editor in September 1968 and managed the difficult task of not only maintaining the high standard that had been set from the beginning, but in fact developing and improving it through almost 20 years in charge.

He was not alone either, but was helped by David Brown as Assistant Editor for most of these years. David has been Editor since Peter Hoggett left and will now face the even more difficult task of seeing the *Journal* through many more years, continuing the development without losing its essential character. I have every confidence that he will succeed, no matter how difficult it will be.

Throughout the life of *The Arup Journal*, Desmond Wyeth has been Art Editor. He has managed to maintain a very high level of design without standing still in any way. Desmond's sense of perfection is such that there was always the danger of the *Journal* looking so immaculate that it could become visually dull. I do not think we have fallen into this trap, though we may have come close once or twice.

In tribute to the first 10 years Peter Dunican expressed his concern: 'This I suppose is now the central difficulty which confronts us: how to maintain and improve on the standard which has been set?'

I think this has been achieved, but we must now address ourselves to this task for the next 25 years. Right from the beginning my personal worry was that the *Journal* would absorb all our energy for writing papers, so that we would fail to publish our efforts in the appropriate technical or architectural journals. There were certainly signs that this could happen, but in recent years our quality and skills have developed so enormously that we have had no difficulty in achieving both. Also we seem to have developed an ability to adapt specific papers for outside journals into more general and rounded papers for *The Arup Journal*.

It would be too much to list the papers we have published since the beginning — even the most important ones. But I think it is worth mentioning that since 1966, when we undertook mainly structures for buildings, we have extended our spectrum to services to buildings, to Total Architecture, bridges, civil engineering in general, and industrial engineering. We have also opened more offices in many parts of the world.

All this development is obviously reflected in *The Arup Journal*, which has also expanded into colour in recent years. The first colour cover came out in spring 1985, and the first full colour issue in autumn the same year. Since then they have all been in colour. It might be argued that black and white can occasionally be more satisfying from an artistic point of view, and indeed is still used when appropriate, but that is only one of the criteria for the *Journal* and there is no doubt that colour has added another dimension and improved the clarity of the presentation.

Though this is not intended to be a specific 'Birthday Issue' it nevertheless contains more articles and more pages than usual. Also the Editor has tried to make the representation as broad as possible. Over the years the *Journal* has included both large and prestigious projects and small ones with unique or particularly interesting features, as well as articles of a more personal or philosophical nature. All three types are deliberately included.

I am sure that you will feel that this is an issue worthy of the occasion and I wish a bright future for *The Arup Journal*, the team which produces it and the firm and its people who produce the ideas, the thoughts and the projects which determine the quality of the content.

Structural engineering: Some social and political implications

Peter Dunican

Peter Dunican died on 18 December 1989. This was his Presidential Address to the Institution of Structural Engineers, delivered on 6 October 1977 and originally published in The Structural Engineer, 55*(12), December 1977. The tone of voice and style of argument will be familiar to the many people who knew him. For the greater number who did not, it is to be hoped that it conveys something of a unique personality and engineer.*

To many minds, structural engineering seems to be limited to the conception and analysis and detailed embodiment of structural systems. And there is no doubt that this is the very core of our science. Obviously the art is concerned with the application of the science, but it is also concerned with wider issues; social and political issues such as the particular purpose for which the system is intended, the need for it, the resources which are required to realize it and the consequences of its realization. And also, even if in self interest, creating a demand for buildings which need the sort of structures which we would like to design.

Structural engineering is a social art which is dependent on technology, but it is the wide range of the technological possibilities which cause some of our present-day problems, and which require the wider involvement of the structural engineer, particularly with respect to their consequences. This range of choice, both in principle and in detail, requires a very careful evaluation before we commit ourselves finally. Technology can confuse simple issues and, through this confusion, design can be made much more difficult than it has to be.

Structural engineers, I hope with clear minds unconfused by excessive education, are essentially concerned with design. Design is a step-by-step process proceeding from analysis through synthesis to evaluation. If the evaluation is unacceptable, the whole process must be repeated until an acceptable result is reached.

Design is repetitive; design is invention and invention requires imagination, inspiration and intuition perhaps even more than it requires knowledge of the available means to realize it, the design that is. But no designer should proceed with a design unless he knows a sensible way of making what it is he is designing.

To find out about what means are available is mainly a matter of time, patient enquiry and experience. The mathematical analysis of the structural system can also be separated from the conceptual synthesis and the reasons for its existence, but only at some risk to the quality of the result. However, the ultimate quality of the result is very much dependent on the breadth of the designer's understanding and his capacity for being inspired. Here it is implied that inspiration is a special point in the rational process, which it is quite impossible to anticipate, despite the imperative need for it.

Nevertheless, invention, imagination, inspiration, and intuition are gifts which need to be invoked, if not provoked, if we wish to achieve an acceptable result.

But what causes this provocation or stimulation? What makes structural engineers try to do things which may be difficult it not impossible? Enthusiasm, often in the face of ignorance, is one possible and plausible explanation. On the other hand there is the human urge to pursue ends which are apparently beyond our wildest dreams. But for what purpose? The uplifting of the human spirit — to satisfy our personal pride; the incentive or incitement to penetrate the prevailing boundaries of our individual and collective knowledge or ignorance; to achieve the apparently impossible — that is the realisation of dreams, architectural more often than not, but dreams nevertheless. The best example which comes to mind here is the Sydney Opera House, but there are many others which we can all think of.

I believe that it is the desire to advance knowledge and understanding and to challenge the status quo which most strongly motivates us to achieve ends which, for one reason or another, have been considered extremely difficult, if not impossible to attain. I would like to think that the triumph of the human spirit is also very much concerned with the challenge of ignorance and the desire for individual success and affluence. These are powerful forces which, through commitment, can establish yardsticks to measure achievement. Perhaps commitment, or what might be called caring, is the most potent factor, particularly when it is allied to inspired leadership, which can certainly stimulate individual effort to rise above its natural limitations.

We need to be continuously challenged by the total demand which is made on us. And this is what structural engineering is all about — the impossible task of creating the perfect structure — an objective to which the members of this Institution — and who are in fact the real body of the Institution — are totally committed. But what is the perfect structure? Certainly it must be aesthetically acceptable; affordable, buildable, suitable and stable and above all needed. But how do we bring it about? What means do we have to realize these aims and objectives,

Two of Peter Dunican's most important Ove Arup & Partners projects of the 1950s/'60s.

1 (above). TUC headquarters, Great Russell St., London W1 (Photo: Peter Mackinven)

2 (left). Crystal Palace Sports Centre (Photo: Poul Beckmann)

particularly if we recognize that as engineers we are not very articulate collectively, despite the fact that some of us talk quite a lot, if not too much.

We must appreciate that in the most general terms buildings represent the main reason for our being. If there is no building then there is no structure, and equally, it is very difficult to imagine a building without a structure although, of course, this may not be impossible if you have the right sort of imagination. But generally a structure which has no purpose can only be regarded as a folly.

There must be an acceptable reason for the existence of any structural system. Structural systems are realities which exist for a purpose. They are not myths to satisfy the intellectual interests of academics or the calculating curiosity of technologists or to pander to the possible tastes of unpredictable patrons.

The simplest example which I can give now of what I mean about acceptable reasons for existence — and which has been given before — is not a building but a bridge, a road bridge across a river. This could be and should be designed by a structural or civil engineer, but there are some initial questions which must be answered before it is necessary to actually start designing the bridge.

For instance, the authorities presumably require the road to join two points, but is such a road really necessary? What sort of traffic would it be required to carry during its lifetime? Is this the best route for it to follow? Does it have to cross the river? How does it fit in with the other systems of communication, not only locally but regionally, and if necessary nationally; and what effect will it have on them? How much is it going to cost? How will it be paid for and what are the social and other benefits arising from such spending? What other resources will be needed and above all what impact will it have on its environment? Given time to think there may well be other pertinent questions. Certainly, the idea that a well designed bridge sited in the most favourable position could be aesthetically pleasing is not sufficient to satisfy any searching enquiry.

Eventually, sooner rather than later, we hope it will be decided to build the bridge and then it will be necessary to begin its detailed design, not only structurally but also aesthetically. The aesthetics are most important because of the environmental consequences. The design will then have to be built. The way it is built should be determined by the designer but the actual building of it will be managed and organized by the contractor within the designer's conception.

So the role of the structural engineer is limited, although it is not necessarily a subordinate one within the totality of the situation.

But how much should he be concerned with the social and political issues; deciding whether or not the bridge should be built? I would argue without reservation that if he thought that the bridge was not necessary or desirable then he should oppose the building of it even if this could lead to his own redundancy. It is this fundamental purpose, the purpose for which the structural system is intended, which must be the central concern in the first place.

We are not here to design any structure which is demanded of us; we do have a choice. But we do exist to meet the needs of our society. So there could be a dilemma or a conflict, which in the end only we can resolve for ourselves individually and collectively. Perhaps our Institution should provide more guidance on this sort of issue as it is very much a professional one to which much further thought must be given. It does have political overtones which could be most controversial and possibly polarizing, Institutionally speaking that is.

But we are seeking the total intellectual, emotional, political and social commitment of our members to our society through their professionalism. These questions are not usually discussed by engineers, at least not as engineers within the walls of their Institutions, but nevertheless they do bear on the important question — to what extent should an engineer consider the purpose for which his particular skill is required, having regard to the nature of the project? This concerns the very essence of professionalism and here I would like to be guided by what Prof. R.H. Tawney had to say in 1923 in *The Acquisitive Society:*

'A Profession may be defined most simply as a trade which is organized, incompletely, no doubt, but genuinely, for the performance of function. It is not simply a question of individuals who get a living for themselves by the same kind of work. Nor is it merely a group which is organized exclusively for the economic protection of its members, though that is normally among its purposes. It is a body of men who carry on their work in accordance with rules designed to enforce certain standards both for the better protection of its members and for the better service of the public.'

'The standard which it maintains may be high or low: all professions have some rules which protect the interest of the community and others which are an imposition on it. Its essence is that it assumes certain responsibilities for the competence of its members or the quality of its wares.'

'The rules themselves may sometimes appear to the layman arbitrary and ill conceived. But their object is clear. It is to impose on the profession itself the obligation of maintaining the quality of the service, and to prevent its common purpose being frustrated through the undue influence of pecuniary gain upon the necessities or cupidity of the individual.'

'The difference between industry as it exists today and a profession is, then, simple and unmistakable. The former is organized for the protection of rights, mainly rights to pecuniary gain. The latter is organized, imperfectly indeed, but none the less genuinely, for the performance of duties. The essence of the one is that its only criterion is the financial return which it offers to its shareholders. The essence of the other is that, though men enter it for the sake of livelihood, the measure of their success is the service which they perform, not the gains which they amass.'

So much for Tawney. It must be obvious that the essence of any professional relationship is integrity, mutual trust, confidence and competence. Ideally what one would like would be for industry to fall into line with the professions, or at least the way in which some of us think the professions should be; not necessarily what they are. We are all professionals even if we are not all consulting engineers in private practice. Nevertheless it is worthwhile spending a minute or two considering the consulting engineer.

In my own words, the consulting engineer is an independent, qualified, professional engineer, who gives advice and opinions on engineering matters; who does not have any pecuniary interest in or derive any financial benefit from the client he is advising, and to whom he is completely responsible. His main qualities are his engineering knowledge, experience and personal integrity which are usually established by his academic and professional qualifications and standing.

This does not mean to say that he is incapable of making mistakes, but it does

Some post-war housing schemes closely associated with Peter Dunican.


3


4


5


6

3. Rosebery Avenue, Finsbury.

4. South Island Place, Lambeth.

5. Roehampton Lane, Wandsworth.

6. Bishop's Bridge Road, Paddington.

(Photos: 3, 5, 6: Ove Arup & Partners; 4: Poul Beckmann) establish a basis upon which society can make a judgement upon him. But to reach a balanced value judgement, that is a judgement as to whether or not a particular skill, experience or ability has been properly used, may well demand a second Solomon.

Nevertheless, this is the only way in which our society can in fact reap the full benefit of the professional skills and experience available to it.

We must not allow ourselves to be dominated by technocrats or bureaucrats.

To quote Krishnamurti, 'the ends are not achieved by any means, rather the means are the ends, so therefore we must be equally concerned with means as with ends.'

But the professional engineer must be concerned with the ends as he has always been concerned with the means when, for instance, directing 'the Great Sources of Power in Nature for the use and convenience of man.'

The fact is that our society has not yet established any sensible and satisfactory way of deciding between equally desirable but conflicting ends. Presumably it is reasonable to argue, particularly in a social democracy, that the community should decide on the ends, on how it wants to invest its resources, what it can reasonably expect from people like us, and how to exploit the technologist's advice on the consequences of the possibilities: if we do this, what do you think is the likely effect? and if we do that . . ? . . and so on. In fact is it for us to tell them what we think they should do? Are not they us? But they do not have to accept our advice and they do have the final choice.

Technologists must not dominate the decision making processes of our society, but technologists must speak up and be heard and the problem is how to establish this hearing. It would be quite wrong for us to be forced to find what I would call party political channels to bring our technical views and opinions to bear on governmental decisions; and here it does not help very much either to recognize that different sorts of technologists may have different sorts of views. But they do.

We must set up formal processes of consultation to ensure that our views, as well as the views of others, are really understood and digested before any fundamental decision is made. And here we must particularly emphasize the importance of new ideas, of innovation and of change, and that to achieve more with less is a worthy end in itself.

Nevertheless innovation and change can have unexpected consequences, although they are more often than not unfairly blamed for bad consequences which might have been foreseen if the right foresight had been exercised, or was exercisable.

Here I have in mind particularly a number of different sorts of disasters, crashes, collisions of crashes if you like, Aldershot barracks, Camden girls' school, the Comet, Ferrybridge, Milford Haven, Ronan Point, and Yarra. These are in alphabetical order, certainly not in order of importance or even exhaustive as a list.

All these incidents have something in common which I think is our failure to recognize the initial danger signal before the incident occurred. Certainly such danger signals would have been different in each particular case and probably difficult to recognize.

Nevertheless I think that the signal could have been seen had we been looking in the right direction at the right time. I do not think that in these matters there was some great unknown or unrevealed principle or reason for what happened, needing a Royal Commission to resolve. In my opinion generally they were genuine accidents, resulting from human error.

However, without in any way departing from the 'Pugsley Principle' which I have always taken to mean that accidents are inevitable and necessary if engineering science is to develop, the present situation is unsatisfactory. And it will not change or improve until we, the engineers that is, do something about it. No one else will.

What I think is absolutely unsatisfactory is the way in which political expediency appears to determine the public reaction to a particular incident often when political decision, if not expediency, has given rise to the circumstances which, even if they did not encourage or provoke the incident, were central to its coming about.

On the other hand our response in these sorts of situations is not usually as forthright, or timely, unequivocal or positive as it should be. It is difficult to admit to error, even on a second-hand basis, but as an example in the wisdom of hindsight let us take Ronan Point; do you think that we as a professional body responded as quickly or positively as we should have done to the needs of the situation? I do not and I was certainly very central to our response. At no time in what was undoubtedly a demanding technical situation in my opinion did we have the initiative. Why was this?

No doubt there were many reasons but above all I think it was because the machinery of the Institution is not geared to respond to this sort of demand. Our committee structure has been evolved over the years to deal with the normal business of the Institution efficiently and economically but not to meet any urgent technopolitical demand or need. I am not implying that we cannot respond to this sort of demand but that we must organize ourselves to do so if we wish to respond positively.

Quite what the cost of Ronan Point has been I do not know but I am sure that it would have been significantly less if we could have stated firmly that this accident was a one-in-a-billion happening which our society must accept just as it accepts, albeit, unwillingly but without too much fuss, the the daily toll of death on the roads. What have we done, what are we doing to convince the public and their political representatives that, despite our technology and our professional skill and integrity, we are human beings and therefore are fallible and that mistakes will and do occur? Clearly not enough. Only hindsight is a certainty.

However I do not care to contemplate what would have happened following Ronan Point if we had not responded as we did, inadequate as our response may now appear to have been.

We must do more to inform the politicians about the technical consequences of their possible decisions, and therefore to be willing to expose our limitations. We are not politically impotent, nor are we omniscient, but neither are they. Engineers and technologists are not always right as has been well demonstrated, but neither are the politicians.

We must all try harder.

Our approach to matters of public policy must be honest, realistic, logical, positive and of course professional, but we must reject any solution which is proposed for its own sake.

Our society has its own culture and so does each of us individually within it, although with subtle differences. These differences normally do not matter but they can do so under stress and so it is with Institutions. When external difficulties arise, Institutions tend to align themselves with establishment views replete as they can be with expediency; or what are thought to be establishment views, which do not only lack logic and technical justification, but which in fact may not exist at all — in a collective sense that is — because of lack of stimulation or because no technical input from the Institutions has been forthcoming to catalyze it.

In theory I am opposed to lobbying but in practice, with our present system, there does not appear to be any alternative, if we are to make known our opinions in any meaningful manner to those who should be in receipt of them.

My personal dislike of lobbies stems from my belief that they exist to further sectional interests rather than the interests of the community. The sort of lobby I would support is not intended to advance any specific cause but to inform the decision makers about the facts of the matter as we see them, the available options in given technical situations and the foreseeable consequences of adopting one solution or another. We have no more right to be heard generally than any other group but we do have a responsibility to present our professional view. We must leave the decision making to the elected decision makers but we must do all that we can to ensure that their decisions are based on the best possible information. Present decision making with respect to our industry seems to be based mainly on political expediency. This is not good enough. We do have some responsibility to inform and to inform each other. If you want me to know about you and what you think, then you must tell me. You cannot expect me to ask, particularly if I don't know what you can offer me in response to what I am seeking. On the other hand no longer is it reasonable for us to accept political decisions made without reference to the technical consequences.

So I would accept lobbying, provided that it does not inhibit the freedom of the individual to act independently. Then you do have to make sure that you are in the right lobby. And here I believe that our Institution must review its position. Firstly, so far as our individual position is concerned, we must assume that we can agree on a viewpoint and that we can put it over effectively. Secondly, in a collective situation, we must establish the necessary cohesion and concordance with our partners to initiate and ensure a worthwhile lobby. And it is here that we have another problem. Who are our partners? Academically our affinity is mainly with the other engineering institutions but in everyday practice we must be part of the building and construction lobby.

We need to strengthen our relationships, particularly with the architects, the builders, the quantity surveyors and services engineers, not only out of enlightened self interest but to stimulate and strengthen the industry's response to the community's need for guidance, help and advice when it is establishing its building requirements and the way in which it would like its resources to be used. Strengthening these industrial links need not be at the expense of our engineering Institution connections where they exist to achieve different objectives. We cannot afford to neglect either avenue so we have to learn to live with an inbuilt ambivalence. This should not be too difficult, provided we recognize its existence and the reasons for it.

Also we must strengthen our building connections because of the significance of our role in the building process. Building must be dominated by design if it is to realize its primary objective of meeting the needs of the users of the buildings. The fact is that design is the single most significant part of the building process. How can you possibly get the right sort of building, unless you have the right design to begin with? And the design cannot be right to begin with unless it relates also to the available processes of production, which is simply its buildability within the existing constraints.

It is here again we have an important role to play, apart from reducing the constraints. We must convince our users that our primary contribution to the building, that is its structural design, is significant, because it can and does impose order and stability on the realization of the project.

Unfortunately some of our newer customers, which we need if we are to survive, do not appear to be as concerned as they should be in the quality of design. To put it crudely, to them the cost of making the design is much more important than the cost of what is being designed. This is despite the fact that what is being designed could well be very much more expensive than the alternative solution which might cost more to design but far less to build.

We are in a competitive situation, and certainly I have no objection to design competitions. Why should I, particularly if I think that I am a good designer? But such competitions must be conducted on a proper and equitable basis which must include an assessment of the quality of the proposed design. If an equitable comparison based on appropriate parameters cannot be ensured, then design competitions can only be to the disadvantage of the client, and to us.

But there is another factor in the current situation which must concern us. This is the effect the present shortage of work and the resulting competition can have on our professional standards, exacerbated by the fact that we are operating now in alient market places which have significantly different standards from the ones which we have been accustomed to; not better or worse necessarily but different. I do not automatically believe that our ways are best, but I do believe that it can be very difficult, if not impossible, to give these new clients the advice which they should have, if as a consequence the agreed fee, a fee which inevitably has been the subject of some hard and possibly erratic and unpredictable negotiation, will only barely cover the cost of the basic design and certainly will not allow any adequate investigation and consideration of alternative design possibilities. Only instant design solutions are acceptable despite the consequences. Economic forces are not helping us at all. I am beginning to question whether they ever did or ever will.

However, this is a commercial as well as a professional issue which must be kept under continuous review. It is not a matter which requires immediate or direct action by us, but on the other hand we must do all that we can to safeguard the overall concern of our members, who are both employees and employers with common professional interests. This I believe we can do by not deviating from our professional standards and very simple rules of conduct on the one hand, and on the other hand by ensuring that the work of our members is to the highest possible technical standards. But how do we do this? I have not yet heard of any member of our Institution being disbarred or suspended because the Council thought the technical standard of his work was not good enough. We seem to be much more concerned about soliciting and the like. So if we as an Institution wish to have any real public credibility we must actively concern ourselves more with the quality of the professional performance of our members.

In other words, we must be willing to judge ourselves on technical as well as on other professional matters without waiting to be pre-empted externally and being publicly forced to do so, or to accept the dictate of some overall public authority or inquiry. For instance, if we see a structure, ill conceived, badly designed or detailed by a member, at least we should be able to discuss the matter within the Institution without rancour or recrimination or prejudice.

How else can we publicly maintain the credibility of our Institution to ensure professional standards, which is one of the very reasons for our existence?

I think we have to be continually demonstrating the need for our existence as an Institution. We cannot afford to rest on our achievements. We must show that we are continuing to meet the needs of the society which we exist to serve. Also we must expect our *raison d'être* to be continuously challenged. If we believe in ourselves and we are competent, we should have no difficulty in justifying ourselves. But we must be competent, technically that is, and most sensitive to the needs of our society; and with a properly developed and sensitive social conscience — which we must listen to if we are to ensure that our technology is to be devoted to the service of man.

△7

7. The Barbican scheme, City of London. (Photo: Harry Sowden)

8. Royal College of Physicians, Regent's Park, London. (Photo: Peter Mackinven)

8▽

So we come back to the beginning. Structural engineering is not only concerned with the conception of structural systems, their calculation, construction and stability, but it is equally concerned with service; service to the community, ensuring that our society is adequately informed about what we can do for it and about the structural possibilities which are available to meet its building needs, the consequences of using them and perhaps more arrogantly what we think its building needs should be, having regard to the means available.

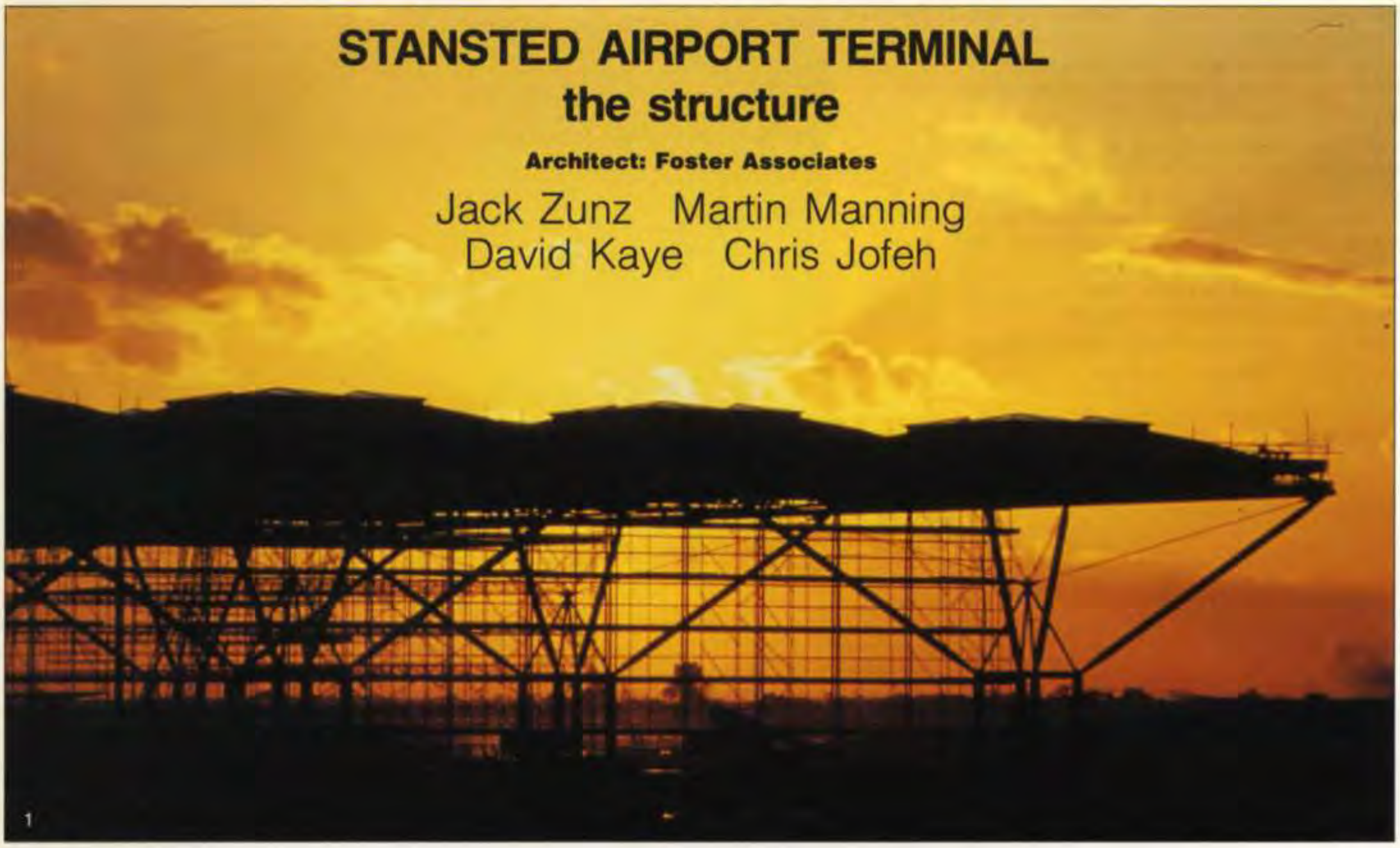
Ultimately, however, we must be concerned about our competence and our integrity and our ability to respond professionally in what could be adverse, unknown and unforeseeable circumstances significantly different from those which we are accustomed to working within.

Only we can maintain our standards in these difficult circumstances, and the initiative to do so clearly rests with us.

STANSTED AIRPORT TERMINAL
the structure

Architect: Foster Associates

Jack Zunz Martin Manning
David Kaye Chris Jofeh



1

Introduction

In 1942 the United States Air Force built a military airfield at Stansted, north-west Essex, for World War 2 bomber operations. After the war, the base continued as a civilian aerodrome, but in 1952 the USAF returned and extended the runway. In the following year, the British Government decided that London's principal airport should be Heathrow, with Gatwick as the main alternative and Blackbushe the first reserve. A notional role for Stansted was retained, however, in the event of any unexpected increase in air traffic.

The USAF finally withdrew in 1957, and four years later an interdepartmental Government Committee was set up to look into future airport provision. In 1964 it reported not only that a third London airport would be needed by 1973, but that Stansted was the only one of 18 sites that was clearly suitable. In the following year, a public enquiry into Stansted's development opened, which duly turned down the proposal and recommended a much wider review. As a result, the Roskill Commission began its public enquiry into both the need for, and the siting of, a third London airport, eventually shortlisting Cublington, Foulness, Nuthampstead, and Thurleigh. Stansted was discarded as an alternative, and Cublington selected. Professor Colin Buchanan, however, favoured Foulness, and following his lead the Maplin Development Authority was set up in 1973 to reclaim Maplin Sands off Foulness Island as both an airport and seaport.

In 1974 the new Labour Government reviewed Maplin and speedily cancelled the project, taking into account both the oil crisis and the increased use of widebodied aircraft.

After only two years, however, the Government began to look again at airport strategy and in 1978 produced a White Paper which argued that further capacity would have to be found by 1990.

During the '60s Stansted had increased its capacity greatly. By 1968, when the Roskill Commission was set up, its traffic had increased tenfold to 147 000 people p.a., and the opening of a new passenger terminal the following year resulted in almost half a million passengers passing through in 1970.

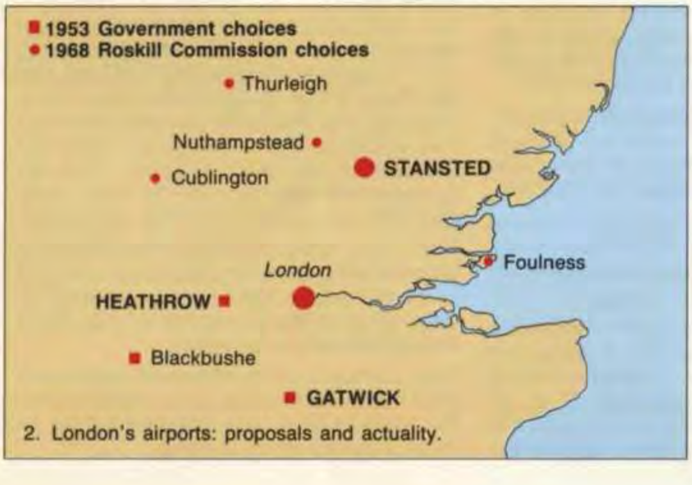
In 1979 the new Conservative Government, after a further study, selected Stansted as the most promising option for the third London Airport and announced the intention for it to expand to a capacity of 15M passengers p.a. Foster Associates were appointed as architects to carry out preliminary studies for the terminal building, with the primary objective of having ready a viable scheme if and when Parliamentary approval was given, so that adequate facilities could be available to meet anticipated traffic demands in time. Ove Arup & Partners were appointed as the consulting civil and structural engineers for the terminal building in February 1981.

The public enquiry into the proposals opened on 29 September 1981 and sat for a total of 258 days. Various other options were duly taken into consideration, but in 1984 the Inspector issued his conclusion that, while regional airports should be expanded, they could not meet the needs of the south east and that the major expansion of Stansted should go ahead. Despite further concerted protests, the Government gave the go-ahead to a compromise first phase expansion to 8M passengers p.a. and construction commenced on 15 April 1986.

The brief and the planning response

The brief for the terminal building was to create a potential capacity of 15M passengers p.a., and so it was decided that the building was to be constructed in phases.

BAA planners had developed a number of different planning schemes for the terminal building, but consideration had still to be given to integrating these with transportation planning on both land and airside, the layout of the terminal zone with the necessary ancillary buildings, and the site conditions. Particular attention was to be paid to the size and scale of the building in the landscape.



2. London's airports: proposals and actuality.

3. Location plan.

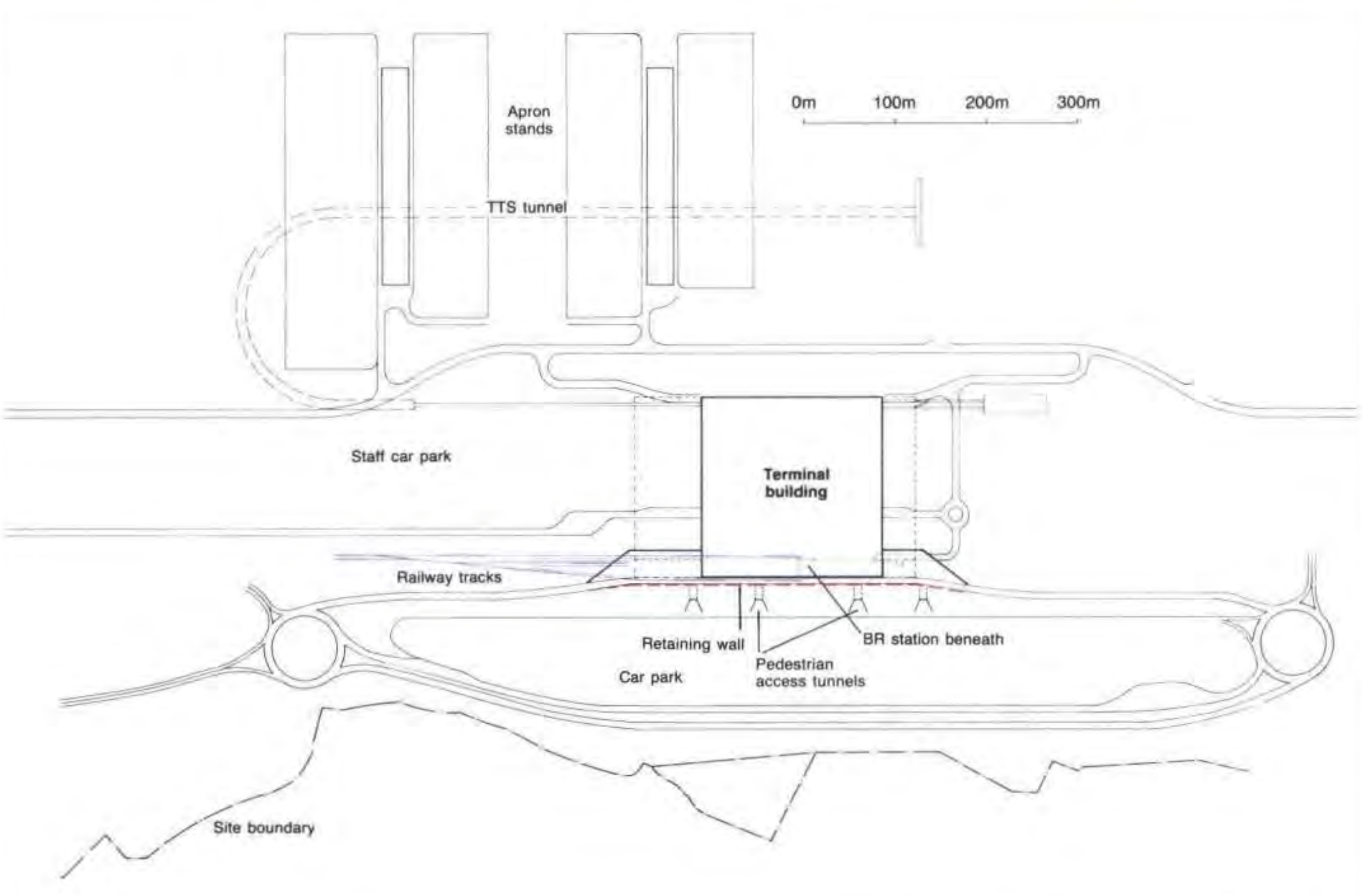
The decision to develop Stansted (at that time a greenfield site) into a major international airport enabled BAA's expertise in planning terminal and support facilities to be deployed from first principles.

The brief contained two key principles: firstly, the plan had to be flexible so that, as air transport technology and fashions changed, the building would be able to respond to changing needs; secondly, the movement of passengers through it should be as simple as possible, making the terminal calm, clear and convenient.

BAA also set cost targets below those of comparable terminal buildings.

4

4. Aerial photograph showing the Terminal site.



5

5. Site plan.

A quickly established planning principle was that the building should be arranged so that passengers could continue to move in one direction and remain at one level. The existing topography of the site held a clue to this.

At the likely terminal access point, existing ground level was firstly some 6-7m above what had already been established as the appropriate level for the main apron, and secondly, fell towards it. Thus, to enter the terminal at the existing ground level and remain at that level while moving towards the planes seemed to be a good starting point and one which reflected the existing topography.

A second principle was to keep the passengers' walking distance from the entrance of the terminal to the point where they left it for the planes as short as possible.

The architects developed a master plan for the terminal area, based on zones running parallel to the main runway. Any further expansion of the terminal building can take place from either end of it within these parallel zones.

The form of the terminal building

The passenger concourse consists of four parts: departures and arrivals, both divided into landside and airside. The depth of the building (162m) was determined by the maximum desirable walking distance, and by the distance necessary to allow a check-in point and an inclined ramp (taking baggage to a 60m-long baggage hall below) to be arranged in a straight line. The width of the building was determined by its capacity.

The check-in desks are arranged so that the passengers can then move on through passport and security checks to departures in as uninterrupted a manner as possible.

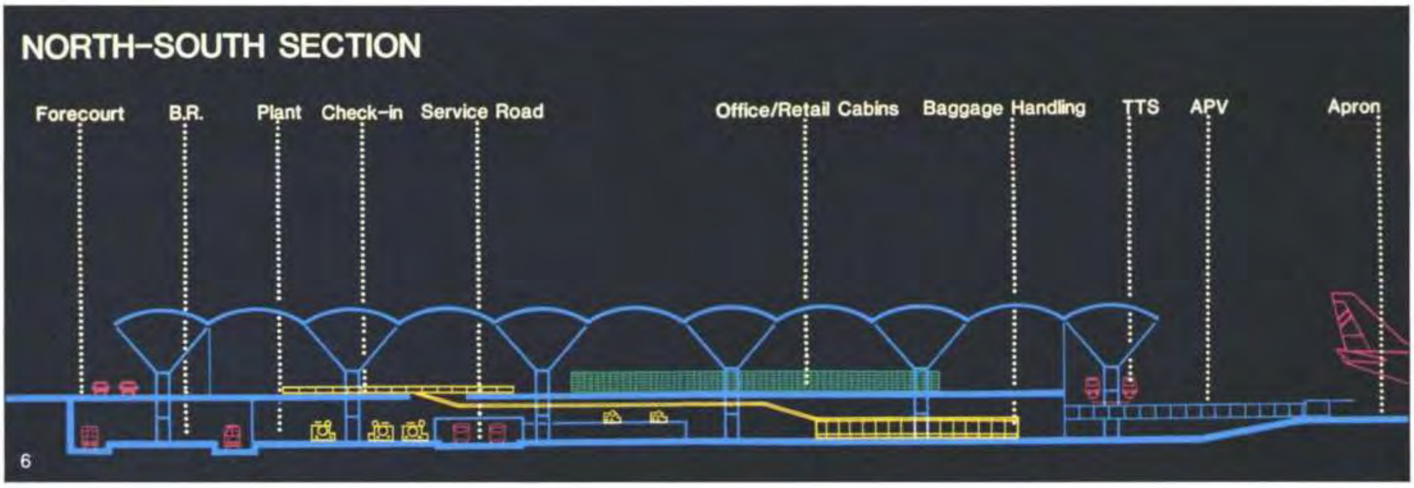
After studying a number of grids, a proposal for a column spacing of 36m in both directions for the roof over the passenger concourse was accepted.

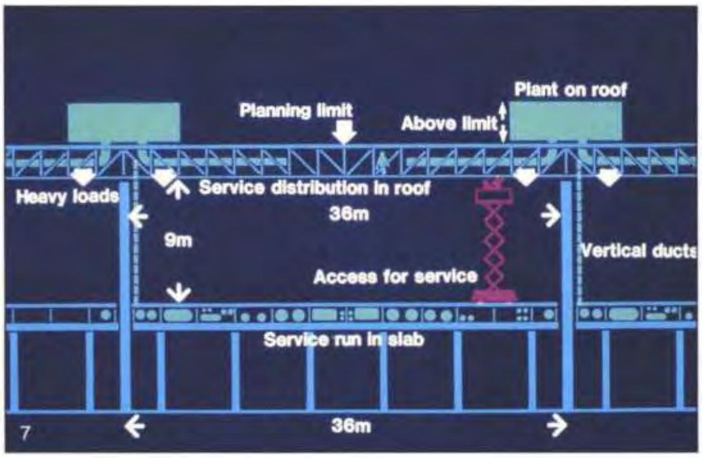
All engineering support to the concourse area, in terms of the plant for building services as well as the baggage-handling machinery, is located beneath it in an undercroft. The site levels encouraged this arrangement, which also allows easy access to the undercroft for service vehicles at a level different from that occupied by the passengers.

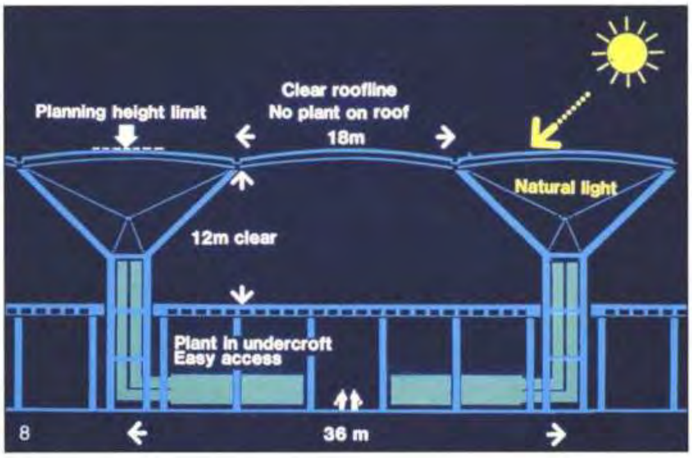
For architectural reasons, a single-level open concourse of this size needs to be high, even though environmentally only the bottom 3m or 4m needs to be controlled. It was proposed that this could be done effectively from points on a grid, similar to that for the columns of the roof structure. Such an arrangement also seemed to allow easy planning and replanning of the concourse.

The design of the roof structure thus had to respond to the span, the height, and the need to accommodate the building services requirements at the grid points without dominating the concourse space.

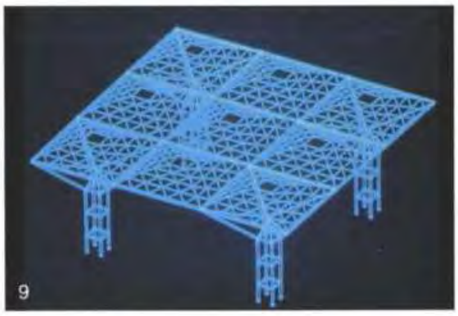
One consequential benefit to the passengers of all this is that they can see the planes from the moment they enter the terminal — an early objective of the architect.







6. North-south section.
7. The conventional solution.
8. The Stansted solution.
9. Foster Associates' computer illustration of roof structure.



Fire safety

One of the issues raised by proposing a public space 198m long, 162m wide, and about 12m high, is fire safety. Detailed studies for the fire planning of the terminal were carried out. In particular, a substantial amount of work on the probable smoke movement within the space was done to demonstrate that escape times were acceptable when related to the amount of smoke which would be generated by a fire on the concourse. The fire strategy for the structure is based on this study.

The form of the structure

The structure obviously has to support the building but, in one of this size and quality, it has to do a number of other things as well. Firstly, it must define the scale of the public space. Secondly, it should be conceived and detailed to take maximum advantage of offsite prefabrication and onsite pre-assembly at ground level. Thirdly, it needs to respond to a construction sequence which can proceed as independently of the weather as possible and on a number of fronts across the building.

Construction sequence

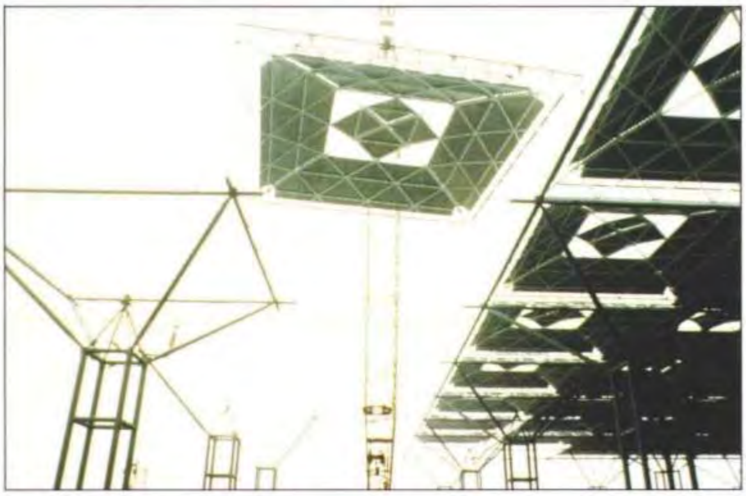
12. Trunk being erected, June 1987.
13. The branches go on.
14. The grid line beams are positioned and the canopy stressed.
15. Roof shell being transported from assembly at ground level to the tree.
16. The shell is positioned.
17. 14 shells in position; 107 to go!
18. 121 shells in position, June 1988.


12 ◁


13 ▷


14 ◁


15 ▷


16 ◁


17 ▷

18 ▽

After investigations into possible construction sequences to determine the best overall project programme, the one chosen — which was largely influenced by geotechnical considerations, and in its turn influenced the design of the structure — was as follows:

(a) The main contractor for the overall airfield earthworks would carry out bulk excavation over the area of the terminal building to approximately 0.5m above the final formation level with the surface sloped to drain.

(b) The terminal substructure contractor would then profile the excavated area of the terminal building to a tented shape, also to allow it to drain, and install the temporary construction access roads.

(c) Piezometers and wells would be installed to lower the ground-water to a specified level.

(d) The contractor would then construct land drains across the terminal area at 36m centres and begin the foundations.

(e) The erection of the steelwork and roofing could then start, allowing all subsequent construction to take place under cover.

(f) By working in small areas under cover, the remaining overburden was reduced to formation level, a drainage blanket placed (with the top of the land drains being cleaned of any contaminated material) and the ground slab cast.

(g) The concourse was then constructed from falsework propped from the ground slab.

(h) When the connection between the concourse slab and the steel trees was made, the erection of the wall between the concourse and steel roof could start.

In parallel with the above were a number of secondary construction activities:

(i) Precast and in situ mezzanines were constructed in the undercroft, supported on concrete corbels cast with the main concourse columns.

(ii) The steel cabin structures in the concourse were erected with the secondary steelwork within the undercroft.

(iii) Blockwork walls could be constructed in the undercroft in parallel with installing the mechanical and electrical services, and subsequent works.

The main retaining wall along the south side of the terminal building was installed in parallel with the construction of the concourse slab.

Geotechnical constraints

A site investigation was carried out in 1983 to determine the ground conditions. The site consists of the following soil profile:

(a) Top soil and fill between 0.1m and 0.5m thick

(b) Weathered and unweathered glacial till between 13.2m and 26.5m thick

(c) Kesgrave sands and gravels between 0 and 4.45m thick

(d) London Clay between 18.2m and 28.2m thick

(e) Woolwich and Reading beds proved to a depth of 11.4m.

The glacial till contains sand lenses which are waterbearing. The initial investigation did not determine the horizontal or vertical hydraulic continuity of these.

Piezometers and standpipes were placed in a number of the bore holes which showed that the water in the Kesgrave sands and gravels was under some pressure, as was the water within the sand lenses in the glacial till.

A subsequent comprehensive investigation over the terminal site was carried out to try to estimate the hydraulic continuity of the granular soils. The earthworks necessary to provide the undercroft and service areas implied excavation and fill over the area of the terminal building which would lead to movements of the order of 200mm because of heave and 50mm because of total long-term settlements.


19. Pedestrian entrance from car park.

THE STRUCTURE

Considering the size of the building, the number of main structural components is small, comprising the foundations, the ground slab, the main concourse slab and the roof. Underneath the main forecourt, which is itself merely an extension of the concourse slab, lies the British Rail station, along the southern side of which is a 10m high cantilever retaining wall.

The two major components of the structure are the steel roof and the reinforced concrete undercroft. These support a number of secondary structural elements.

The roof structure

Form

The roof structure was always seen as the technical design generator of the building. The strategy was to erect a canopy about 20m high, of which the principal function was to keep out the rain, but in its form and detail provide the architecture for the building. It was also to give cover beneath which the builders could operate. The basic principles for this canopy were:

- The 36m span
- Integration of the 'columns' with the M&E services for the concourse volume
- The main roof elements occupying the upper 8m of the 12m high concourse, but so arranged as to minimize the obstruction to views through it.

Early studies soon converged onto a concept of 'trees' at 36m centres in each direction, but the form and configuration of the structure between the 'trees' went through a long development. Ultimately the structural form was proposed as follows:

(a) The 'trunks' would be square towers, enclosing the service risers for the concourse, founded at undercroft level and extending to about 4m above the concourse slab.

(b) Branches would spring from the top of these trunks so that the roof itself would be supported at 18m centres rather than 36m. While a 36m span is well within the capability of modern engineering, half that span was likely to be cheaper and offer more scope for repetition.

(c) The roof would consist of elements on an 18m square grid, supporting 18m square independent panels which would be pre-assembled and erected whole.

From that starting point consideration was given to:

(1) The ways in which the overall stability of the structure could be provided

(2) Whether the trunks should be pin-jointed and cross-braced, or portal frames

(3) How the bracing in the branch zone should be arranged, whether or not it should be prestressed and, if so, by how much

(4) Whether the gridline beams should be continuous over the tops of the branches or pinned to them

(5) Whether the trunks should be propped by the concourse slab.

Above all, the roof structure had to be economic, despite it being a major feature in the architecture of the building. Additional factors in preparing a solution were:

- The deflections that the roofing and cladding would have to accommodate
- Roof drainage
- Ease of service access within the trunks
- The amount of high level erection access and lifting capacity required
- Perhaps most importantly, what contribution or otherwise the steelwork made to the openness of scale of the whole concourse.

This led to a concept which embodied the following salient features:

(a) The trunks would be fully welded vierendeels propped by the concourse slab which would both allow unrestricted access to the services within them and take advantage of the stiffening which the concourse slab would provide. It became clear that cross-bracing would obstruct the passage of large air ducts into and out of the trunks. At the same time the design of the roof waterproofing was complicated by the need for structural expansion joints. Removing the cross-bracing made it possible, firstly, to provide elegant routing for the service ducts and, secondly, after much analytical work, to demonstrate that the resulting increase in trunk flexibility, while not impairing stability, meant that the structural joints in the roof were not required. The additional weight in the columns and vierendeel members of the trunking was marginal.

(b) The branch sections would be sway-stiffened by two opposed pyramids. The upper inverted pyramid would be formed from prestressed tension members and the lower by members capable of taking both tension and compression. Prestressing the upper bracing kept it small and unobtrusive and by having members in the lower pyramid capable of taking some compression, albeit comparatively little, the forces in the system were markedly reduced, and minimized the increase in size of the branch members.

(c) Each tree, with its 18m canopy, would be self-supporting and provide support for the 18m square infill.

The member sizes are as follows:

- trunk members: 457mm CHS vertically and 356mm CHS horizontally
- branch members: 406mm CHS
- upper prestressing members: two 40mm Macalloy bars each prestressed to 330kN
- lower bracing pyramid members: 168mm CHS
- gridline beams: 323mm CHS


20 ◁


21 ▷

Many solutions were considered for the infill panels in the 18m square bays. These ranged from conventional beam sections to thin aluminium shells, but the one adopted was independent lattice domes consisting of intersecting orthogonal barrel vaults. Thus the cladding could be singly curved. These lattice shells rely on their out-of-plane bending stiffness for stability.

The diagonal arch members are 194mm CHS and the lattice members 114mm CHS.

Analysis

The analysis of the roof structure has assumed that the roof is loaded simultaneously by:

⋆ Its self-weight

⋆ The worst distribution of live load

⋆ The one-in-50-year wind from the worst direction

⋆ A dominant opening on the windward face (if indeed that is critical)

⋆ The worst overall or differential imposed strains due to temperature, settlement or differential movement of the sections of concourse slab. To assess the wind loads, a wind tunnel test was carried out at the University of Bristol. This also determined the profile of the eaves cladding which would trap a stationary vortex around the perimeter of the roof to reduce the Cpe values for which the roof structure has to be designed.

The mathematical models used for analysis included one of the entire roof structure restrained at concourse level by springs for overall behaviour, as well as one of part of the roof which included every member within the structure. Section justification has been carried out to *BS5950*.

Details

For a structure of this size which is fully expressed and which has people close to it, the design of the joint details is critical.

The joints at each end of the branches were the most difficult ones to resolve. Clearly, structural considerations were important and centrelines had to pass through centrelines as far as possible. But for these joints, the architectural hierarchy within the structure was most important in determining their arrangement. They not only had to work, but the way in which they worked had to be both apparent and sensible.

Finishes

The surface finish of the steelwork is important in the architectural expression of the structure. Approved samples of painted tube were made available at tender. To try to minimize the difference between the tube and the joints, the tender drawings showed all the joints as fabrication made from tube and plate. However, the successful contractor proposed that joints should be cast, rather than welded from material to grade A4 to *BS3100*, in order to save time. To assure the quality of the foundry process, a series of prototypes and tests was undertaken to check that it provided both the material strength and the surface finish required.

The steelwork is painted for corrosion protection and difficult joints are silicon-sealed.

Erection

The erection of the steelwork was based on getting it right first time and not on making adjustments at the end of construction. The process used is shown in Figs. 12 to 18.

(1) Shim the gridline beams to achieve a length tolerance of +0 −2mm

(2) Erect and prestress each tree with its trunk, branch and four gridline beams

(3) Jack/push the tree to ensure that the four corners are in an acceptable position

(4) Insert the joining gridline beam.

The first tree was assembled in situ and used as the learning prototype to refine erection techniques. It rapidly became apparent that, when the contractor got the erection and prestressing arrangement right, the prestressing corrected any minor errors in initial setting-out and seemed to be self-squaring.

The undercroft

The concourse

The planning of the basement resulted in two basic column grids for the structure for the concourse floor: the southern half of the building at basement level is occupied mostly by M&E plant and is planned on a 6m square column grid, while the northern half, in which the baggage-handling hall is located, is planned on a 12m square grid.

The planning grid for the accommodation on the concourse floor is 1.2m.

For ease of operation it was decided to suspend most of the baggage handling and servicing in the basement from the concourse slab. The most concentrated accumulation of those loads is also where the heaviest duty-free shop live loads are provided on the concourse. Thus the concourse slab loading is substantial — approximately $14kN/m^2$.

Reinforced concrete was chosen for economy. The floor is a coffered slab, without drops or downstands, with an overall depth varying from 400mm deep for the 6m square bays to 850mm deep for the 12m square. *Visaform* formwork was used for the solid areas and preformed GRP moulds for the coffers. The ribs in each direction are at 1.2m centres with a 125mm thick reinforced topping. The mesh in the topping had to be positioned between the two top layers of steel in one of the rib directions. The contractor successfully found a way of doing this, even though the ribs had closed links, by threading the top bars through later. Service hangers were anchored in steel channels cast into the ribs.

The numerous and heavy mechanical systems supported from these, and the complexity of their distribution, suggests that in similar circumstances a profitable study might be made for an independent steel grillage to span between the columns as the actual service locations require.

Expansion joints are at 72m in the north/south direction and a maximum of 60m centred east/west. Stability is provided by frame action between the coffered slab and the 8m high columns.

In areas of the undercroft, there is a mezzanine floor between the groundslab and concourse slab. At Laing Management Contracting's suggestion the mezzanines were designed to be erected after the concourse was completed, which in the terminal building involved the use of precast concrete. Standard planks were contractor-designed to an Arup performance specification and supported by Arup-designed precast and in situ concrete beams. In the British Rail station, the mezzanines are of in situ lightweight concrete with void formers, supported on steel brackets bolted to the columns.

The groundslab is ground-bearing. Generally it is 175mm thick and reinforced with one layer of mesh in the top. It is cast onto a 225mm thick layer of granular material. The grading of this was modified from DOT type 1 to improve its drainage characteristics. The contractor was required to lay this blanket and construct the ground slab in an area within seven days of it being reduced to formation. The slab was cast in the long strip method with 6m wide strips and transverse crack inducers were placed at 9m centres.

In the permanent case the action of the 225mm thick granular layer and the land drains keeps the groundwater to an acceptable level.

The building is founded on shallow pad foundations to accommodate the heave movements in the glacial till. This heave and potential pore water pressure in the till raised two issues. That of upward pressure on the ground slab was dealt with as described above; that of unacceptable softening of the unloaded formation level for the large pad excavations was dealt with by both a general lowering of pore water pressures in the granular materials across the whole site and a requirement that the contractor should excavate and complete the foundations within seven days.

The British Rail station and forecourt

Access to the terminal at concourse level is provided by the forecourt road which is positioned over the BR station and immediately adjacent to the main ground level car park. The structure of the forecourt is similar to that of the concourse floor with some additional provisions to satisfy accidental damage requirements which flow from BR regulations.

The retaining wall along the southern side of the forecourt and British Rail station supports the forecourt slab and retains some 10m of earth. It is 10m high, 600m long, and consists of 1.05m diameter bored piles at 3.0m centres anchored to piles of similar diameter 20m away. The soil between them is retained by a 300mm thick facing wall, formed integrally with the piles, which has a fair-faced finish with 25mm × 40mm deep rebates forming 3.6m long by 1.2m high panels. A geotextile drainage membrane is placed behind the wall.

22△

23△

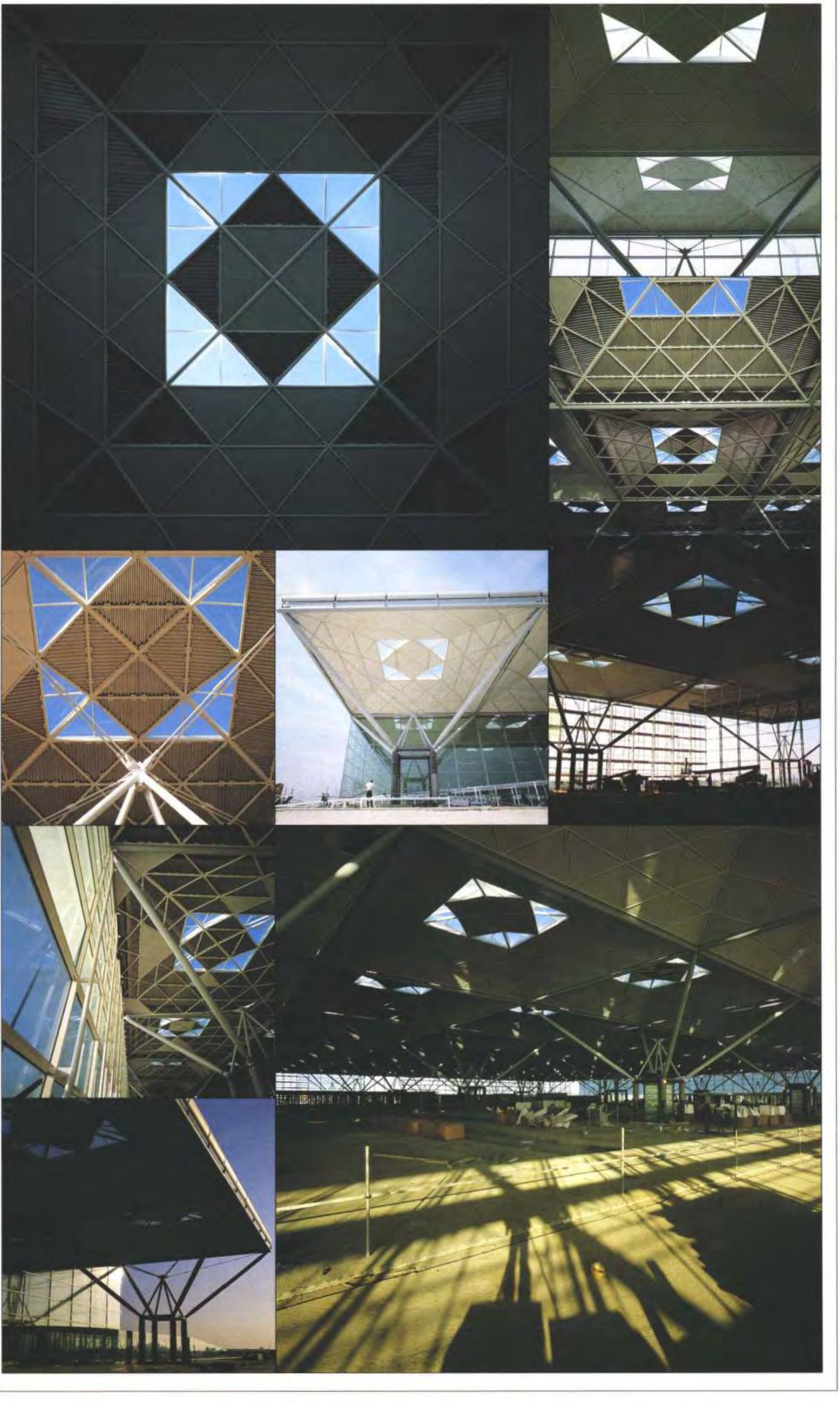
24▽

After constructing the piles the construction sequence was to excavate in front of them with the soil arching between. A reinforced concrete wall was then built, anchored to the front of the piles from the bottom up. The section above the ties was then backfilled against an in situ reinforced concrete wall.

20. Baggage hall beneath the concourse.
21. Retaining wall showing sprayed concrete as temporary works to assist support of the earth face.
22. BR retaining wall showing position relative to the terminal building.
23. Partially completed retaining wall.
24. British Rail station.
25. Forecourt showing glazing over the ramp to the BR station.

25▽

Stansted Airport Terminal



26. Aspects of the structure.

The secondary steelwork

Significant elements of secondary steelwork are associated with the perimeter cladding of the building and the independent free-standing cabin structures which form the enclosed offices in the concourse space. The perimeter glass wall is supported by the concrete slab and spans vertically 12m to the roof above.

Vierendeel mullions are positioned at 3.6m centres with transoms at 1.8m centres. At the mullion head, the roof structure can move in all three directions, but restrains the wall only in a direction normal to it.

In the other two directions the wall is free of the roof. The in plane stiffness of the wall is produced by in plane bracing.

The cabin structures mirror the independent tree and servicing philosophy of the main roof structure. 3.6m square mushrooms are assembled at 6m centres and contain the service risers. Simply supported beams are positioned between them. The roof is formed of woodwool slabs.

THE PROGRAMME

Preliminary designs were prepared during the period 1981-84 when a confirmed scheme design was submitted to the British Airports Authority. A consultant contractor was appointed in 1985. Construction on site commenced in June 1986, tenders for steelwork and some of the reinforced concrete works having been called for earlier.

The construction of the primary structure of the terminal building and British Rail station was completed at the end of 1988. The buildings are now being fitted out and will be completed by the end of 1990. The airlines' fit-out will be completed to allow the first planes in spring 1991.

Credits

Client:
Stansted Airport Ltd.
Architect:
Foster Associates
Civil and structural engineers:
Ove Arup & Partners
Services engineers:
British Airports Services Ltd.
Consultant contractor and construction superintendent:
Laing Management Contracting Ltd.
Photos and illustrations:
1, 3, 4, 6-10, 16, 27, 29: Foster Associates
2: Fred English; 5: Nigel Dore
11, 12, 14, 15, 17-20, 24, 25, 28: Peter Mackinven
13: John Mitchell; 21-23: Steve Hope;
26: Ben Johnson

27. Detail of mullion head.
28. Interior showing secondary steelwork at perimeter wall, vierendeel mullions at head.
29. Completed structure from landside.

27△

28▽

29▽

Liffey Valley Bridge

Bill Smyth
John Higgins

Introduction

The designer writing about the progress of a design is in the same position as an historian. He is trying to give a coherent account of a rather complicated and muddled set of events. Whether the fact that he was an eyewitness of the events puts him in a better or worse position is an open question. The account which follows probably bears about the same relationship to what happened as a conceptual model does to the real structure; in both cases the model is not very good, but we have to make do with it.

The Liffey Valley Bridge is the second major bridge designed by Arups in the Irish Republic, but the first to be built, having overtaken the Shannon Bridge at Athlone. It is the second bridge across the Liffey built by private finance under a toll concession. The success of the first, opened in 1984 to carry a relief road on the eastern side of Dublin, oiled the wheels for ours.

A new, and badly needed, ring road to the west of Dublin forms part of Euroroute E1. The 3.6km length which is being built under the toll concession crosses the river valley near Palmerstown about 8km west of the centre of Dublin. In 1984 Dublin County Council appointed Ove Arup & Partners Ireland to design the bridge across the valley, on the understanding that Civil Engineering Bridges would play the same role as for the Shannon Bridge. OAP Ireland were also appointed for three smaller bridges. During the design of the valley bridge we reported to a client committee chaired by the County Council's Chief Engineer and including representatives of the Department of the Environment and Conor Holdings, a private investment company.

The traffic predicted (in a 1987 study) over the first 10 years of the life of the bridge can be handled by a four-lane carriageway 14m wide. The authorities intend to provide a second bridge in the future, allowing for separate carriageways.

The site

The area, known as the Strawberry Beds, is beautiful and has been designated as a Special Amenity Area. The Liffey is a picturesque small river lying in the bottom of a gently curving valley cut some 45m into the landscape and over ½km wide.

The cross-section of the valley is markedly asymmetrical. The southern slopes are gentle with fields, hedges and belts of trees. On the narrow valley floor there are three roughly parallel features, a millrace, the river, and a narrow road. The predominantly wooded northern slopes rise steeply up beside the road.

The site is underlain by a buried valley carved in the limestone bedrock, covered by glacial deposits which vary considerably in nature and thickness.

1. Location plan showing the Liffey Valley Bridge and the East Link Bridge (the first toll bridge).

2. The Liffey valley with the bridge site in the middle distance.

3. The 1:500 model being used to study the embankment at the southern end.

Design studies

Dublin County Council and the Department of the Environment made it quite clear that they wanted a bridge worthy of the site, as well as one which was technically sound. Conor Holdings obviously were concerned that it should not cost too much.

Arups appointed an architect/landscape architect, Philip Shipman, as a member of the design team and together we defined the following landscape objectives:

(1) The natural flow of the valley topography and views up and down its curving alignment should be maintained.

(2) Piers should be as few and as small as possible and not restrict access along the river banks or millrace.

(3) Spacing of piers should relate to the profile and alignment of the valley, should avoid the river, millrace and road, and should take into account the second bridge to come.

A 1:500 topographical model of the valley around the site was made. This was used to study the effect on the valley of each possibility investigated, including the effects of a second bridge.

Other larger-scale models of piers and part of the deck were used at later stages.

The road alignment established by Dublin County Council was more or less at ground level on the plateau above the steep northern slope and declined southwards at just over 1% over the valley about 45m above the floor, meeting the gentle southern slope some way below the top. The bridge is therefore very much a crossing of the valley, which is seen through the bridge and not over it. The alignment crosses the southern edge of the valley at almost 90° to the slope but to the north, where the curving alignment of the river and the steeper slope are more pronounced, it crosses at about 70°. From certain viewpoints up and downstream the bridge appears to be slightly skew to the valley.

For a bridge in this sort of setting we think it right to underplay the abutments. Because the steep northern slope meets the plateau above fairly abruptly, the position of the northern abutment more or less determines itself. On the gentler southern slope it is necessary to provide a short length of embankment to lift the soffit of the bridge off the ground. The actual position of the abutment was influenced by two things:

(1) The cost of extra embankment (whose volume goes up very rapidly as it goes further down the slope) versus the cost of bridge deck

(2) How the embankment could be shaped to fit the shape of the valley; this was the first exercise with the model (Fig. 3).

Preliminary studies were made of schemes with a maximum of 11 spans and a minimum of four, and with varying positions of the south abutment, taking account of the higher foundation costs in some areas. The cheapest schemes were those with spans of the order of 80m to 90m, although the cost curve was fairly flat to about 70m. As one would expect, the model confirmed that the longer spans with the fewest piers were the least intrusive.

Studies were then made of a number of types of deck, including steel and composite. The cheapest scheme was a prestressed concrete box girder, to be constructed by balanced cantilevering, with haunches which were either straight or curved (Fig. 4). The second cheapest was a similar box girder, but of constant depth. Conor Holdings suggested that not enough account had been taken of the greater simplicity of construction of the constant depth structure. Whether this was so, or not, the constant depth structure seemed to us to offer the possibility of a better solution for this particular site.

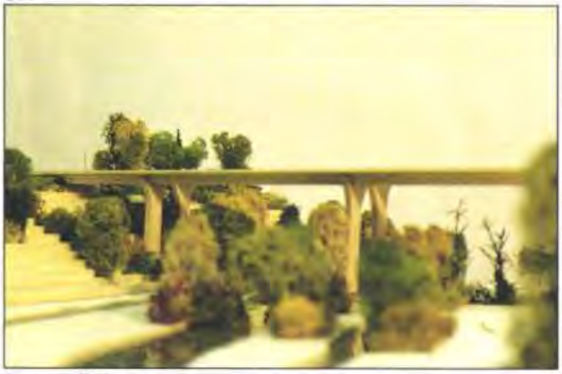
Up to this time the exercises had been based on regular spans. Now by using the landscape model and a crude photomontage made by sticking thin white tape on a photograph of the site taken from a distance, we were able to demonstrate the much-improved appearance obtained by having the longest span over the valley floor with gradually decreasing spans over the shallower slopes, so that there is a rough proportionality between spans and height above ground (Fig. 5). What emerged was a five-span scheme with the longest, of 90m, over road and river, spans of 84m, 75m and 66m going southwards and a 70m span over the northern slope. As balanced cantilever construction is done segment by segment, it lends itself well to this sort of variation, and the contractor can do his learning on the shorter cantilevers. The result is a natural and comfortable progression, without increasing the cost of the structure. The span over the northern slope would look better if slightly longer, but the distance between the road and the top of the slope does not allow it.

The curve of the valley makes the bridge slightly skew to the northern side. The piers are comparatively narrow and far apart and it seems visually acceptable that they should be at right angles to the line of the bridge, and that the piers of the second bridge should be handled similarly. The design of the first bridge is such that the piers of the second could be located in line with those of the first or in a skew relationship. Model studies showed that the relationship of the two bridges to the landscape seems to be most satisfactory when the shape of the valley is acknowledged by the relationships of the piers.

The proposed arrangement (Fig. 7) has the piers in line at the southern end with increasing offsets going northward. The span arrangement of the second bridge is satisfactory for balanced cantilever construction.


4△


5△


6△

4. The 1:500 model with a variable depth scheme, including the second bridge.
5. Photo-montage of bridge with varying spans
6. The 1:500 model showing both bridges with piers rigidly connected to the deck.
7. The presentation model showing the scheme with piers rigidly connected to the deck.

7▽

8

9

Various arrangements for articulating the structure to allow for thermal movements were examined and at this stage it was intended to fix the piers to the deck, and allow them to flex. There would be expansion joints at the abutments only, where the deck would be carried on bearings allowing sliding and rotation. The scheme was, we thought, agreed and the design report had been presented, when Conor Holdings asked that we should look at a scheme with five equal spans of 75m, and also at construction by incremental launching. This produced a scheme which was clearly less satisfactory visually and not acceptable to the other members of the client committee. After some hard discussion a compromise was agreed. The spans were to remain as they were, but the rigid connection between piers and deck was to be abandoned and bearings were to be used instead, which would permit incremental launching. The deck would still be detailed for balanced cantilever construction, but tenderers would be allowed to price for alternative methods of construction without altering the appearance of the bridge. In the event, the lowest tenderer offered balanced cantilever construction and the second lowest offered incremental launching, using intermediate temporary piers.

The piers now needed to be reconsidered structurally and aesthetically. The shape was studied with models and the Arup Model Shop made one at 1:50 scale for the benefit of the committee, showing the grooved finish proposed (Fig. 8). The large chamfers on the corners reduce the visual bulk in diagonal views and the inset of the chamfer sharpens the appearance of the pier when seen in elevation.

10

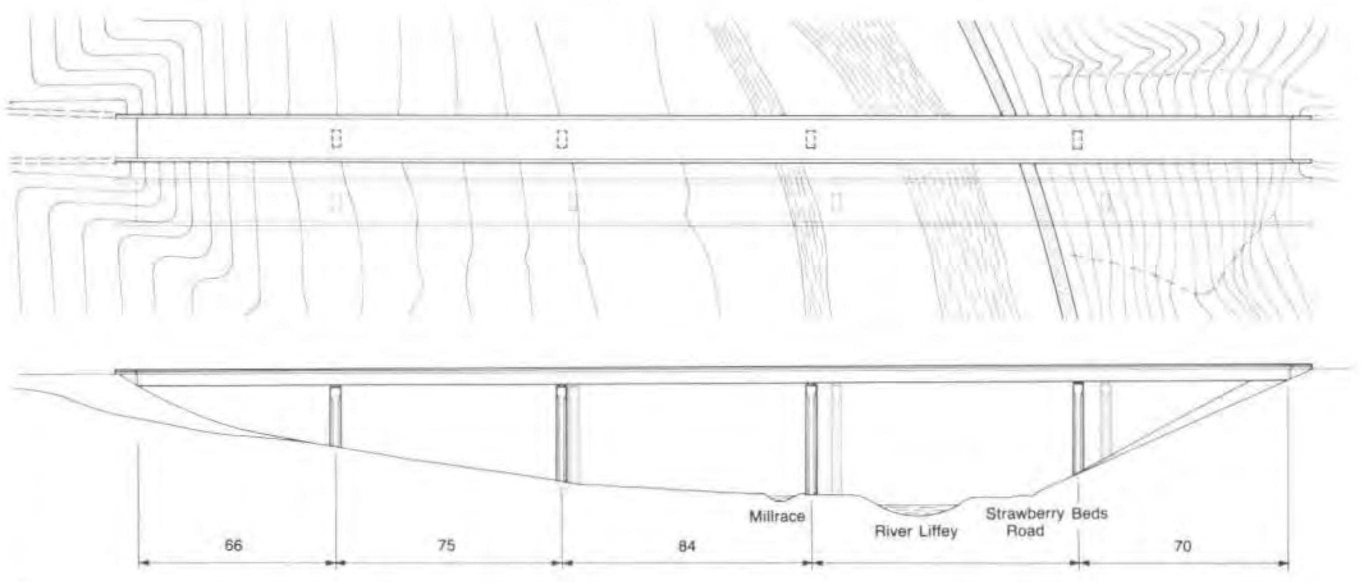
Detailed design and construction

The detailed design of the bridge was carried out and tenders invited from seven of the contractors who had replied to the advertisements in the *EC Journal* and Irish newspapers. After negotiations about the conditions of contract with the lowest tenderer, Irishenco-Dywidag JV, an Irish/German joint venture, it entered into a fixed price contract with the toll company Westlink Toll Bridge Ltd. The contract started in January 1988.

Dyckerhoff & Widmann (Dywidag) built the first post-war concrete cantilever bridge and probably have more experience of building such bridges than anyone else. They proposed several modifications of the construction method. Arups had designed and detailed for 3.58m segments with the cantilevers one segment out of balance at any time. D&W's modification had 5m segments which were only half a segment out of balance at any time. This meant that the contractor had to redetail completely the prestressing and reinforcement of the deck. The Arup design allowed for temporary prop/ties on both sides of each pier, sitting on the edge of the pier foundation to take the out-of-balance moment in conjunction with the pier.

The contractor's arrangement consisted of precast concrete segments 1.2m × 1.2m × 1.0m high which were stressed together by 36mm Dywidag prestressing bars, some within the precast sections and some outside. Two prop/ties were provided at each pier, on one side of the pier only.

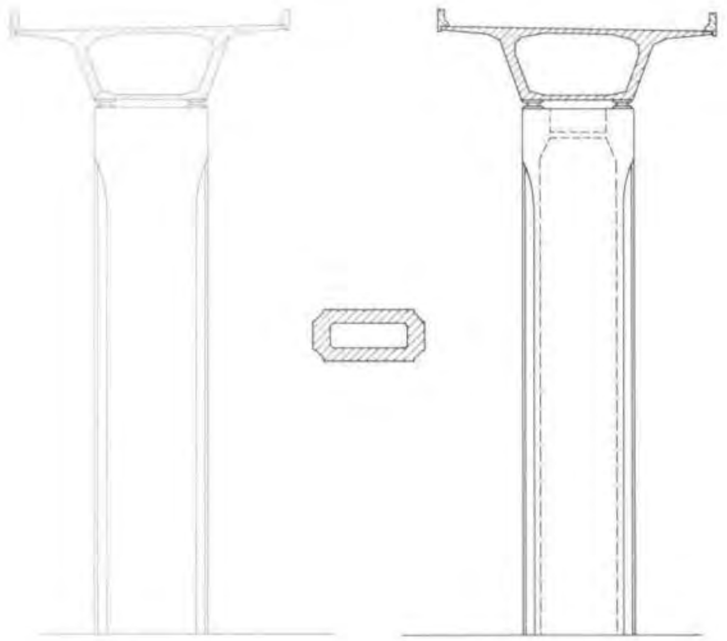
Fig. 13 shows the start of cantilevering from a pier. Props similar to the prop/ties on temporary foundations were used towards the outer ends of the end spans.



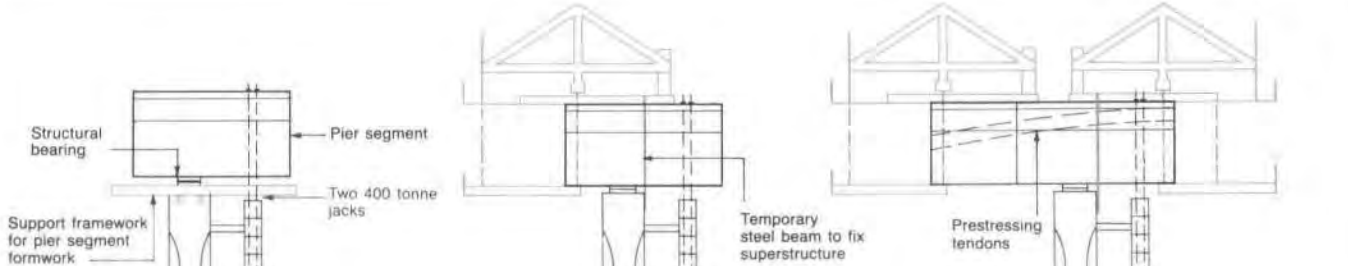
11

8. Model of the tallest pier. The Gothic doorway has been replaced in the final scheme by square hatches only accessible by ladder.
9. The first cantilevers are complete and cantilevering from pier 2 is proceeding. The outer shutter for the pier segment on pier 3 is in place.
10. A closer view of the deck during cantilevering.
11. Plan and elevation with future bridge in grey.
12. Cross section of deck with typical pier (second bridge in grey).
13. Sequence at start of construction of each cantilever:
    - A Pier segment constructed.
    - B First carriage erected.
    - C First cantilever segment constructed and stressed. Carriage moved. Second carriage erected.

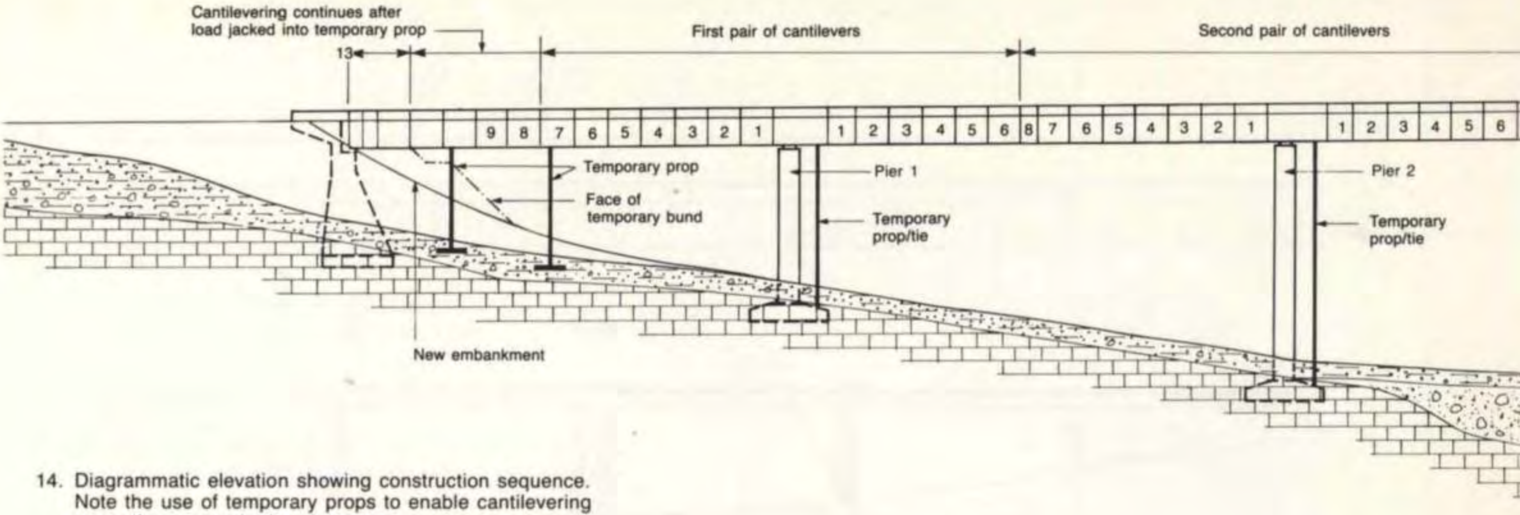
    One segment each side was cast each week.



12



13



14. Diagrammatic elevation showing construction sequence. Note the use of temporary props to enable cantilevering to continue towards the abutments.

15, 16. The completed Liffey Valley Bridge.

Construction proceeded successfully until the fifth cantilever segment north of Pier 3 was being cast, when one of the bearings suddenly failed. The deck rocked alarmingly back and forwards while the deck crew scrambled for the ladders and it was several minutes before it came to rest. Luckily, no-one was hurt and they were able to finish the pour.

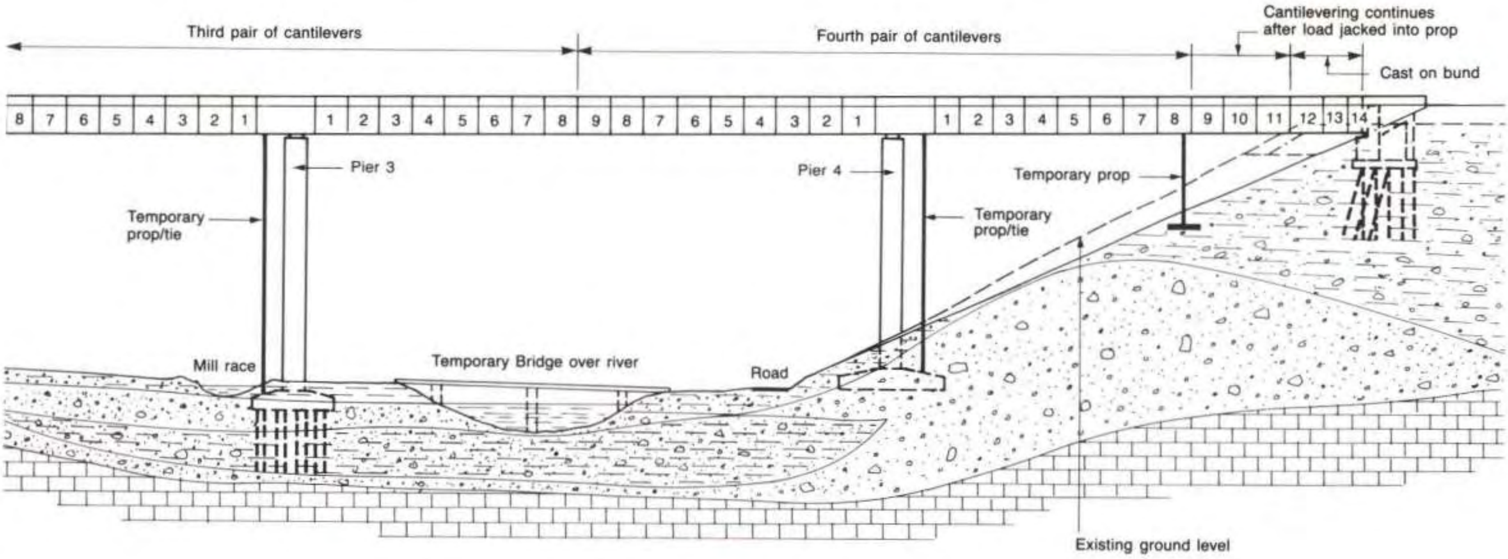
The failure turned out to be due to a void in the grout under the bearing plate of nearly half its area. As well as the failed bearing, the other on the same pier has been replaced, because this was more economical than testing to demonstrate that it had not been damaged during the failure. At all the other piers the deck was jacked up so that the bearing grout could be examined; smaller but significant voids were found in three. Before lowering the deck a thin layer of liquid grout was poured over each plinth.

Finishing works included landscaping to remove the scars of construction, final shaping of the southern embankment, and regrading of the northern slope which improved its stability and appearance.

The main structure was successfully completed in November 1989, and the finished bridge was handed over in February 1990.

Credits

Client for design:
Dublin County Council
Client for construction:
Westlink Toll Bridge Ltd.
Designer & Engineer:
Ove Arup & Partners Ireland + Civil Engineering Bridges and Civil Engineering Geotechnics
Consulting architect/landscape architect:
Brady Shipman and Martin
Main contractor:
Irishenco-Dywidag J.V.
Photos and illustrations:
1, 11-14: Fred English.
2-7: John Higgins. 8: Harry Sowden.
9, 10, 15, 16: Mary Croke.


Third pair of cantilevers
Fourth pair of cantilevers
Cantilevering continues after load jacked into prop
Cast on bund
8 7 6 5 4 3 2 1 1 2 3 4 5 6 7 8 9 8 7 6 5 4 3 2 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Pier 3
Pier 4
Temporary prop
Temporary prop/tie
Temporary prop/tie
Mill race
Temporary Bridge over river
Road
Existing ground level


1△


2△


3△


4△

5▽

6▽

Awards and Commendations

Association of Consulting Engineers of Australia 1989 Special Merit Award

1. *Sydney Football Stadium*
Architect: Philip Cox Richardson Taylor & Partners
Client, project manager and main contractor: Civil and Civic Pty Ltd.
Structural, civil and geotechnical engineers: Ove Arup & Partners, Australia

Europa Nostra *(Winner)*

**Whiteleys, Bayswater*
Architect: Building Design Partnership
Client: The Whiteleys Partnership
Structural and services engineers: Ove Arup & Partners

PA Awards *(Winner, Private section)*

**Broadgate Phases 1-4*
Arup Associates Architects + Engineers + Quantity Surveyors

RIBA National Awards *(Winners)*

**Next Headquarters, Enderby, Leicestershire*
Architect: ORMS Architects
Structural engineer: Ove Arup & Partners

**Billingsgate Market Refurbishment*
Architect: Richard Rogers Partnership Ltd.
Structural and services engineers: Ove Arup & Partners

2. *St. Michael Financial Services Ltd., Kings Meadow*
Architect: Michael Aukett Associates
Client: St. Michael Financial Services
Structural engineer: Ove Arup & Partners

Shopping Centre of the Year *(Refurbishment section)*

† King's Shade Walk, Epsom
Architect: Renton Howard Wood Levin
Client: Friends' Provident Managed Pension Funds Ltd.
Structural and services engineers: Ove Arup & Partners

Civic Trust Awards *(Winners)*

**Stockley Park*
Arup Associates Architects + Engineers + Quantity Surveyors

3. *Orchard Square, Sheffield*
Architect: Chapman Taylor Partnership
Client: MEPC Ltd.
Structural engineer: Ove Arup & Partners

Billingsgate and Broadgate phases 1-4 also won Civic Trust Awards, the latter receiving the Steetley Brick and Tile Special Urban Design Award

4. *Mound Stand, Lord's Cricket Ground*
Architect: Michael Hopkins & Partners
Client: Marylebone Cricket Club
Structural and services engineers: Ove Arup & Partners

(Commendations)

5. *Unit for the Elderly, Northern General Hospital, Sheffield*
Architect: Hutchinson, Locke & Monk
Client: Trent Regional Health Authority
Structural engineer: Ove Arup & Partners

6. *Kingsmere Gardens and Park View Court: rehabilitation of severely stigmatised housing*
Architect: Jane and David Darbyshire
Client: North British Housing Association
Structural engineer: Ove Arup & Partners

**Princes Square, Glasgow*
Architect: Hugh Martin & Partners
Structural engineer: Ove Arup & Partners Scotland

Photos:
1: Patrick Bingham-Hall;
2, 3, 5, 6: the architects;
4: Richard Bryant

**illustrated in the Winter 1989/90 issue*
† to be included in the Summer 1990 issue

Riyadh Diplomatic Quarter Sports Club

Arup Associates Group 5

In May 1981, Arup Associates were appointed to develop a brief and prepare the design for a sports club to serve the community of a new Diplomatic Quarter situated some 7km to the west of the centre of Riyadh, Saudi Arabia.

The site, determined by a master plan devised by the German consultants Speerplan, was a virtually featureless expanse of rocky desert and covered an irregular area of some 9.4ha. It was located within a residential neighbourhood with a main pedestrian route designated to run through the site.

The concept was to create a recreational sports club within an informal park-like setting. Consequently the sports facilities were planned as a series of separate buildings and enclosures linked together by the pedestrian walkway. This arrangement provided the maximum area possible for a continuously open and intensively landscaped park which connected to the adjoining neighbourhood walkways. To minimize the visual impact of the 250 car parking spaces required, the parking areas were restricted to 12m wide margins planned alongside the existing roads around the site. Vehicular service access routes were screened from public view by locating them between the buildings and the internal site boundaries.

Key:
1. Indoor Pool
2. Outdoor Pool
3. North Courtyard
4. Squash Courts
5. Spectator Seating
6. Gymnasium
7. Outdoor Courts
8. Perimeter Road
9. Changing
10. Club House
11. Central Terrace
12. Cafeteria
13. Management Offices
14. Sports Hall
15. Double Sports Hall
16. East Courtyard
17. Kick-About Area
18. Lawn
19. Service Roads
20. Public Parking
21. Staff Parking
22. Plant Room
23. Park

Within this planning framework the major sports buildings were placed so as to create two formal planted courtyards with the sports halls and gymnasium at the eastern end, and the indoor and outdoor pools and the squash courts on the northern boundary. At the hub of the site, where the pedestrian walkway changes direction, an existing rise in the ground level was emphasized to provide a visual point of reference. The main social facilities of the sports club, the club house and cafeteria, were located here to create a communal focus for the development.

The open multi-purpose courts and the associated changing rooms were planned between these groups of buildings along the main pedestrian thoroughfare.

The requirement for complete male and female segregation was a significant influence on the design, as it involved the provision of separate entrances and the need for visual screening to all sports activities. To this end, the groups of buildings were linked by walled enclosures screening the open courts. These provided a visual continuity and spatial back-drop along one side of the main pedestrian route, with an open landscaped park on the other. From the formal courtyards on the north and east, the main pedestrian route was designed to accommodate the change in level and to create a progression of similar but varied spaces as it continued throughout the 800m length of the site.

The outdoor leisure pool is located within a walled enclosure on the eastern side of the north courtyard. Two buildings housing the changing accommodation frame a stepped terrace area, a 'beach', which leads down to the central pool with its wave-making facility. Alongside are learner and toddler pools, with a plunge pool and 4m high water slide to the south.

The landscaping concept was constrained by the limited quantity of surface water and treated wastewater provided by the Diplomatic Quarter itself. This was supplemented to a small degree by the utilization of treated back-wash water from the pools' filtration plant. As a result the lush planting was concentrated into formal arrangements along the pedestrian walkway with less formal planting to the edges of the site. The remainder of the site was planted with 'indigenous' trees to provide, in time, a substantial shade canopy over large areas of the park. The edges of the site were also defined by shelter belts of denser taller species and ground cover planting on raised rock berms to create a sense of enclosure and the illusion of a continuous landscape. The route through this landscape was to be a longer, more informal alternative to the main pedestrian route linking the sports facilities, but with a similar degree of variety created by the use of level changes and open and enclosed space.

To the north of the cafeteria a luxurious lawn was created which, together with several smaller grassed areas, ranged throughout the park, offered space for picnics and family recreation.

It was important to retain a single overall distinctive identity for the sports club, given its extended and disparate arrangement. The buildings therefore have all been designed as a family of concrete-framed structures and utilize a generic construction system comprising precast roof T-beams supported by primary beams and columns, and flanked by independent and physically separate walls of local limestone.

These walls, very much in the Saudi tradition of buildings designed to cope with harsh environmental conditions, are predominantly solid. They act as moderators of external and internal climatic change and resolve the need for visual privacy, as well as the strict functional requirements of the various sporting activities which limit the possible admission of daylight. Slots between the stone flank walls and the roof decks allow the spaces within to be daylit, with the structural beams acting as baffles to the light which is then reflected off the walls, through Iroko slatted screens. This clear and simple structural system is expressed throughout the sports club, providing an ordering device

within the large column-free spaces whilst defining clear internal circulation routes along the daylit stone walls on the perimeters of these buildings.

The single sports hall and indoor swimming pool have a clear span of 24m whilst the double sports hall has two clear spans of 17m, separated by a central aisle of 4m in width. The main structure consists of precast, post-tensioned, single T-elements, providing ribs at 2m centres supported by primary beams spanning onto columns at 8m centres. Both halls have an in situ concrete mezzanine structure around their perimeter which accommodates the public circulation and spectator areas on an upper floor, with plant, stores and changing rooms located alongside the activity space at a lower level.

The stone-clad walls were constructed of concrete blockwork strengthened by precast concrete mullions to resist the lateral forces due to wind loads.

The gymnasium, changing blocks, club house, cafeteria and management offices follow a similar pattern, with a main structure of single precast T roof units with ribs at 2m centres. These units span 12m onto primary beams with columns at 4m centres. The squash court was designed slightly differently, in order to cope with the physical determinants of the courts and here the ribs were at 2.22m centres with columns at 4.43m centres. The core of the stone clad walls for the smaller buildings was of concrete blockwork.

The brief provided a very limited maximum demand of 2MW for the electrical supply and refrigeration plant constituted the largest part of this. Consequently it was essential to design the buildings for as low a cooling load as possible. One eccentric approach was to analyze very thick walls and it showed that if walls are 6m thick or more they begin to respond to the annual swing in outside conditions rather than the daily swing. The cost of providing 6m thick walls, however, exceeded that of buying and running an air-conditioning plant for 20 years and, as a result, a more traditional wall thickness of approximately 600mm was used.

However, the analysis did show that by using external insulation and exposing the internal thermal mass it was possible to reduce dramatically the cooling load.

For the outdoor swimming pool it was essential to provide some form of winter heating. This resulted in the installation of two large reverse-cycle, electrically-driven heat pumps in order to provide the dual duty of heating in winter and cooling in summer. It was considered necessary to make provision for additional cooling of the shallow water areas in the outdoor pool during the summer months. The solution was to use the wave machine fan to drive air through sewage treatment plant aerators located under perforated tiles in the shallow water areas, providing, in effect, a most unusual jacuzzi!

Hot water to the changing room facilities was given supplementary heat from low efficiency solar collector roofs. This involved a system of steel pipe coils buried in bitumen over 200mm of insulation and provided a low technology solution to hot water production.

An automatically controlled irrigation system was installed to serve the trees, ground cover planting and the lawns with a one-day water storage capacity on site to cater for possible loss of supply. A below-ground trickle feed irrigation system piped a supply of water adjacent to individual plants, or groups, at a pre-set rate. There is scant rainfall in Riyadh but when it does rain it is at a very high rate and our client was concerned that during these infrequent periods of intense rainfall no puddles should be visible on the surface of the park or pedestrian footpath route. Consequently it was necessary to provide enormous soakaway volumes for these short storms even though the annual run-off was extremely small.

The lighting of the sports hall in particular was a critically important aspect of the building design. A minimum level of 350 lux was provided from combined twin-lamp high pressure sodium and metal halide fittings, having polished reflectors and deep louvres.

This combination of lamps provided a high efficiency illumination with good colour appearance. A simple switch control system provided alternative lighting arrangements for games played along and across the courts, thus further limiting the glare arising from direct upward views of the lamps. Separate high level, wall-mounted metal halide lamp fittings, directed upwards, were installed to illuminate the roof of the hall. This reduced the brightness contrast between the surface and the lighting fitting, improving the visual comfort when playing high shots.

The preparation of the design and tender documentation was concluded by the end of 1982. The contract was a client-modified JCT Form, and tender bids were received, analyzed and awarded for a start on site in June 1983; work was completed a year and a half later.

The successful tenderer with a bid of SR70.5M was Kuk Dong, a Korean contractor. Their previous activities in Saudi Arabia had been predominantly civil engineering-based, including responsibility for the infrastructure to the Diplomatic Quarter. The only 'building' type contract of merit which they had undertaken was a housing complex for the Ministry of Foreign Affairs.

Concurrent with the award of the contract for construction, Arup Associates were appointed to the role of project manager/site supervision; the contract required the presence on site of a multi-professional team for the full duration of the works — a role which embraced diplomacy, language, and cultural barriers, the raw appreciation of a desert climate, and much-needed teaching skills.

This site management team had to meet exacting construction standards demanded by the Saudi client whilst working with local materials and an unskilled (ex-Army) workforce. This demand required the establishment of strict quality control procedures, activity method studies and construction teach-ins prior to work commencing on site. The final result produced a quality of construction and finish which would be the envy of most Western contractors.

Since its completion in 1985, the Sports Club has been increasingly used with the completion of the Diplomatic Quarter and, with the establishment of the landscaping, this particular development has become an oasis in the city and a focal point for the local community. It is immensely popular.

Credits

Client:
Riyadh Development Authority

Designers/project managers:
Arup Associates Architects + Engineers + Quantity Surveyors

Contractor:
Kuk Dong

Photos and Illustration:
Arup Associates (Plan by Mick Brundle)

Four Nigerian farms

Bill Haigh

Introduction

Before the advent of petroleum in the economy, Nigeria was primarily an agricultural nation, producing various cash crops such as cocoa, palm oil and kernels, groundnuts, cotton, etc. The oil boom, which overvalued the Nigerian currency, the naira, and caused the migration of rural people to urban areas, spoilt farming. The drop in oil production and oil prices in the '80s has brought a change of strategy and government policies on agriculture (Fig. 1). The devaluation of the naira has made imports prohibitive and encouraged exports. Industrialists are now forced to obtain their raw materials in Nigeria and Nigerians must eat locally-grown food.

The projects described below are examples of four new farms being developed to provide raw materials for local industry and processed food for local and export markets; they are the Afcott cotton plantation, UTC Nigeria Ltd.'s tomato farm, Guinness's cereal farm and the Iwo fish farm. They show how we have been involved in Nigerian farming projects all the way from the beginning to the end: from civil and structural engineering commissions for the farm infrastructure, such as farm roads, farmyards, silos and water supply, right up to structural and building engineering commissions for factories set up for the processing and manufacturing of the finished products.

Sites

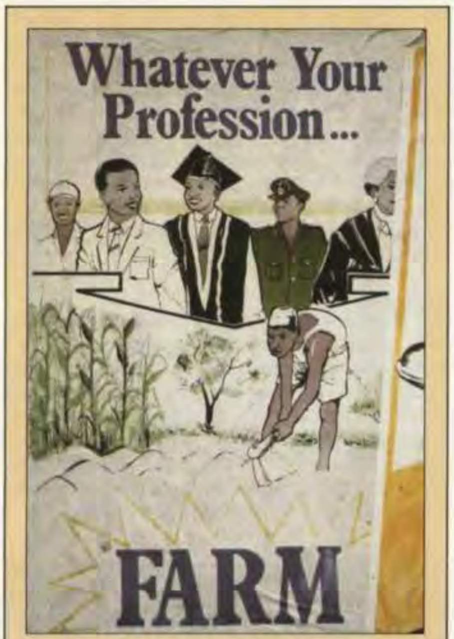
The climate in Nigeria can be divided broadly into three zones: the arid zone in the north, the guinea savanna in the middle belt and the tropical zone in the south (Fig. 3). The Afcott cotton plantation is located near Yola where temperature, rainfall, humidity levels and soil characteristics favour a perennial yield of cotton averaging 2 tonnes/ha. The tomato farm is sited at Tenti on the Jos plateau.

Tomatoes need a controlled environment and therefore our client, UTC, decided to cultivate the tomatoes during the dry season only under irrigation. Guinness's cereal farm at Kudu was selected according to climatic, area, soil and accessibility considerations.

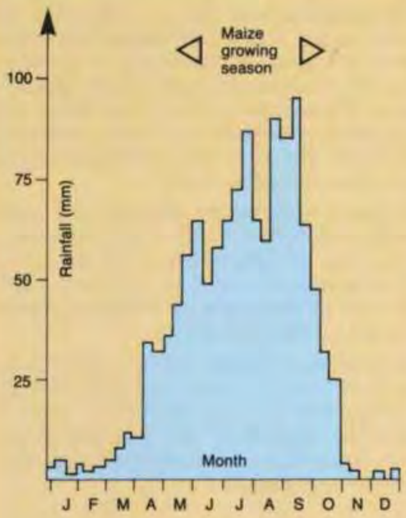
The suitability of an area for crop production is determined by the rainfall, particularly its distribution in relation to evaporation during the critical stages of plant growth. The average rainfall and potential evaporations indicate that precipitation in Kudu is sufficient between May and mid-October for maize production (Fig. 2). The Iwo fish farm lies 60km north-east of Ibadan. The climate of the area is governed by the movement of the inter-tropical convergence zone (ITCZ), the front where the cool, moist Atlantic winds from the south meet the hot savanna winds from the north. Most rainfall in Nigeria takes place south of the ITCZ, where the project is situated. The first phase of the development is in an area chosen for its proximity to a village community, a stream and a motorable access road.

Type of farming

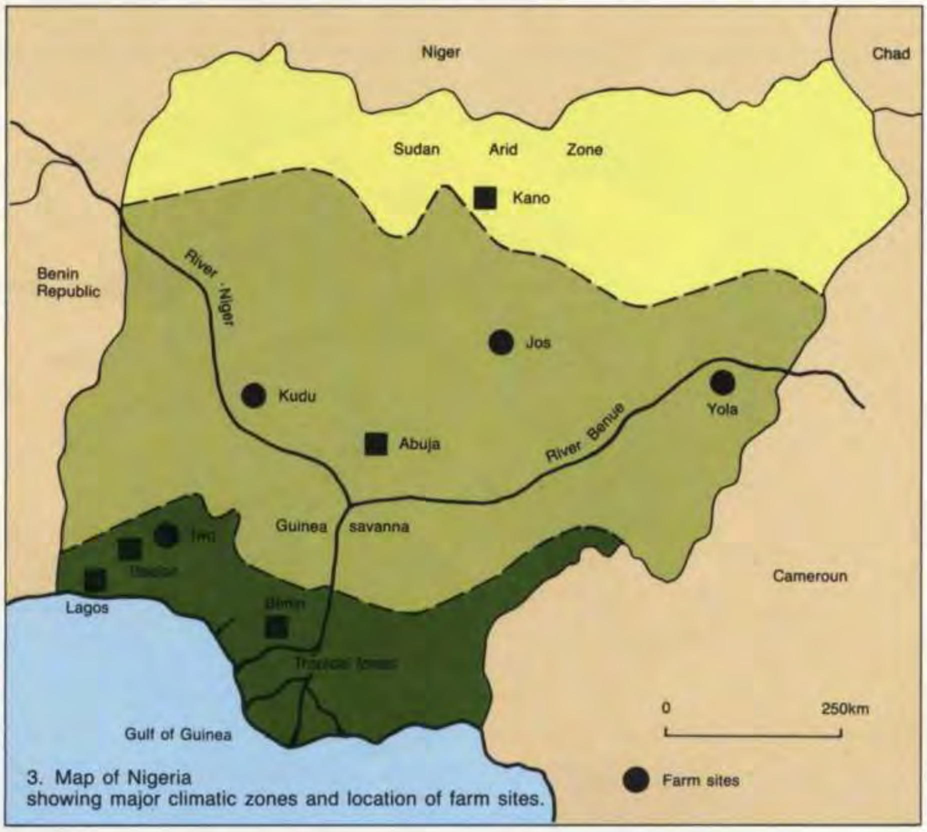
The areas of each farm site and the crops under cultivation are shown in the table on the right (Fig. 4).



1. Government poster in Lagos.



2. Histogram of rainfall for Kudu area.



3. Map of Nigeria
showing major climatic zones and location of farm sites.

4. Table showing main crops harvested (hectares) at four farms.

	Cotton farm, Yola		Tomato farm, Jos	Cereal farm, Kudu	Fish farm, Iwo
	Nucleus farm	*Out-growers*			
Farm area	2500	—	600	6000	500
Cultivated area	2300	4000	170	3500	200
Cotton	2200	4000			
Maize	5		10	2400	
Sorghum				100	
Wheat			100		
Tomatoes			56		
Cowpeas/soyabeans	2		2	1000	40
Cashew nut					80
Fish ponds					27
Sunflower	10			2	5

Cereal farming

At the Kudu cereal farm, the basic concept in its establishment was an integrated approach to the large-scale mechanized cultivation of maize for the supply of brewers' grits to the Guinness breweries at Lagos and Benin. The process of tilling, harrowing, and application of fertilizer to the field starts early in the year and ends with maize planting by May when the rains set in.

The maize is harvested semi-dry at a moisture content of about 18% in the last quarter of the year. Wet grains are dried and stored in the farmyard, and then hauled in large capacity road trailers to the breweries, where they are gritted and stored.

The existing breweries, which were primarily designed to handle malt, had to go through a conversion process to enable them to digest the maize grits into the brewing process. The grits are cooked in large cookers, mashed and filtered.

Cotton farming

The Afcott farm represents the first step in a vertically integrated industrial process that ultimately terminates in the production of finished textile fabrics in Lagos. Harvested cotton from the farm and outgrowers (Fig. 8) is ginned in a saw brush gin plant to extract cotton seeds. The cotton lint is sent to Lagos for spinning into quality yarns (Fig. 9) and weaving into varieties of textile fabrics (Fig. 13 and back cover). Some of the finished yarn is exported to the UK.

Tomato farming

The tomato farm is a joint venture between UTC, who are doing the farming, and Cadbury, who are doing the processing. The harvested tomatoes are converted into purée in a factory on the site, and then transported in plastic containers by road or rail to the Cadbury factory in Lagos for mixing and canning. The final product is *Tomapep* which is very popular in indigenous cooking.

Fish farming

A diversified approach is being applied at the Iwo fish farm, where carp and catfish will be farmed on 27ha. About 60ha of soya beans (*Slycine max*) and cowpeas (*Vignic campanulata*) will be cropped for use as fish-meal together with other supplements. The crops have been laid out in plots, demarcated by cashew nut (*Anacardium occidentale*) trees which have been interplanted with banana trees (*Musa sapientum*) to provide shade during the early years of the former. This integrated farm project when completed is expected to cover the entire 500ha site and will be one of the largest inland fish farms in the country. As fish is usually available only around coastal areas, the venture provided a good investment in view of the high demand for fish, a relatively cheap source of mineral protein.

The four farms are described in the following panels.

Cereal farm, Kudu

Cliff Ejim

This complex comprises farm blocks, the farmyard and the residential quarters on a hill near the farm centre (Fig. 5).

The farmyard (Fig. 6), which is the nerve centre of the farm, consists of a reinforced concrete storage building 30m × 30m × 8m high (eaves), designed to hold about 7000 tonnes of grains with dryer and elevators, a workshop, crop input store, equipment shed, power and water supply, office and amenities block. Residential accommodation is provided for the farm manager, farm engineer, agronomist and other key personnel, together with a guest chalet. We handled the project management, civil and structural engineering design and supervision of the farmyard, housing and access roads, as well as the extensions to the existing breweries to adapt them to maize.

Total civil costs are estimated to be £4M.

5. Guinness maize farm, Kudu: layout.

6. Farmyard.

7. Harvesting maize.

Cotton farm, Yola

Soji Dina

Yola and its environs are underlain, geomorphologically speaking, by three main formations referred to as Bima Sandstone, Yolde and Yola, which are characterized by the existence of clay shales of which the mineral montmorillonite is predominant. This mineral is present in desiccated clays and, coupled with the varying water table, leads to foundation difficulties which manifest as heaving of the ground, causing varying degree of distress from simple cracks to outright collapse of the building. Our soil investigations in the project areas indicated that pad footings at approximately 2.5m depths would generally be on good ground. For those buildings where rafts were needed, excavation to good ground was backfilled with sand.

For the ginnery and seed warehouse, building forms were 'profiled' as simple portals with or without roofing monitors in structural steelwork, with heights to eaves varying between 6m and 12m, and conventional pad footing foundation. The oil mill uses concrete rather than steel for its portal frames, as concrete is at present proving cheaper than steel. The 180 tonnes/day oil mill comprises a refinery (Fig. 10), solvent extraction plant, dehulling/pre-expelling building, filling line, water reservoir and boiler house (Fig. 11). The total value of civil works for the above projects exceeds £3M.

External works comprise concrete hardstanding around buildings to ensure run-off of rainwater into concrete drains. The interlinking road network is a flexible pavement with surface dressing. The downstream Aflon rotor-spinning factory in Lagos, however, retains a different identity from the oil mill and ginnery, having been profiled as a tied two-bay barrel vault in consonance with the sail vaults of the original parent Afprint factory, with which it shares a common site (Fig. 12).

We are structural/civil engineers on the upstream projects: cotton bale warehouse, ginnery, seeds store, oil mill, farm housing, roads, etc., near Yola and for the spinning mill in Lagos.


8. Cotton-picking.


9. Aflon factory, Lagos: spinning cotton yarn


10. Afcott cotton farm: construction of oil refinery.


△11. View of oil mill construction.


▽12. Aflon factory, Lagos: barrel vault roofs.

13. Afprint textiles at Lagos fashion show (Photos: Afcott).

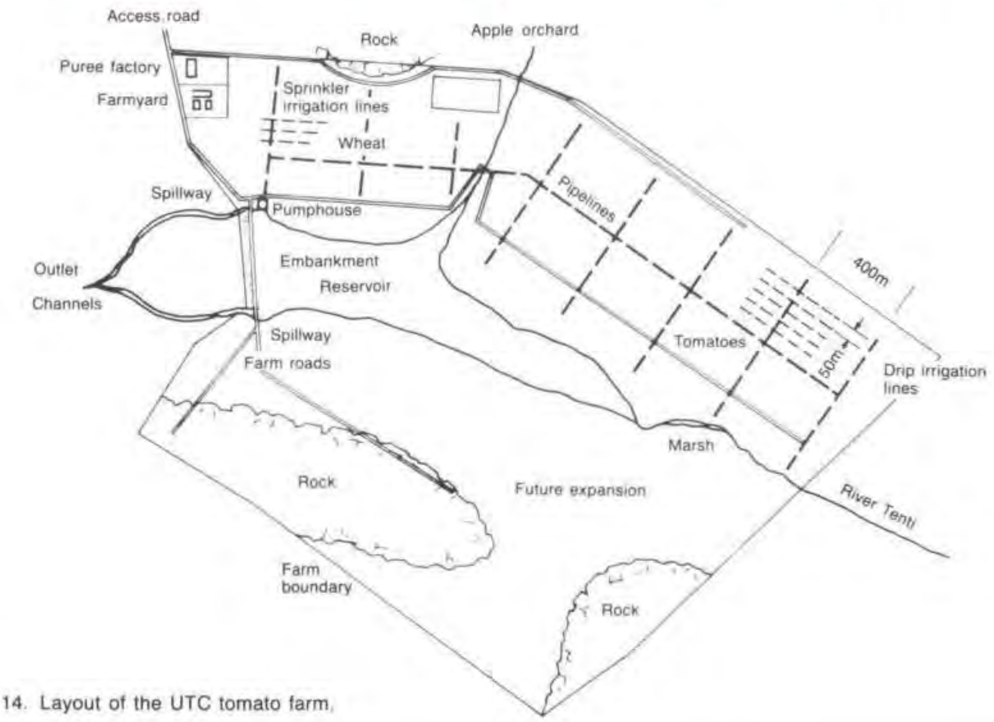
Tomato farm, Jos

Emeka Okide

We were initially commissioned for the subsoil investigations and topographical surveys of the farm centre and dam. Design commissions followed to upgrade both the existing dam including a new pumphouse, and the existing site access roads and bridges, as well as the civil/structural works in connection with the new farm centre and purée factory. We were also involved in the design of the Cadbury factory in Lagos.

Water for irrigation as well as for factory use is obtained from an existing reservoir which has been upgraded to impound 1.5M m^3 of water. Most of the 600ha of land leased by UTC forms the catchment area of this reservoir. The existing embankment was built in the late '40s/early '50s, and was in a bad state of disrepair at the start of the project. The necessity to increase the reservoir capacity of the dam by over 100% entailed a lot of remedial works. The final scheme that evolved consisted of a 1.7m increase in the embankment height with compacted laterite (Fig. 15), constructing two new concrete spillways designed for a 100 years' design flood period (Fig. 17), additional rip-rap protection on the upstream embankment, grassing the down-stream embankment and road surfacing on the dam crest. Stability of the proposed dam was checked with respect to the expected seepage losses and new vehicle loading and found to be adequate. Five centrifugal pumps supply water to the main lines of the irrigation network (Fig. 14). Sprinkler irrigation equipment was initially installed on the farm, but due to the prevalence of high winds on the site which has reduced the efficiency of sprinkler irrigation, drip irrigation equipment has now been installed to complement it.

The farmyard consists of a purée factory (Fig. 18), boilerhouse, ground and overhead water tanks, an elevated fuel tank, farm buildings, canteen, offices, a power house, and associated infrastructure. The total value of the civil works was approximately £2M.



14. Layout of the UTC tomato farm.

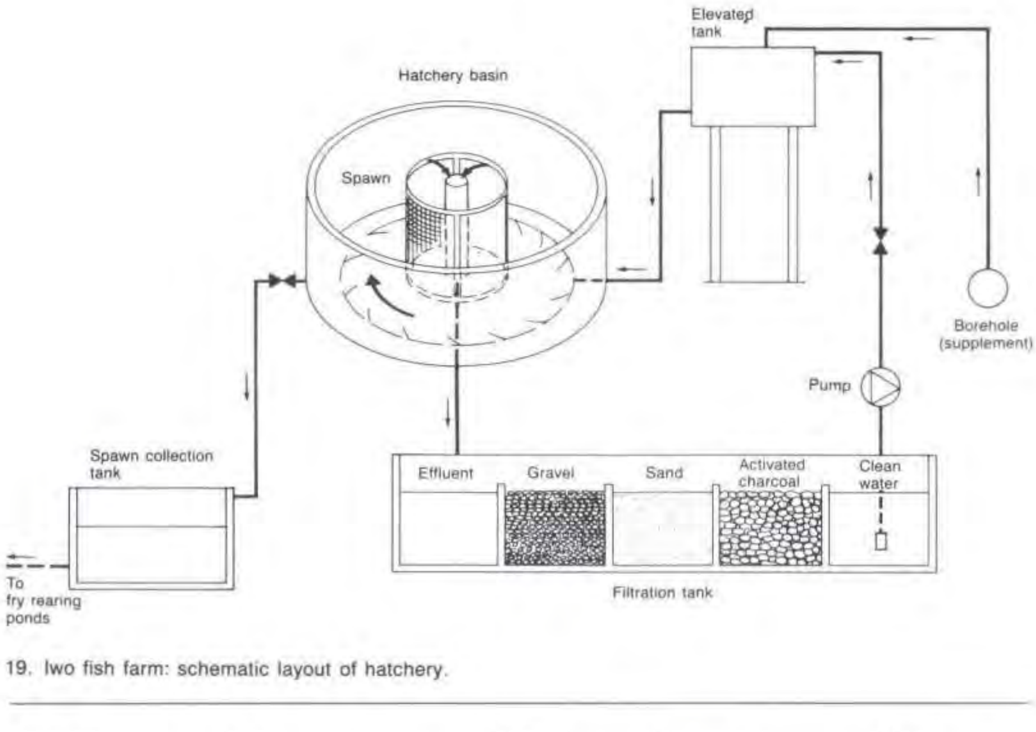
Fish farm, Iwo

Rotimi Anthonio

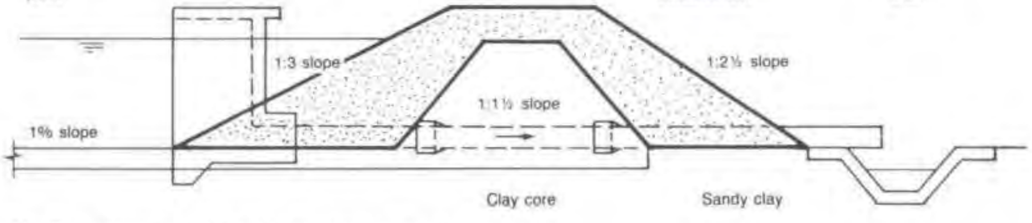
Subsoil investigations revealed that considerable areas of the site were overlain by pervious soil and fractured rock. This warranted a land use development plan to locate the various facilities and structures:

- Rocky highland areas for the farm centre, including a feed mill, laboratory, residential houses, workshop, office, generator house, fuel storage and water borehole.
- Pervious/sandy highland areas for the hatchery facility and rearing ponds.
- Low-lying and clayey low areas for the nursery and production ponds.

The hatchery unit is essential in the technological process of artificial reproduction of fingerlings (Fig. 19). The hatchery itself is a 6m diameter circular concrete basin, 1.2m high, divided into an inner and outer compartment by a synthetic cloth tied around four small columns held together by reinforced concrete ring beams at the top and bottom. The outer section of the basin houses the fingerlings and a network of pipes at the bottom. Water from an elevated storage tank is introduced tangentially through nozzle pipes to maintain permanent circulation. The water passes through the synthetic cloth into the inner compartment, where it overflows through a sink to a filtration tank.



19. Iwo fish farm: schematic layout of hatchery.

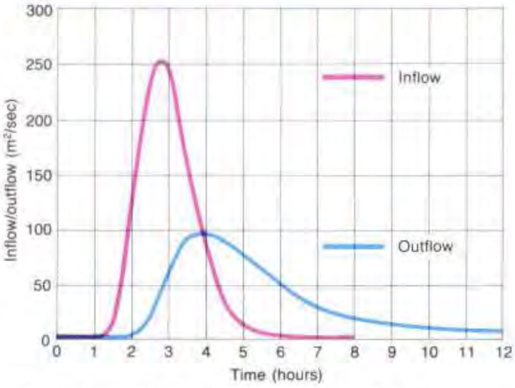


20. Typical section of dike for production pond.

15. Embankment.

16. Picking tomatoes (Photo: UTC).

18. Purée factory.

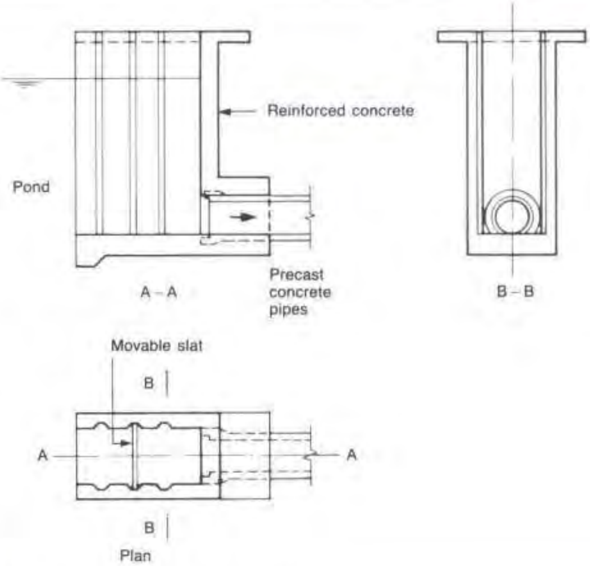


17. Hydrograph for 42m weir, UTC dam, Tenti.

A sluice valve is provided just outside the basin to regulate the flow of water and fingerlings into a spawn collection tank. Here the fingerlings are collected and counted before transfer for stocking in the rearing pond. 10 fry rearing ponds are to be constructed in reinforced sandcrete blockwork.

The general arrangement of the earthen nursery and production ponds can be described as 'contoured', with inflow and outflow operations relying on gravity. Most of the excavated material, where suitable, will be used in constructing the dikes. The dikes are likely to be either homogeneous or requiring impervious cores and upstream blankets, in view of the limited quantity of clayey soils available on site (Fig. 20). The slopes and corresponding lengths of embankments have been checked against possible slip failure and piping or movement of soil particles under the action of seepage forces. 10 each of 0.05, 0.10, 0.20 and 0.30 ha (bottom area) nursery ponds and 10 2ha production ponds are proposed in the Phase I development. The dike tops are provided with pathways for pedestrian and vehicular traffic. Pond bottoms have been designed to slope 0.5% to 1.0% along the longitudinal axis towards the monk sluices (Fig. 21).

Civil works for the first phase are estimated to cost approximately £200 000.



21. Typical detail of monk outlet.

22. Construction of ponds.

Construction

Farm projects by their very nature tend to be of relatively low cost and in isolated areas. This makes it difficult to attract contractors. For the four farms various contractors and, in one case, direct labour had to be closely supervised to ensure that standards were met.

Local materials are used wherever possible but certain items such as water bars and acid-resistant tiles have to be imported and are therefore difficult to obtain. The plant available is also very basic and many activities, which in the city would be carried out by machine, are undertaken by hand.

As can be seen from the map the distances from our design office in Lagos to the farms are huge, over 1000km to the cotton farm, the distance from London to Berlin. A site visit and meeting of two hours may involve three days of travelling. Flying can be frustrating and driving can be dangerous, especially at night.

Conclusion

Although many of the structures and the civil engineering works involved in farm projects are uncomplicated and do not need a high degree of design, the project management and supervision of the construction in difficult conditions has been very satisfying.

Credits

Cereal Farm, Kudu

Client:
Guinness Nigeria Ltd., Farms Division
Project managers, structural and civil engineers:
Ove Arup and Partners Nigeria
Architect
for farmyard buildings and housing:
Tunde Kuye and Partners
Architect
for mash filter extensions to brewhouses:
Godwin & Hopwood

Design work started March 1986
Construction work started December 1986
Dryer commissioned October 1987
Farm project completed May 1988
Mash filter extension December 1989

Cotton Farm, Yola

Clients:
Afcott Nigeria Ltd, Aflon Nigeria Ltd. and Afprint Nigeria Ltd.
Architect:
Design Group Nigeria
Structural and civil engineers:
Ove Arup and Partners Nigeria

Design work started March 1988
Construction started May 1988 and ongoing

Tomato Farm, Jos

Client:
UTC Nigeria Ltd.
Architect for farmyard and puree factory:
Design Group Nigeria
Structural and civil engineers:
Ove Arup and Partners Nigeria

Design work started January 1985
Construction started May 1985
Construction completed July 1986

Fish Farm, Iwo

Client:
Tropical Aquaculture Products Ltd.
Structural and civil engineers:
Ove Arup and Partners Nigeria

Design work started January 1989
Construction work started August 1989 and ongoing

Illustrations:
Fred English
Photos:
Bill Haigh, unless otherwise credited

Cheltenham & Gloucester Building Society new headquarters

Architect: Dyer Associates

John Loader
Alf Perry
Phil Wood

1

Introduction

The association of Ove Arup & Partners' Bristol office with Cheltenham & Gloucester Building Society goes back to 1984 when the Society had ambitious plans for growth, as well as for the adoption of new technology both in data communication and for the storage of deeds and other documents. The Society had outgrown its existing headquarters in the centre of Cheltenham, which were also increasingly unable to accommodate the level of services required in a modern electronic office. From the outset, the Society emphasized the need for a building of quality, not only for reasons of prestige, but also because it wanted its staff to work in the best possible conditions.

Negotiations were in progress for a large derelict site, formerly St. James Station, in the centre of Cheltenham. The new headquarters were planned in three phases, with an exceptionally high standard of external and internal finishes. Sadly, however, the opportunity to create a major building in the heart of the city was lost when negotiations for the purchase of the site broke down.

We then embarked on an extensive appraisal of seven sites around Cheltenham and Gloucester, the process being spiced by the rivalry between the two cities, only 5km apart, for the prestige and employment opportunities offered by the Society. Our studies covered aspects of soil conditions, transportation, infrastructure and the building types appropriate to each of the sites.

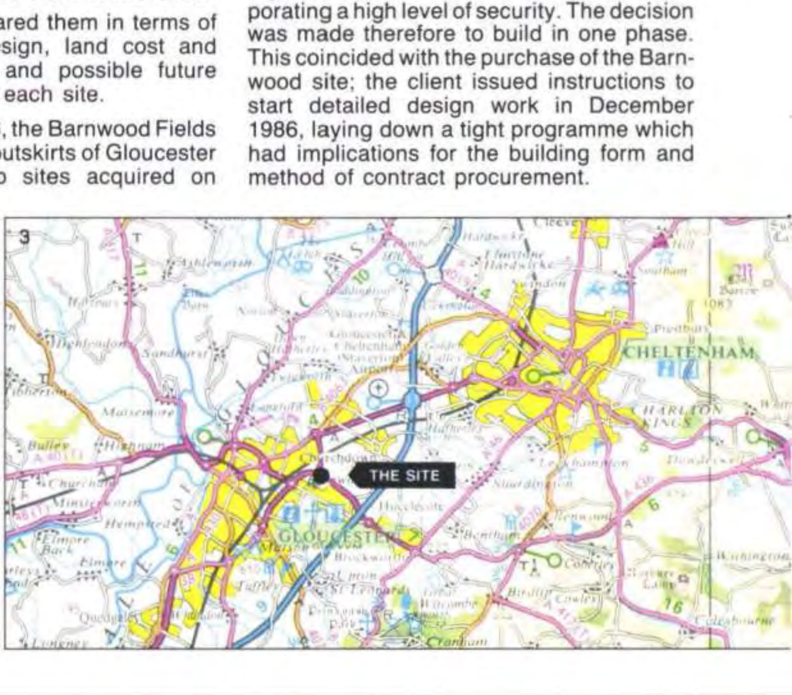
The final report compared them in terms of building cost and design, land cost and value, infrastructure, and possible future developments around each site.

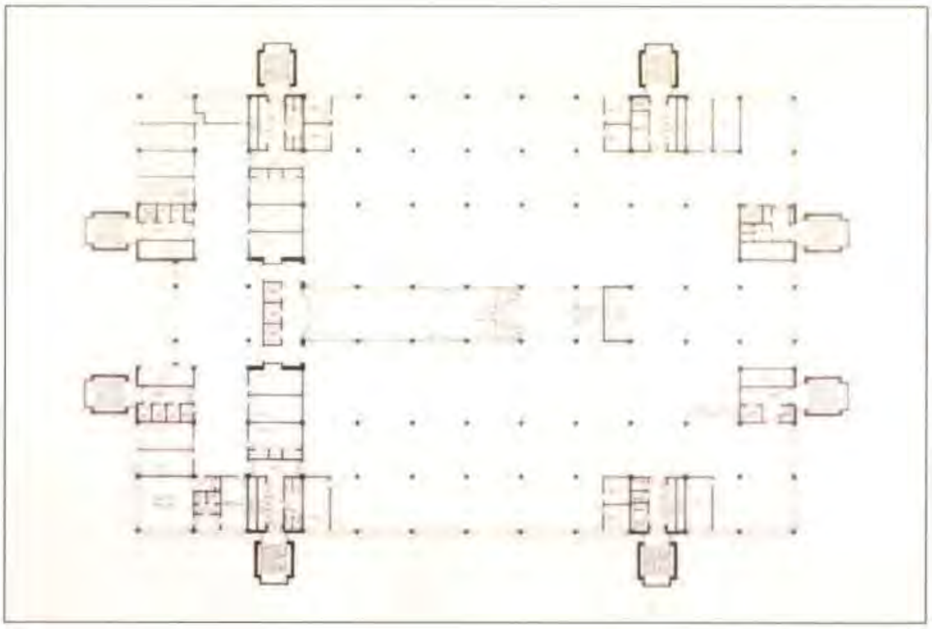
Eventually, in late 1986, the Barnwood Fields Business Park on the outskirts of Gloucester was chosen and two sites acquired on opposite sides of a road, allowing office accommodation on one and car parking, with expansion possibilities, on the other. Despite the somewhat mixed quality of buildings already on the development, the client and architect continued to aim for a building of the highest quality. With the 'Big Bang' the following year, the Society moved rapidly into other financial sectors, growing quickly in staff numbers and in services offered.

Early studies had revealed the enormous complexities of the proposed phased building with sophisticated M&E services incorporating a high level of security. The decision was made therefore to build in one phase. This coincided with the purchase of the Barnwood site; the client issued instructions to start detailed design work in December 1986, laying down a tight programme which had implications for the building form and method of contract procurement.

2

3



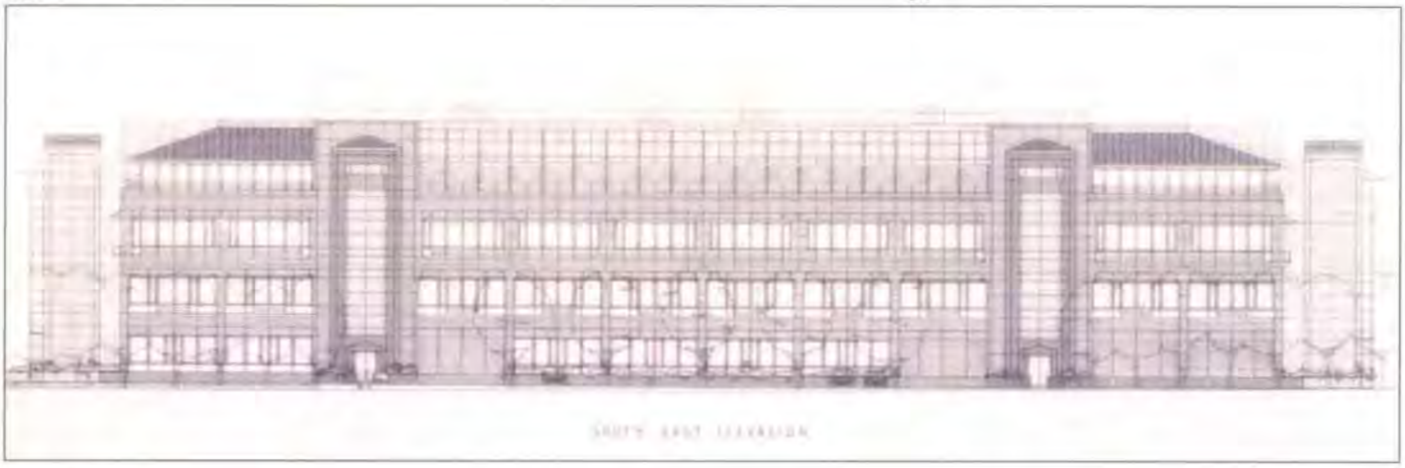


4△

6△

4. Typical floor plan.
5. Side elevation.
6. Steelwork and metal decking.

5▽



The site

The adjoining sites are about 3km east of Gloucester city centre, that for the office being approximately 100m × 140m in plan and essentially flat. There are very good dual carriageway links to Cheltenham and Gloucester and to the M5.

Following our studies of the seven possibilities, this location was favoured for a number of reasons. Communication links were important for the major staff relocation, and the business park has good shopping facilities. The relatively cheap land also allowed the Society to plan for a high level of car parking and recreational amenities. In addition, ground conditions were favourable.

The whole site is underlain by Lower Lias Clay below Terrace Deposits of sand and gravel. The Lias is weathered to a depth of 2m to 4m allowing bearing pressures under pad foundations of 150kN/m^2 at shallow depth and up to 400kN/m^2 in the unweathered Lias Clay at greater depth.

The building design

Following a series of space-planning exercises, the overall layout was decided as follows:

Ground floor:
computer suite, data and paper handling

First floor:
automated deeds and document storage, general offices

Second floor:
executive and general offices

Third floor:
board suite, staff facilities and plant

The ground floor is a highly secure area both structurally and in its provision of services and communications. The deed and document store is a very sophisticated installation, allowing for the automatic retrieval of any of the 1.3M documents within 14 seconds! This allows an 'instant' response to telephone queries on the deeds of customers' mortgaged properties and avoids the cost of returning calls later. The floor loading equates to about 12.5kN/m^2.

The decision to build in one phase rather than three did not alter the office configuration, but did allow for the planning of a large atrium space rising through the centre of the building. It also gave us the opportunity to rationalize the core, stairs and stability systems, and to arrive at a simple and clear structural layout.

Building structure

With the building plan fixed, we explored grid and materials options. Initial designs envisaged a curtain walling system above a more secure stone cladding at ground floor level. This cladding system and the need for speed of erection led naturally to a composite steel and metal deck solution. The layout offered the possibility of long spans but the architect and client could find no advantages and remained concerned, despite our technical input, about floor vibrations and their effect on computers. A mixed grid of 7.2m × 7.2m and 7.2m × 10.8m was finally adopted. The deed store loading and the need to minimize structural depth were also influential in choosing a more modest grid.

Late in the scheme development, the cladding design changed from a curtain wall system to one based on polished granite for beams, columns and core walls, which led to a complete reappraisal of the structural system. We became convinced early in the design of cladding fixings that the edge beams and columns should be concrete-cased. The modest structural grid could then be formed in a variety of concrete solutions quite economically, as well as in steel.

However, the shortage of good concrete tradesmen in the area and the need to waterproof the roof at the earliest possible date (so that the M&E contract could start) led us back to a steel solution, with pre-encased edge beams and site-cased columns.

We carried out detailed studies comparing light and dense concrete floors, and the use of props during concreting. We eventually settled for dense concrete on cost grounds and because the site is remote from areas of lightweight aggregate supply; and we specified propped beams to minimize dead load deflections and to reduce steel weight, after the contractor had confirmed that props would not affect his programme.

The board suite and restaurant are next to plant rooms and, in conjunction with the M&E engineers, particular attention was paid to the dynamic behaviour of the entire floor and walling systems.

The full-height atrium runs along the spine of the building, its roof structure consisting of light curved universal beam sections forming a two-pinned arch, and a system of purlins. The roof over the main area is of similar construction to the floor, except that steelwork is laid to falls and the slab is of a constant thickness. The arch thrust from the atrium roof is resisted by deep beam action in the roof slab, tied together at the ends of the building by the steel roof beams.

THE ATRIUM

7.
View looking east.

8.
The ceiling.

9.
Architect's concept.

10.
Entrance at the west.

11.
Third level in use.

At third floor level the externally-positioned plant is hidden behind a system of steel frames and aluminium grilles which are demountable to allow plant replacement without disturbing the wall or roof finishes.

Staircase construction follows the general theme of prefabrication off-site, lightweight construction, and simply in situ concrete work. Each flight is prefabricated from steel plate to form landings and stringers, and the treads comprise folded plates forming trays onto which concrete can be cast on site. The stairs provided the main vertical circulation as soon as they were installed.

Vertical 'K' bracing located at each stair core provides resistance to lateral forces. The bracing members are designed as both struts and ties and are positioned to accommodate the doorway common to every stair tower at each level.

The distance between the stair towers, and therefore the longitudinal bracing, is approximately 65m; consequently, we decided to omit expansion joints as the building beyond the stiff-braced stair towers is free to move.

The cladding materials were not finally chosen by the architect until the structural design was already well-advanced. A white granite was selected as the main cladding, with a glass-reinforced polyester and anodized aluminium window system. To achieve a reliable fixing, the granite cladding manufacturers needed a concrete perimeter structure. Beams were encased off-site, leaving gaps to allow bolted connections. Joint infill and columns were encased on site. Cast-in channels were provided each side of the gaps to allow the simple fixing of formwork before the infills were concreted. The cladding panels were bolted to the concrete by drilling and fixing on site, thus avoiding the problem of tolerances on cast-in fixings.

Concrete encasement of the perimeter steelwork gave protection against corrosion and fire. Internally, fire protection was achieved by dry lining the columns and spraying the beams.

A Scottish steel fabricator was the successful tenderer, and we worked very closely with him to exploit his semi-automated workshops. Studies included a high level of standardization for end connections, minimization of column splices, and rationalization of member sizes to produce more 'typical' elements, particularly to reduce edge beam mould costs.

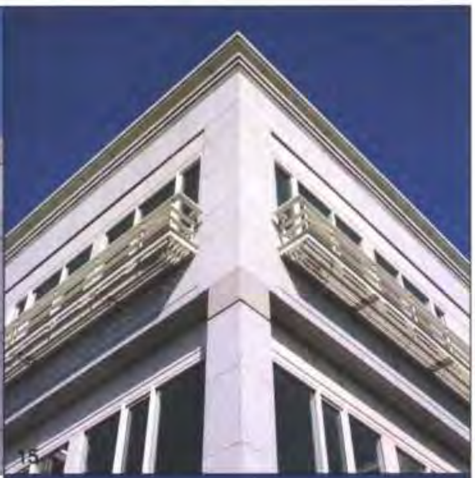
Car park

There was sufficient land on the site to have surface parking for 500 cars, but a three-level, 470-space car park was chosen to allow the maximum possible landscaped

12. Car park.


13


14


15


16


17


18

13-18
Aspects of the building's exterior

areas and to release surplus land for other uses or sale. The lowest level was set 1.2m below ground to reduce the building's profile.

The client was particularly concerned for the car park to be 'user-friendly', so that their staff could feel safe and secure. The layout was affected by the desire for visibility from any point over the whole floor, and generous floor-to-floor heights were adopted with a high level of lighting. A large open single ramp system runs up the centre of the structure, reflecting the atrium arrangement in the office building.

A waffle slab was chosen for the upper floor structure to give a flat-modelled soffit. The lighting units fit neatly into the waffles, giving an illumination level of 50 lux on average, with 100 lux on the roadways.

The car park has unusually high quality concrete finishes: the cladding is precast with a white granite exposed aggregate finish of similar colour to the polished granite on the main building. This and the internal finishes to the stairs and lift reflect the client's desire for quality throughout the development.

Contract procurement

Operational pressures relating to staff numbers and particularly the installation and commissioning of the new computer system required occupation by the Society in June 1989, with a priority on the completion of certain office areas and the computer suite.

Arups' Project Planning and Site Services Group gave valuable assistance in identifying critical elements of construction and lead-in times, and advising on appropriate construction programmes, bearing in mind the major impact of the M&E services content of the project. The construction period dictated a site start no later than 1 September 1987, leaving just six months from approval of a basic scheme to the start on site. This was insufficient for competitive tenders based on a fully-designed, co-ordinated, specified and measured scheme, and so an overlapping design and construct programme was adopted, with a two-stage selection procedure for the appointment of the main contractor.

The Society's need to be accountable to its members required a firm commitment on cost and programme at the earliest time, with demonstrable competition on the maximum number of elements. It was also felt that it would be beneficial to the scheme to select the main contractor early and to involve him in the detailed design decisions.

The following procedure was therefore followed:

(1) The scheme concept was developed to allow scheme design and the specification of main components to be frozen by the end of April 1987.

(2) A detailed cost plan for the building and services was prepared by mid-May and frozen to become the cost control document for the design development and negotiating process.

(3) From the first contractors' interviews (late May 1987) a short-list of six was selected. They were given the scheme drawings, site information, draft programme of building and M&E works and the unpriced detailed measured cost plan.

(4) Four weeks later, the contractors returned for 'in-depth' interviews at which they tabled their method statement, detailed construction programmes and their priced cost plans showing in detail all 'mark-ups' and preliminaries required.

(5) The preferred contractor was selected in mid-July 1987 on the basis of price, programme and the team put forward.

(6) During the selection period, critical elements of construction such as the structural steelwork and cladding packages were competitively tendered and the sub-contractor appointed for later adoption by the preferred main contractor as a domestic sub-contract.

(7) A building contract was finalized in December 1987 covering the whole of the construction, including M&E services. Between September and December, the contractor completed the substructure and steel frame on a letter of intent from the Society, allowing negotiations on the measured work packages to continue using the original cost plan submission as a basis. Further work was not instructed until negotiations were successfully completed.

The client accepted that there were certain risks in proceeding this way and took a positive role in the interviewing and selection procedure. The Society therefore committed itself to freezing the scheme design and to commencing work on site four months before the full contract sum was known and the overall contract programme confirmed.

At the same time the client reserved the right not to proceed with the selected contractor if satisfactory finalization of the contract details was not achieved.

The procurement method has been very successful. An excellent working relationship was established between client, design team and contractor from the start, enabling all parties to work together for the client's benefit. Changes in the client's requirements have been incorporated during construction with minimum disruption. Completion of the building contract was in November 1989, with early handover of specific areas to meet the client's needs.

Credits

Client:
Cheltenham & Gloucester Building Society
Architect:
Dyer Associates
Structural and civil engineers:
Ove Arup & Partners
Mechanical and electrical engineers:
Hoare Lea & Partners
Quantity surveyors:
Gleeds, Bristol
Main contractor:
Wimpey Construction Ltd.
Steelwork sub-contractor:
Rippin Structures Ltd.

Photos:
2, 9: Courtesy of the architect
3: © Crown Copyright
1, 4-8, 10-18: Brian Donan

Alderham Farmhouse

Peter Ross
John Henderson

Alderham Farmhouse, three miles from Warwick, stands with a few outbuildings at the end of a gravel lane — and 35m from the Warwick bypass, built in 1967. When in 1980 the Department of Transport decided to upgrade the road to full motorway standard, Arups became responsible for this, the Gaydon section of the new M40 — with the farmhouse now roughly in the middle of the northbound carriageway.

As the property has a Grade II listing, the Department agreed to a feasibility study for moving it. Originally two houses, the building is a composite structure — part timber frame, part brick. A 'lift-and-slide' move did not look feasible, due in part to the length of the building but more significantly to the general slope of the land. This left dismantling and re-erection, which, in conservation terms, is a last option.

The frame itself is of oak, probably 17th century, and a typically Northern pattern with double-pegged mortise and tenon joints. It is now infilled with brick, obviously a later replacement for wattle and daub, and dating probably from the 18th century. There was in fact evidence of the original finish, since some of the frame members showed a shallow groove into which the hazel twigs would have been set to form the wattle, before daubing with a render — some of the members, that is, but not all, and it was clear that with tenoned joints throughout, individual members could not be replaced without dismantling the whole assembly. It seemed that the frame, like so many others, had already been dismantled and re-erected, and our proposal was nothing new. The bricks date variously from the 18th and 19th centuries, but the external joinery, much repaired, as well as most of the internal finishes, are clearly 20th-century work.

We thus concluded, with our consulting architect Rodney Melville & Associates, that the principal materials of historic significance — the frame, the bricks, the tiles and some of the joinery — could all be re-used, and that the items which would be lost, mainly the internal plaster and decorations, were of relatively recent date. The farmhouse would still retain enough of its historic significance for the move to be a valid option in conservation terms. There remained the question of the form of our necessary 20th-century construction. Engineers take a simple view on these matters — contemporary work should be expressed frankly as such. It had become obvious, after all, that this was the approach favoured by the previous rebuilders of the house.

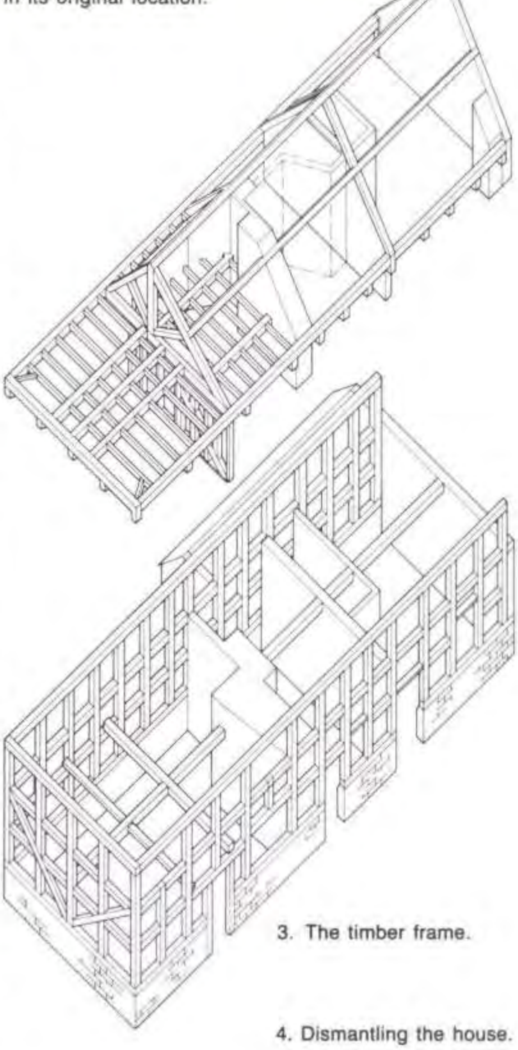
With a contractor appointed, the dismantling commenced in November 1988. The individual frame members were identified with a coding stamped onto metal tags, since so many of them were almost identical. Apart from the cill, which we decided to renew totally, the frame members were in good condition for their age. Only one member was replaced, and three others received new ends. These were joined by simple half-laps, fixed with stainless steel bolts. Bituminous paint had been applied to the external timber, creating the 'black-and-white' image of the frame which was first popularized by the Victorians. This was removed by careful sand-blasting, using very fine material.

An adequate number of bricks was recovered, due to the relatively weak mortar, and the additional stock obtained from outbuildings which were not to be rebuilt. And so by Christmas the farmhouse lay in kit form, ready for reassembly.

The external wall was originally a solid 9 in. leaf. The contemporary equivalent is the cavity wall, which would give better thermal and moisture performance. These improvements would be useful, since Warwick District Council, after some hesitation, had decided to regard the rebuild as a 'new' building, which would be required to comply with the Regulations. The existence of the cavity is honestly expressed, as the outer leaf appears as plain stretcher bond.

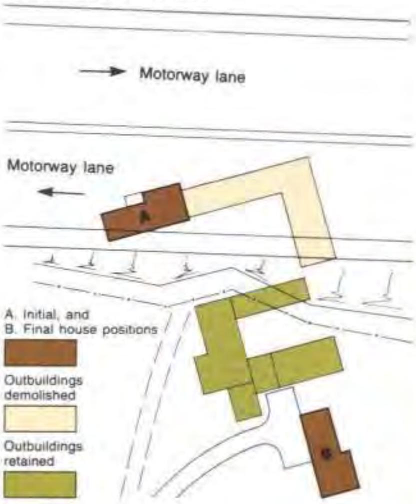
The timber frame is a very robust box, and there were no problems in justifying the members for strength. Small patch repairs were made, mainly to improve the weather resistance of the surface and eliminate any pockets where water could lie.

1. (Above) Farmhouse in its original location.



3. The timber frame.

2. Farmhouse location.

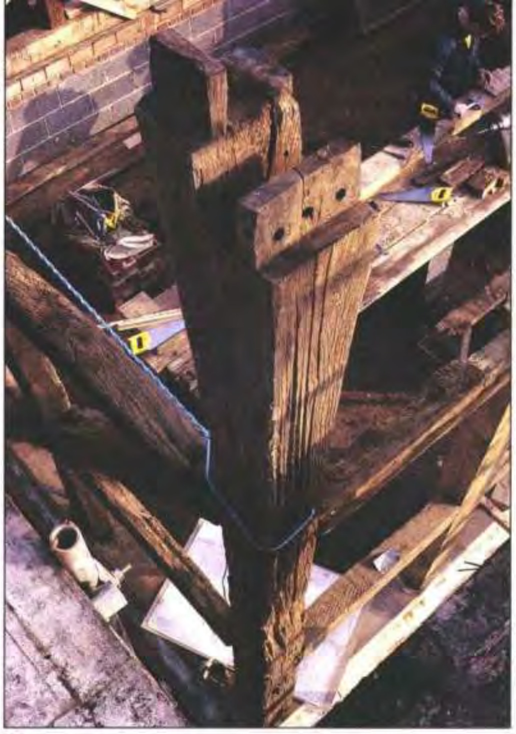


4. Dismantling the house.

5 ◁

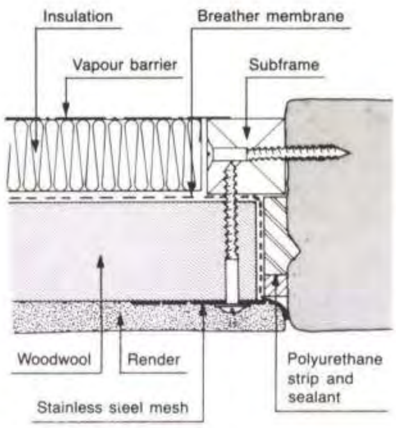
The most difficult decision related to the way in which the frame panel infill of a single brick leaf was to be rebuilt. Apart from a very poor thermal performance, which could perhaps be supplemented by an inner lining, it would be difficult to stop the brick holding water against the frame — a point which had become evident during our initial survey. We eventually decided to revert to the 'original' solution of a render infill. The base for the render is a panel of woodwool fixed to a subframe. The panel is enveloped by a breather membrane, and the perimeter gap is filled by a bitumen-impregnated polyurethane strip. The aim of this detail is to minimize the depth to which water can penetrate along the side of the frame.

The render itself is a 1:1:6 mix, finished off with a weaker coat of 1:2:9. Stainless steel mesh supports the render at the perimeter of the panel. The original intention had been to coat the panels with a lime wash, but the final appearance of the render was pleasing enough for them to be left plain. Indeed the work on site generally bears testimony to the skill and experience of the contractor.



6△

8△ 9▽



7. Frame infill: detail.

5. Repaired timbers.

6. Frame re-erection.

8. Panel infill showing the perimeter stainless steel mesh, and the breather membrane before trimming.

9. The re-located Alderham Farmhouse with its restrained palette of earth colours.

The external frame and finishes were completed by the end of June 1989, although the internal finishes and services, have, by agreement, been left for completion by the owner. The farmhouse is now starting out on its third 'life'. Not a bad performance for a frame which is already 300 years old.

Credits

Client:
Sir Charles Smith-Ryland
Consulting engineers:
Ove Arup and Partners
Consulting architects:
Rodney Melville & Associates
Quantity surveyors:
Wrightson, Pitt and Emmett
Contractor:
Linford-Bridgman Ltd.

Photos and illustrations:
1, 4-6, 8:
Peter Ross
2, 3, 7:
Andy Tsaroulla
9: John Right Photography

THE 'OTHER BUILDINGS' AT STOCKLEY PARK

Mike Glover

The masterplan concept for Stockley Park as developed by Arup Associates (described in *The Arup Journal*, *22*(1), pp.4-7, Spring 1987) envisaged the early phase buildings being designed by them to set the mood and tenor of the Park. Later phases would include, apart from further Arup Associates buildings, others designed by different architects within the constraints of the masterplan and the brief developed as part of the early Arup Associates building designs.

Design of the first of these later buildings began in late 1986. Three are now complete, another is under construction and four more are being designed and starting on site in early 1990 (see Table right).

Building	*Architect*	*Status*	*Nominal floor area*	*Number of storeys*
B2	Troughton McAslan	Completed 1988	5000m^2	2
B3	Foster Associates Ltd.	Completed 1988	12 000m^2	3
B4	Troughton McAslan	Design: On site Feb. 1990	6000m^2	3
B6	Geoffrey Darke Associates	Completed 1989	8000m^2	3
B8	Ian Ritchie Architects	Construction: Completion April 1990	9000m^2	2
W3	Eric Parry Associates	Design: On site March 1990	4000m^2	2
W1.1	Richard Rogers Partnership Ltd.	Design: On site Sept. 1990	10 000m^2	4
W1.2	Richard Rogers Partnership Ltd.	Design: On site Sept. 1990	15 000m^2	4

The buildings are all designed to the same client brief to a shell and core specification. The brief is comprehensive and in many respects prescriptive: there are simple fixed geometric constraints related to planning and column grids; floor to floor heights and numbers of storeys are given; the type of HVAC system and the environmental design criteria are stipulated.

The spur to innovation comes from the particular challenge offered by the client, Stockley Park Consortium Ltd., which is to design buildings of quality, with identities and clear differentiation from the other buildings, within the prescribed budget and brief.

The budget for the buildings currently under design at Stockley is about £650/m^2, excluding external works. The completed buildings B2, B3 and B6 were constructed for about £530/m^2, at least 30% below construction costs in the general London area; the margin is increasing in the later buildings.

A number of factors enable these exceptional budget costs to be achieved. For example, apart from the architect, the project team for all these buildings has been the same. Stanhope are project managers, Arups are responsible for a full multidisciplinary service, Davis Langdon and Everest are quantity surveyors, and Schal are construction managers. This consistent arrangement has benefited the project immensely. The team has been able to build up strong and trusting relationships with works contractors, apply the lessons learnt on previous buildings, and develop ways of improving construction details and servicing concepts. By contrast, the architects have introduced new approaches to each building to challenge and develop the brief and hence bring freshness to the design. These combined efforts have enabled costs to be held down while maintaining quality.

Other advantages have come from the provision of all the infrastructure and the ideal foundation conditions given by the gravel pads, both formed in advance of the buildings as a part of the masterplan works, all designed by Arups' Civil Engineering Infrastructure group. We have also been able to agree realistic prices on a rolling annual basis with preferred works contractors for key elements of the buildings.

The notional target programme for the buildings is one year from start of design to completion of shell and core. To date this programme has always been slightly exceeded due to external factors, but it still remains the target and represents the last remaining challenge to be overcome by the project team.

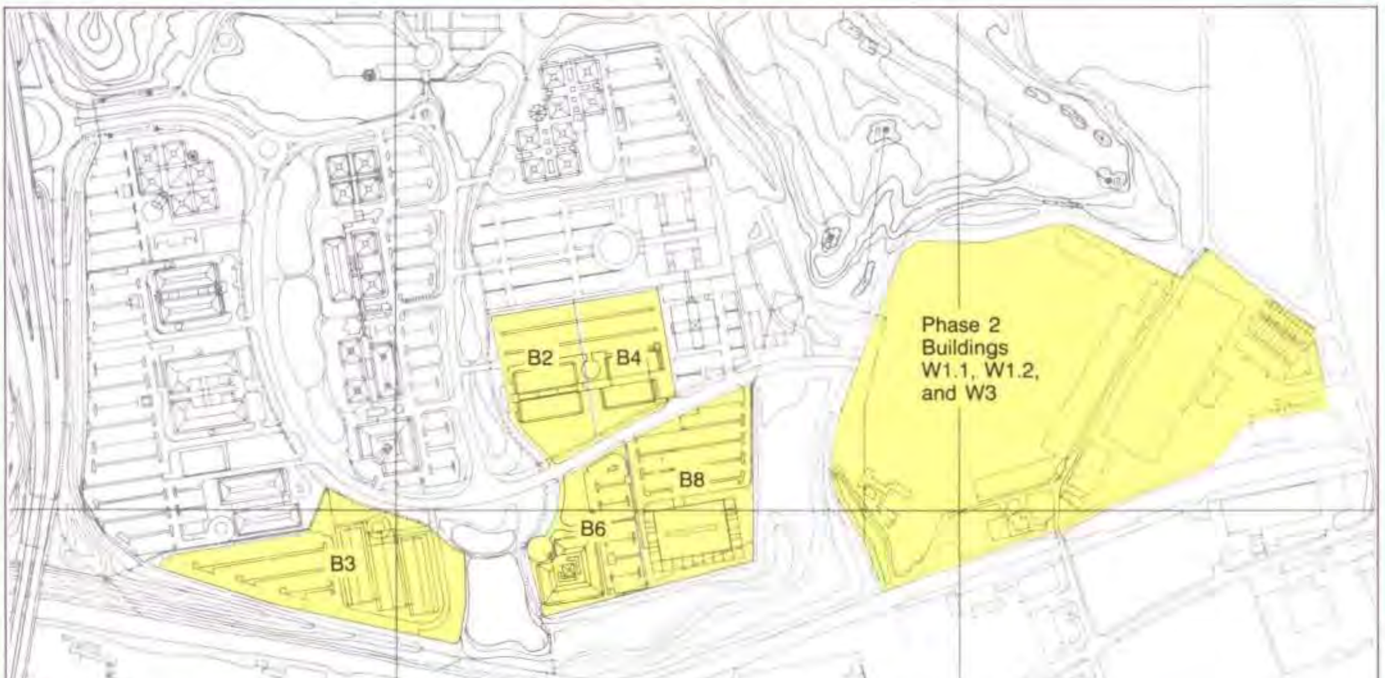
To illustrate the way the team has responded to the standard client brief, the concepts for four of the buildings, B2, B3, B6 and B8, are shown on subsequent pages. Some of the engineering design features are summarized below.

The structural frame for all of the buildings is a steel frame based on a 9m square grid with composite concrete floors onto metal decking. Foundations for the buildings illustrated are pad footings onto gravel at ground level. However, because of a change in ground conditions across the site, buildings W3, W1.1 and W1.2 will be bored pile foundations with integral pile caps.

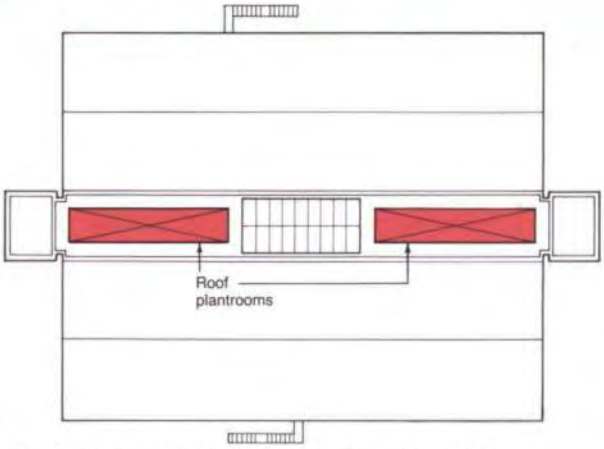
Despite the conventional wisdom about dry-lined stud walls and steel staircases for buildings of this type, there has been widespread use of blockwork walls (for weather and robustness reasons) and concrete stairs (for price and delivery reasons).

HVAC is provided by a VAV system to normal commercial office design criteria. However, two features of the brief have been revised progressively upwards: fresh air has been increased from 8 litres/person/second to 15 litres/person/second and small power provision has been increased from 20 watts/m^2 to 45 watts/m^2. Both have been included with little increase in the final budget.

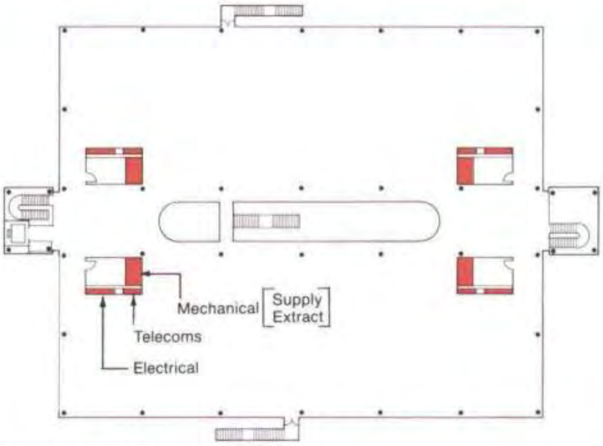
Plant has been handled in a variety of ways: integrated rooftop plantroom modules including airhandling, boiler, water tanks and chiller for B2 and B6, and separate units housed in a plant enclosure for B3 and B8. The plant for the later buildings has moved away from integrated arrangements: B4 has a separate area at roof level, W3 has an internal plantroom, and W1.1 and W1.2 have a proposed undercroft concept to take advantage of the poor ground conditions at the site.



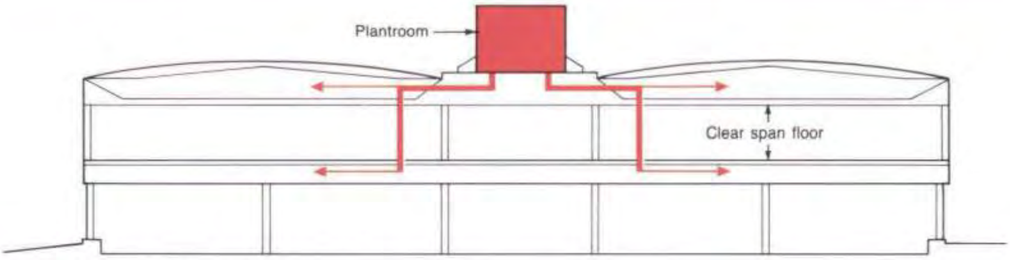
Site plan



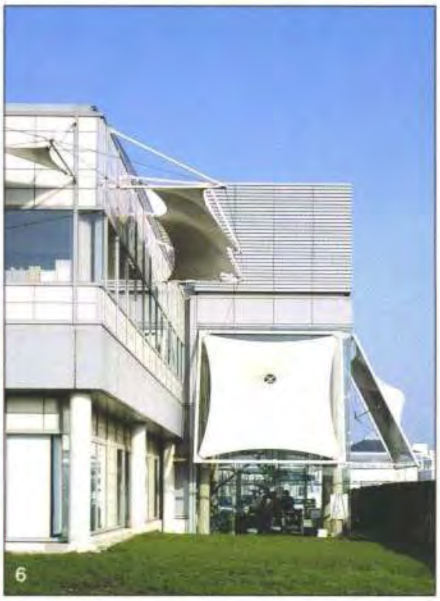
1. Roof level plan showing integrated plantroom modules



2. First floor plan showing vertical risers



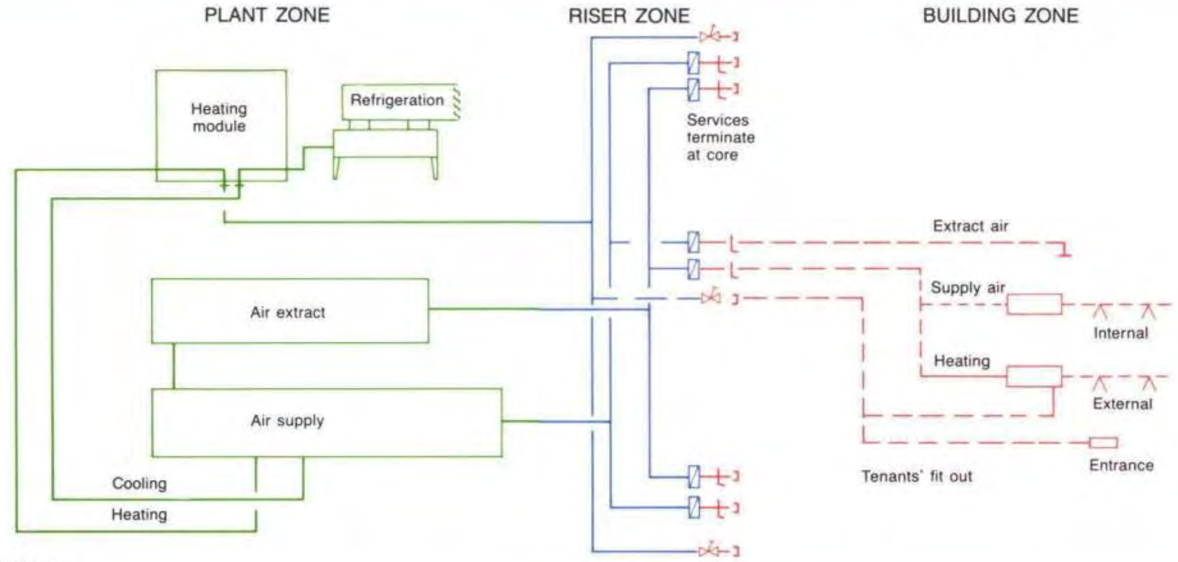
3. North-south section showing air distribution



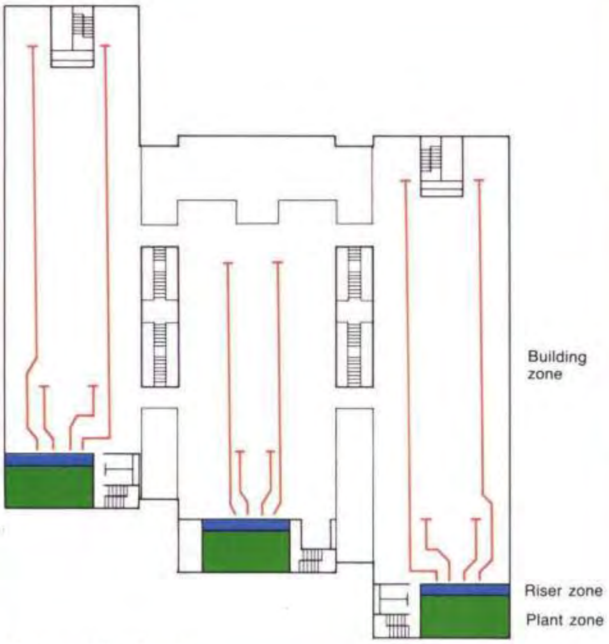
4. North elevation

5. South elevation

6. West end from the north



1. Central plant



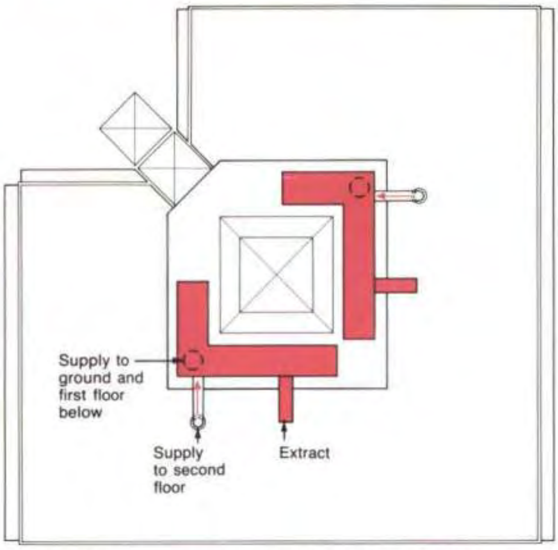
2. Services distribution

3. West elevation

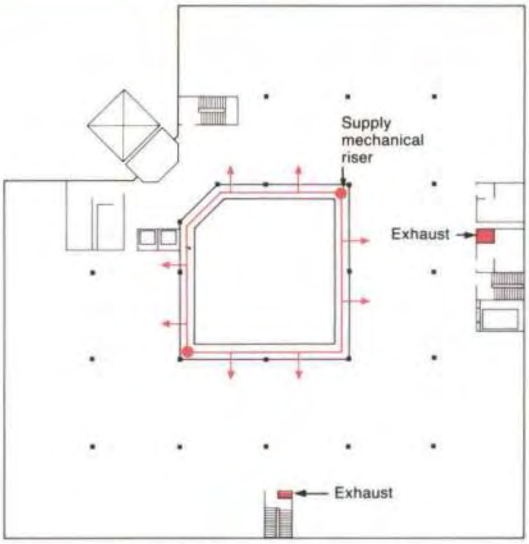
4. Interior showing atrium

5. North elevation

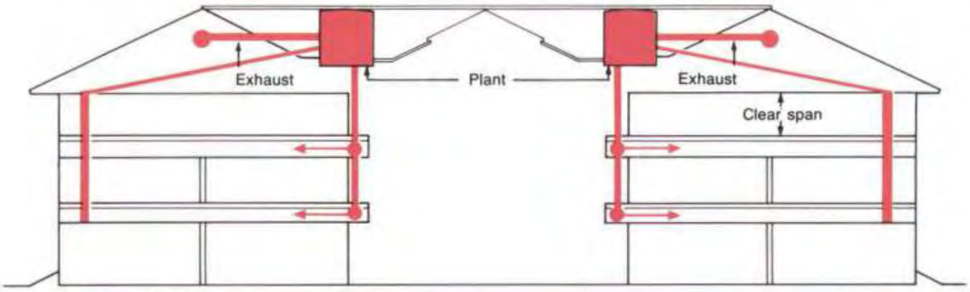
B6 Architect: Geoffrey Darke Associates



1. Roof level plan showing integrated plantroom modules



2. First floor plan showing horizontal air distribution

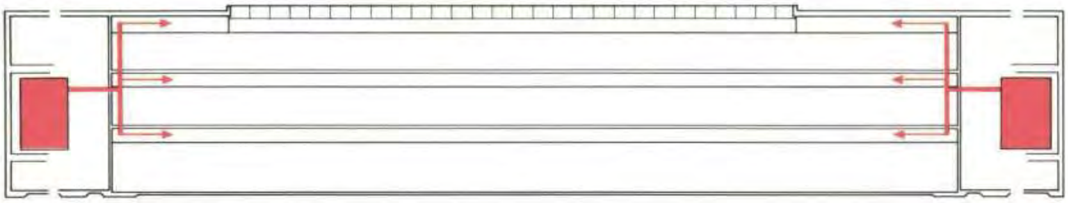


3. Section showing plant and horizontal feeders

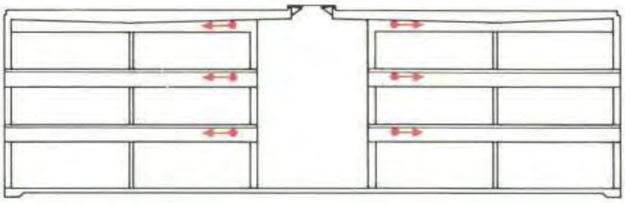
4. Roof showing plantroom and roof light

5. West elevation

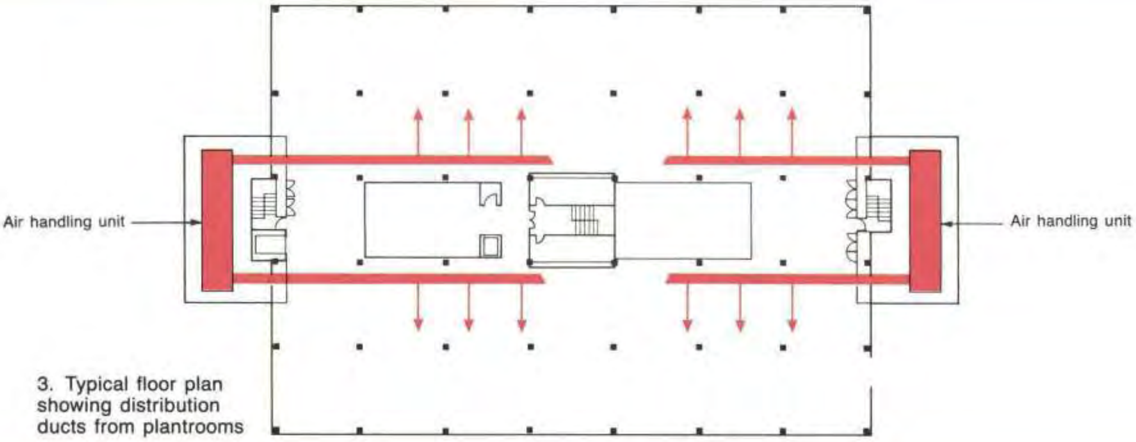
B8 Architect: Ian Ritchie Architects



1. East-west section showing perimeter multi-level distributed plantrooms and air distribution

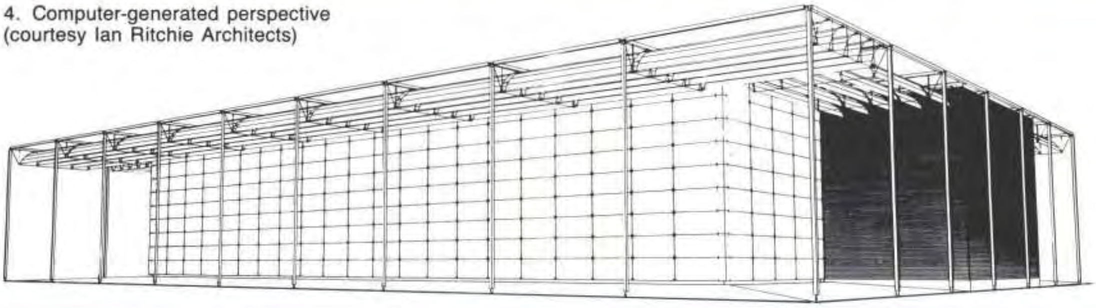


2. North-south section showing horizontal air distribution



3. Typical floor plan showing distribution ducts from plantrooms

4. Computer-generated perspective (courtesy Ian Ritchie Architects)



Aerial view of Stockley Park (Photo: Marcus Taylor)

Photos: Peter Mackinven

Illustrations: Andy Tsaroulla

A celebration of the life and work of Ove Arup

Peter Rice

This paper was delivered to a meeting of the Royal Society of Arts on 1 March 1989.

When I joined Arups in 1958 Ove Arup was already — The Old Man — a vague and venerable figure, who floated above and around a young aggressive, ambitious organization.

For a young engineer, lost in the vastness of London, and cocooned in layers of seniority, the name evoked a sense of myth. I saw him occasionally, at the Christmas party, at the summer outing, a tall patrician figure, detached and kindly, watching benignly as the young ones enjoyed themselves. You could feel a sense of fun, an impishness that belied his position. It was the time of Hemingway's *The Old Man and the Sea,* a book which had impressed on me the remoteness and detachment of age, the distillation of wisdom and purpose, which old people embody. It all seemed to fit.

I had joined Ove Arup & Partners because I had heard that it was a place where an oddball could fit. Engineering then was a very serious profession. Perhaps it still is. Engineers were expected to know what they were about, to have a natural feel for their profession. I was an engineer by accident, tentatively feeling my way to a career, without any natural instinct for engineering. The atmosphere of Arups helped me survive. Where then did this atmosphere come from? — clearly 'the Old Man' was the fountain, but how? Why? One of the real pleasures of giving this talk has been the opportunity to find out, to discover the real Ove Arup, beneath the myth that he had become in my mind.

Ove Arup's honours came late in life. He was 76 when knighted and 91 when he became a Royal Academician, the honour which gave him most pleasure. Earlier, he had first become Chevalier in 1965, then Commander (First Class) in 1975 of the Order of the Dannebrog. This honour was a rare tribute, because it was seldom given to a foreigner.

He had taken British nationality before the War, once he realised he was going to make his life here. He was given the Gold Medal of the RIBA in 1966 and the Institution of Structural Engineers' Gold Medal in 1973, a double which has been achieved by only one other person, Pier Luigi Nervi. He also received five honorary degrees, from Durham, Heriot-Watt, East Anglia, City and Danmarks Tekniske Højskule. All these honours, and the many special invitations he received to talk to learned societies, are a testimony to the quality of his work and the high regard in which it was held by his peers and in the public mind.

His university career began in Copenhagen in 1913, when he studied philosophy. He had previously attended Sorø Academy, often called the Danish Eton, and before that had been to a preparatory school in Hamburg. In fact he had been born in England — in 1895 — in Newcastle-upon-Tyne, which has always had a sizeable Danish colony resulting from the dairy trade between Denmark and Britain. His father was a veterinary commissioner to the Danish Government and before Ove Arup was a year old, the family moved to Hamburg.


Ove Arup in 1938.

Ove's study of philosophy did not satisfy him and in 1916 he transferred to the Polytechnisk Laereanstalt, Denmark's Technical College, and in 1922 graduated as a civil engineer and became a Member of the Danish Society of Engineers.

His first job was as a designer in the Hamburg office of the Danish firm of Christiani & Nielsen who were designers and contractors. Joining Christiani & Nielsen at this time was the objective of every young graduating Danish civil engineer. It was a time when Danish engineering led the world, particularly in concrete construction, and Christiani & Nielsen was its brightest star. To have joined them straight from university shows that he got a good degree and that he had the highest engineering credentials.

Christiani & Nielsen built mostly harbour structures, such as jetties, piers and bridges, and had made a speciality of the then new material, reinforced concrete. Ove Arup often recalled later how important it had been for him that he had started work in a contractor's office. He had been transferred from the theoretical world of the university to the practical, real world of construction. He saw that concrete was made by a couple of buckets of sand and cement, by people on site who mostly did not understand. From those early years on, he knew that to design you had to know how to build. For Ove Arup the two went hand-in-hand.

His actual work was designing and estimating and this he did in Hamburg for a couple of years before being moved to the firm's office in London in 1924. In London he was promoted to Chief Designer but we read in his own reminiscences in the 1968 Maitland Lecture[1] how frustrated he became because he was not able to put into practice his many ideas for using reinforced concrete.

He was also frustrated because, as a contractor, he was not able to get his clients to try new methods.

It was important at this time that Ove Arup was a Continental engineer. He did not feel the classic Anglo-Saxon separation between thinking and doing. He was interested in everything. He read widely — in German as well as in English and in Danish. Art, music, philosophy, and architecture: all interested him, and he was aware of the changes in art and architecture then taking place in Germany and France. It was as natural for him to be reading about art one minute as it was to be solving some construction problem in a jetty the next.

In the early '30s Ove Arup met architects of the Modern Movement, among whom were Berthold Lubetkin and the partners of Tecton, who were planning an eight-storey block of flats in Highgate, north London, to be called 'Highpoint'.

The project was in reinforced concrete; Ove Arup had many ideas about how it could be built, but Christiani & Nielsen were not


Highpoint flats, Highgate, north London. (Photo: John Donat)

interested in the job. They were after all civil engineering contractors, so in 1934 he moved to Kiers, also civil engineering contractors, but willing to work in the construction of buildings. He accepted an offer of a job as Chief Design Engineer and a directorship in return for an undertaking that they would endeavour to take on jobs with modern architects. Olaf Kier was also Danish and he and Arup had been friends. At this time there was still a big distinction between civil engineering and building contractors. Civil engineering contractors engaged only in large-scale construction which required considerable engineering skill, whereas building contractors were craft-based and often did not employ engineers at all. This distinction, which has now largely disappeared, meant that the switch which Ove Arup and Kiers made was quite unusual.

Arup and Lubetkin had already worked together on the Gorilla House at London Zoo and now at Kiers, he helped Tecton and Lubetkin create the intertwining spirals in reinforced concrete for the penguins at the Zoo. The Penguin Pool structure, small and simple though it was, was a great success. It helped to show the public what was possible, what an exciting material reinforced concrete could be.

Highpoint pioneered reinforced concrete wall and slab construction in Britain and this, together with the first prize in the 'Working Men's Flats' competition for the Cement Marketing Company, brought Arup to the notice of other engineers and architects. The 'Working Men's Flats' project was never built, but it was of great significance. Most of the well-known engineers of the day had entered, and it established the method of construction using concrete crosswalls as viable and correct

It seems that Ove Arup realised by this point that he still did not have the freedom he sought. In 1938 he and his cousin Arne set up the design and construction firm of Arup & Arup and he also worked on a variety of projects mainly concerned with the war situation. He designed deep air raid shelters for Finsbury Council which became quite controversial but were never built, and published several reports and papers on 'Safe housing in wartime'[2]. He collaborated on these with Cyril Sjøstrøm and Ernö Goldfinger.

In addition to his work with Arup & Arup, he worked during the War on the design of the Mulberry Harbour pontoons with Ronald Jenkins, later to be his senior partner in Ove Arup & Partners.


3. Mulberry Harbour pontoon:
The crank-shaped fender can be seen just clear of the water.
(Photo: Courtesy Imperial War Museum)

In *Code name Mulberry* by Guy Hartcup[3] we read: 'Jenkins and Ove Arup (now the celebrated structural designer) designed a fender 2ft long and weighing 2 tons, crank-shaped so that when it was pushed back and upwards the ship's side would not bear on the bracket. Screwed rods were passed through sleeves in the brackets and hooked into the back of each unit, so preventing the sides of the pontoon from being damaged during towage.'

In 1946, having realized that to control design you had to be a consulting engineer, he left the firm of Arup and Arup and a new firm, 'Ove N Arup Consulting Engineer', emerged. In 1948 he took Ronald Jenkins, Geoffrey Wood and Andrew Young (who later resigned) into partnership, and in 1956 Peter Dunican. The partnership which was to grow and spread throughout the world had been started.

Ove Arup the man, Ove Arup the engineer and designer, Ove Arup the philosopher and lecturer, who were they? What was the central force? To understand Ove Arup and the influence he had, one must find out about the man. He was a man of great charm and total honesty, as all who met him will testify. The charm and honesty meant that he was easy to believe. He had the capacity to articulate simple honest statements, without pomposity, and thereby he disarmed those who were critical. He was a perfectionist, but a somewhat disorganized and haphazard one. He was curious, anything and everything could interest him, so that he would always respond positively to any idea, any proposal, and then see the other side.

But the most striking thing about him was his humanity. He wanted always to see the context of any proposal, and to check its effect on the people concerned. In engineering he wanted to know how the structure was built; in architecture he wanted to know how the people would respond, how it would affect them. It was this humanity, this concern for the effect of our actions, which made him so influential on those he knew. He was difficult, exasperating, even-handed to the point of indecision. 'On the other hand . . .' was probably his favourite phrase. He was also tough. When action was really needed he could take it. Usually this action was taken in the name of honesty. He was as honest and tough on himself as he was with others.

At a personal level he was kind and courteous. He loved music. Bach was his favourite composer. He composed himself, improvising constantly on the piano to help him relax. He would not let these improvisations be recorded. That he felt would be too serious. He liked to cook, particularly when he was younger. Indeed he had a kitchen built alongside his office when new premises were built for Ove Arup & Partners in Fitzroy Street in 1959. When he cooked, the perfectionist in him would come out. John Martin, who worked with him on the Durham footbridge, tells the story of helping him prepare an omelette which had chives. He asked John to cut the chives into short lengths. When he had finished he was told they were too long. They had to be done again.

He enjoyed clothes. He was tall — over six foot — and handsome and could wear anything well. His casual nonchalance was carefully constructed and he was addicted to his French berets. Every five or six years he would go to France to get a new beret. I remember well the problems he created when he came to visit Beaubourg, looking for the right type of Breton beret. I think that was really why he came.

Ove Arup enjoyed playing chess. He played well, but as a gifted amateur, not reading about it, not following standard moves. He would analyze the game as it went along, without allowing his opponent to make silly moves. It was the game, not winning, which counted. In his later life he designed a chess set, and with it a new system of notation. It was stimulated by the publicity in 1972 for the Fischer-Spassky World Championship. He remembered camping in a forest with his brother when he was young. They wanted to play chess but they had no chess set. So they invented the pieces, based on how they moved. The memory convinced him that he should do it again. He was old by then, about 77, and he did not like being dependent on others. Designing and making the chess set was something he could do without help. The resulting chess set was ingenious, and very clear, but too unconventional to be accepted in such a conservative world.

This unconventional and rebellious spirit remained with Ove Arup all his life. Even when tamed by success, he retained an independence of mind and a scepticism towards the many honours he received.

Irrespective of any other qualities Ove Arup may have had, his reputation was founded on his engineering ability. The first evidence of this ability was his design project at the University of Copenhagen. This was a three-span continuous beam bridge, in steel, detailed and formed to resemble a series of arches. The working out of this project was meticulous and logical, a model engineering thesis.

As we have seen in the chronology of his career, he started working in a conventional civil engineering company. Christiani & Nielsen, when he joined them, firstly in Germany and later in Britain, were building harbours, jetties and bridges. The problems were exclusively engineering problems. Aesthetic considerations did not apply. The designer had to design a structure to resist the forces, and to understand how that structure performed in the various tidal and ground conditions which might arise. Ove Arup took nothing for granted. From the beginning he sought to understand and to re-examine the nature of the loading which jetties must carry, and to find the most appropriate structural form to resist them.

In a detailed monograph[4] published in 1935 he outlined the results of this research. He proposed the use of full-length bracing and raking piles as more efficient and as a more correct engineering response than the conventional solutions then in vogue. The monograph examines these conventional solutions of the stiff deck on vertical piles, and compares the failure modes of the different structural forms. This document is interesting, because it is not a complex analytical treatise, but a series of pragmatic arguments justifying a clear engineering choice made, I suspect, instinctively. It is the work of a true engineer, not that of an intellectual playing with engineering. He was working in an environment dominated by the classic engineering values: practicality, simplicity, adequacy and cost. His proposals are interesting from another point of view. Every proposed solution is related to, maybe even derived from, the construction method. And the construction method that most interested him was building in reinforced concrete. The advantages in durability, and flexibility of form were properties that could be exploited to improve on the structures then being built.

The psychological importance of this early work was that it was real engineering. It was the kind other engineers respect. Engineering mixed with architecture is not really the same. To design straightforward primitive structures with large forces in hostile conditions is the essence of engineering. It is what an engineering education prepares you for. And the structures he designed at that time are clear, well-thought-out examples of the genre. They are not fussy or over-detailed.

This work gave Ove Arup a platform from which he could confidently embark on the more delicate problems of designing structure in architecture.

Ove Arup believed in the simple engineering virtues, but they were not enough. He was aware from his reading and observations of the Modern Movement in art and architecture that this was based on exploiting the true engineering properties of modern materials and he longed to participate. He sought out the few architects interested in the Modern Movement, and helped them as much as he could. When this conflicted with his work at Christiani & Nielsen he left. As stated above, he joined J.L. Kier as Chief Design Engineer and Director, a role which enabled him to explore the possibilities of working directly with architects. Working as an engineer with architects became the core of Ove Arup's life. That this move was part of an inevitable progression is evident from a number of early articles and his recollections of later years. While working with Christiani & Nielsen in the early '30s he designed the cafe at the seafront on Canvey Island, a simple concrete structure clearly influenced by Modern thinking. He did not consider this a particularly satisfactory project but it shows where his thoughts were heading.

4. Canvey Island cafe.
(Illustration: Fred English)

The structure of the Highpoint flats was in some ways the clearest example of a marriage of architecture, engineering and construction that Arup achieved. The concept is simple. Walls are load-bearing, and when openings are required underneath to facilitate the architectural planning they act as beams. There are no columns or beams as such, just walls and slabs. The architecture demanded some engineering compromise, but the concept works, and works well. The construction method was developed from silo construction with sliding shutters for the vertical walls.

When he became a consulting engineer in 1946, the idea that an engineer should devote himself to working with architects was at least odd, if not faintly ridiculous. It was considered a marginal activity, one which you did in your spare time. It set Arup apart from the real engineers, a foreigner on two counts. It was an enormous affirmation of his beliefs.

As the firm he had started grew and prospered, Ove Arup's role as the engineering leader changed. He became a figurehead, defining the standards. Certain projects and certain architects attracted him. Two projects, where he had a deep personal involvement, exemplify his contribution, his way of working. One was the footbridge over the River Wear in Durham, the other the Sydney Opera House.

The Kingsgate Footbridge, Durham, was the engineering jewel of his later life. He received the commission in 1961 and worked on it for about a year before going to tender.

The proposal was to build a link between the University and Dunelm House across the River Wear. The commission was a direct one to Ove himself and the client, who had a small budget, gave him as much time as he needed to develop the right design. From the beginning Ove asked himself, how would he build it? That became the motor of his ideas. He produced a whole series of ideas, which he finally reduced to six (the originals have unfortunately been lost). These six ideas were then developed to assess their value as architectural solutions for the space. Finally the solution with two swinging panels was chosen. The development of this solution into a proposal fit to build took eight months. In reality he never stopped designing right to the time the concrete was poured. The design could always be improved. He behaved like the most fastidious architect.

The concept has two panels, each constructed parallel to the river bank and then swung into position. This simple construction idea is allowed to dictate the architectural detailing and to become the finished form of the bridge. The precise form of each leg, the nature of the hand rail, the relationship of the bridge to the embankments, were painstakingly researched and improved. The whole endeavour was treated with enormous attention to detail, a perfectionist seeking perfection, but within the framework of an engineering concept drawn from the most basic of principles.

This mixture is clearly reflected in the central point, a symbolic and graphic link which expresses the separate nature of the two parts, their necessary jointing. It is visible to everyone using or seeing the bridge, a permanent reminder that the form is a product of the process of construction.

5. Kingsgate footbridge.
(Photo: Ove Arup & Partners)

This intellectual rigour is I believe the epitome of the work of Ove Arup the engineer. He has not just solved the engineering problem. He has insisted that the logic of the construction solution should constitute a challenge to everyone who uses the bridge. This quality of mixing intellect with engineering pragmatism is a very rare one in engineers, and has led many to doubt whether he was really a natural engineer. Engineers are supposed to have an instinctive feeling for the right solution, and good engineers know naturally what the best and most correct solution is. Ove's intellectual curiosity would not allow him this luxury. He had to explore. He had to know he was right, because he had already tested most of the alternatives.

I would now like to look at the role Ove Arup played in the development of the roof of the Sydney Opera House. His association with this project was the synthesis of all he believed in. How he was awarded the project is not quite clear. Suffice it to say that for him it was natural and inevitable that he should be the engineer; after all Jørn Utzon, the winning architect, was Danish. The translation of the ephemeral, evocative, competition sketches into the building was slow and complex. It took place in three parts: the design of the base or podium structure, the roof structure, and the inside of the building, including the glass walls. Construction started very quickly after the competition announcement, and the design of the podium overlapped with the construction. Three and a half years were allowed for this work, before the roof structure would start on site. The early development of the roof design had been done by Ronald Jenkins, who saw the structures as shells, that is, structures getting their strength from their curvature, and which could be constructed as a single structural skin. The early shell forms did not have enough curvature to work properly as shell structures. Furthermore, the geometry of the shells was non-uniform, and it would have been extremely difficult to construct them accurately.

The single skin series of solutions was replaced with a set of double skin solutions, i.e. two continuous structural skins, joined by structural ribs. Structurally these worked, but they had a number of serious disadvantages. The geometry was still non-repetitive so every element was different, which was an enormous problem of construction. It was also difficult to see how the external tiles could be arranged on the surface. All this development work had taken three years, and the need for a simpler solution had become critical. It was planned to start construction of the shells at the end of 1961 and it was already spring of that year. To provide an independent assessment of the problem, and of where an appropriate solution might be found, Jack Zunz, who had just returned to London from overseas, was asked to look at the problem. Suitable geometries for repetition were identified in discussion with Utzon. He and Arup met, and for a period they worked together. What emerged was the solution which was built. The early geometrical solutions had been based on the seductive elegance of Utzon's competition sketches. By comparison, this new geometry was tough, aggressive and simplified. All of the shells were taken from segments of the same sphere, bounded and defined by great circular planes. This meant that the shells were constructed from a series of precast concrete ribs, each identical except for their length. The tiles, too, were laid on the surface of a sphere, and identical precast elements were used. A complicated and uncertain design had been transformed into a detailed proposal for construction and a solution where every element had a simple, logical, and necessary existence. There is no doubt that much of the motivation came from Utzon. He was the architect. Only he could initiate change. But Arup was the catalyst. The result has all the hallmarks of his obsession with how to build it. It was in its way a clear example of a maturing relationship between an architect and an engineer. The result reflects the preoccupations of each, and provides a proper solution of all of their joint concerns. This proposal was developed into the built solution over the next 1 ½ years in conjunction with the Australian contractors Hornibrook. Ove Arup did not participate in a detailed way in this work. He was a presiding presence, overseeing the work, and available to guarantee that the central idea was preserved in its development. After 1963, Utzon moved to Sydney, and with him the centre of design.

When in 1966 the rupture came between Utzon and his client, the Government of New South Wales, Arup had lost contact with Utzon, and was unable to help.

During this time, Ove Arup the engineer made way for Ove Arup the thinker, the teacher, and the prophet. Increasingly he allowed his time to become dominated by his writing and speaking. He accepted many opportunities to lecture. Between 1947 and 1984, when he was 89, at least 180 talks and articles are recorded. He used these occasions to develop his views on many subjects. In one way, even more than his contribution to engineering, these were his life's work. With his engineering he could lead, inspire, influence, and persuade others. His personal magnetism was enormous. You could resist his demands only by avoiding them altogether. And in the end the engineering was done by others. His writing he did himself. He wrote well, with a simple clarity, which gave direct access to his mind. As with his engineering design it was painfully perfected through much rewriting, in the pursuit of simplicity and directness.

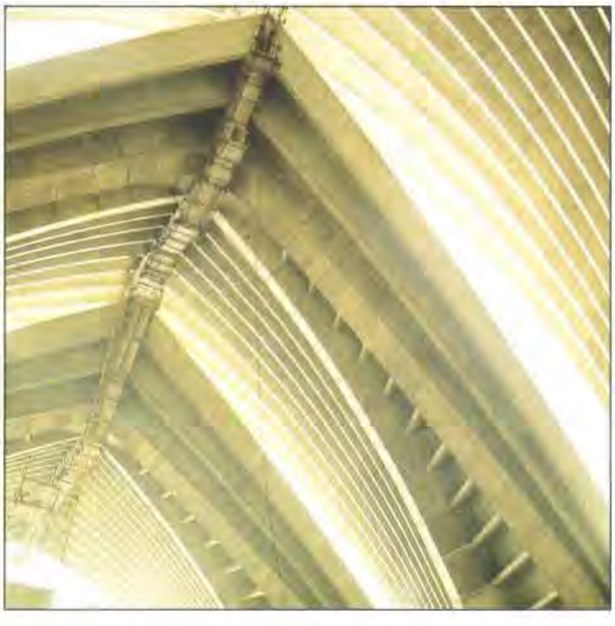
He treated many subjects philosophically and pragmatically, usually with a simple earthiness which left no doubt of where he stood. Reading his writing now, one has the impression of a kind, generous and ordinary man, who liked home truths and who could express them without conceit or pomposity. Never in days of reading did I find a sentence I did not understand, or a word which needed the dictionary. The writing is infused with a concern for people and the planet on which we live. He had a way of writing and speaking which was seductive, gently persuading you to come along, to listen, and gradually, once he had your attention, making a clear unambiguous argument and proposition with which it was impossible to disagree. Each article, each individual piece of writing was a coherent statement.

Each was in fact a response to a demand made by someone else.

You can see that the articles were difficult to write. The quality of effortless simplicity does not come easily. But as you read you want to read more, to hear him talk of other problems. This nice and honest man with so much to say beguiles you. But there is a problem, which highlights the dichotomy and irony of Ove Arup's life. His very success as a writer and lecturer meant that he was always responding to others, never to himself. In a way he never developed a coherent philosophy. About individual subjects he was of course very coherent, very astute, about

6.
Sydney
Opera House:
model of
segmented
sphere
solution
to the design
of the shells.

7 and 8.
Shells
during
construction.
Photographed
by Ove Arup
in 1966.



architecture, and architects, and engineers, for instance. But somehow you feel there was more, a complete philosophy which might have shed light on a larger part of the human predicament. For a man who wrote so much it is strange that he never wrote a book, that he never progressed beyond the carefully written reflection on a particular theme.

There are three broad subjects treated in his articles and lectures. The first is engineering. Then there are his thoughts on the relationship and division of responsibility between architects and engineers, and within this the need for engineers to understand aesthetics and for architects to respect engineers. The final subject concerns the nature of architecture and the responsibility of engineers and architects for the environment in this nuclear age. Interspersed with these public lectures and articles, were a number of addresses to the leaders of his firm where he propounded a philosophy to guide the way the firm should develop.

His public lectures and articles show a gradual change of emphasis from concern about the mechanism of design in the built environment, to a profound unease at the responsibility engineers in particular carry for what he saw as the rapidly deteriorating condition of the environment, and the need for engineers to accept that responsibility squarely and act upon it.

In the first writings in 1926 we already find him seeking co-operation between engineers and architects[5].

It is only natural that the best treatment of reinforced concrete at this stage is to be seen in the domain where the knowledge of reinforced concrete is most advanced, where the properties of reinforced concrete are of most value, and where the architectural proposition is the simplest possible. This, however, does not imply that a collaboration between architects and engineers is not highly desirable in the case of engineering structures. Most structures would profit immensely by such a collaboration, provided of course that the architect treats the reinforced concrete structure as such and does not try to apply ornaments and decorations taken from quite different domains.

This early passage shows that his later writing was not post-rationalization but the development of themes which were present from the beginning of his professional career.

In 1958, in an article and talk entitled 'Structural Honesty', given at the Architectural Association School of Architecture we find him talking on the role of the engineer in architecture[6].

It happens to be my job to design the structures of buildings under the guidance of various architects. A very interesting job, if one happens to be interested both in structure and in architecture. Now if an engineer is put to design a structure which has to satisfy certain conditions, he knows exactly what to aim for, namely to find the most economical solution to the problem. Not so if he is collaborating with an architect, or receiving instructions from an architect. In that case the right structural solution is only part of a wider problem, the right architectural solution. The two are completely mixed up. Economy is still an aim, but not the only one. The effect on the architecture must also be considered, and here the architect has the last word. This means that there is a kind of dual control exercised in the design of what I might term as 'architectural' structure. The engineer designs, but the architect decides what he is to aim for. The architectural guidance varies from case to case, both in intensity, quality and kind. This is only natural, for architects have different personalities and have different views on architecture. At one end of the scale, some architects know exactly what they want, and they exercise strict control to get it. They may even require the structure to suffer the most unnatural contortions in order to produce the desired architectural effect. At the other end of the scale there may be architects who do not think that the structure should be interfered with at all.

That lecture had a very distinguished audience including tonight's chairman, who proposed the vote of thanks. Sir Hugh Casson, Felix Samuely, and R.T. James also spoke that night. Can we wonder that Ove Arup was an influential figure?

In the Alfred Bossom lecture entitled 'Architects, Engineers & Builders' in March 1970 at the Royal Society of Arts, he expanded on the nature of the building industry, and on how, with its almost unlimited power to change and dominate the environment, it needed to be controlled rather than encouraged[7].

In the past the environment, the landscape in all its natural and urban forms just happened, it was never before deliberately created by man, except in small patches. The technological revolution is changing all that. Man's battle with nature has been won. Whether we like it or not, we are now burdened with the administration of the conquered territory. Nature reserves, landscape, townscape: they will all be wantonly destroyed, to the ultimate ruin of man, or they must be deliberately planned to serve his need. Much has been destroyed already and more will be destroyed, but the alarm has sounded. Pollution, population, explosion, etc., is news. The battle is on, and it is a crucial battle for mankind. Those who long to return to the good old days must be told firmly that that road is now closed.

This lecture embodies Ove Arup's developing philosophy, as succinctly relevant today as when it was written. The lecture has that self-deprecating ironic wit so typical of Ove Arup the person. Parts of it are pure Ove[7].

The Modern Movement . . . discovered that the work of bygone engineers was in fact architecture. It is now accepted that bridges and factories and all that are architecture. So is housing, in fact everything built is architecture. And the same spirit which is supposed to be moving architects is behind town-planning and land-scaping as well as interior design and furnishing. Everything made by man for man's use now has to be designed. And in all these spheres dedicated engineers are trying to conjure forth that mystical spiritual quality which is the essence of art.

As he grew older he became more and more concerned with the predicament of man at the end of the 20th century. Perhaps he realised that the lesson of his early years had been learned, and that of course it had not solved the problem. An even greater challenge lies ahead, the challenge of the environment, a challenge whose magnitude had only just become visible. The definition of this challenge pre-occupied his last years; where and by whom must it be met? As engineers, are we but innocent followers of others or truly responsible? This was the theme of a statement made to the Fellowship of Engineering in September 1983, when Ove Arup was 88[8].

. . . it is my conviction that whilst we have become very clever at doing almost anything we like, we are very backward in choosing the right things to do. This is, of course, taking a global view of the behaviour of mankind and that, I submit, we are simply forced to do in view of the tremendous power for good and evil conferred on us by our sophisticated technology. It has brought us tremendous blessings, and it has also done tremendous damage to our planet and its inhabitants . . . And as mentioned, the decision about how to use it is not generally made by the engineers. But engineers are world citizens as we all are and as they are largely represented on the design teams preparing the designs which determine what is made, they are in a good position to judge the consequences for mankind of proceeding with doing what we are about to do. Would it not be a good thing if they had a say in what we should do and have they not a duty as citizens of the world to warn us of any dangerous consequences which would result from our action?

And he ends with a plea. It is remarkable, but at 88 all the passion of his youth is still there.

My only hope is that this well-educated minority will swell to include the less well-educated majority so that even governments can start to think about how to alter course without creating world-wide chaos. It will be extremely difficult. It must be a slow and controlled process and its success depends on whether we can convince a majority of our leaders and their followers that we need to alter course. Doing a 'U-turn' in the mid-stream of traffic is dangerous, we can hardly avoid severe trouble and hardship. We are not helped by fanatic peace-mongers, feeding on simplistic slogans, who think they can achieve universal peace by hate and destruction. Pulling down is easy, building up is difficult. We have to employ slogans which the great mass of people can understand and support, but they should appeal to their good instincts, not their bad ones. This is a source which is not so often tapped by our politicians, but I believe its power could be overwhelming if our leaders had the courage to build on it. Ideals must be tempered by realism but should not be poisoned by cynicism or hate. In the end all depends on our own integrity.

Ove Arup did not rest on his laurels. He did not stop and survey the kingdom he created. He worried on our behalf. He was true to himself to the end, a remarkable achievement for such a long and varied life.

Ove Arup — what a magical name — influenced people and by influencing people be brought about a great change in the way buildings can be designed. Architects and engineers have learned to work together, not everywhere, not always, but sometimes, and that has made possible some very fine buildings. It has also changed things and the message will go on spreading until it will no longer be possible for architects and engineers not to work together as a team. He was a fine engineer himself who pioneered the use of reinforced and prestressed concrete in this country. Above all he was a man of integrity, and that integrity he made the hallmark of his dealings with everyone throughout his life, not always without pain, but with humanity.

References

(1) The world of the structural engineer: Institution of Structural Engineers Maitland Lecture 1968. *Structural Engineer, 47*(1), pp.3-12, 1969.

(2) Safe housing in wartime. D. Gestetner Ltd., 1941.

(3) HARTCUP, G. Code name Mulberry. David & Charles, 1977.

(4) Design of piled jetties and piers. *Concrete and Constructional Engineering, 29*, pp.37-53, 211-222, 333*ff*, 1934; *30*, pp.41-48, 107-113, 1935. Republished privately, Ove Arup & Partners, 1963.

(5) Reinforced concrete in relation to present-day design. *Concrete and Constructional Engineering, 21*, pp.234-238, 1926.

(6) Structural 'honesty'. *Irish Architect and Contractor, 4*(9), pp.25-31, 1954. A lecture delivered to the Architectural Association of Ireland, 25 March 1954.

(7) Architects, engineers and builders. The Alfred Bossom Lecture of the Royal Society of Arts, 11 March 1970.

(8) Statement to the Fellowship of Engineering, September 1983. Unpublished.

Printed in England by Reedprint Limited, Windsor, Berkshire