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Front cover:
Heat recovery boilers at Corby Power Station.
(Photo: Peter Mackinven)

Back cover:
Glass wall at Liverpool John Moores University Learning Resources Centre. (Photo: Peter Mackinven)

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This article looks at some past definitions of 'professions' and 'professionalism', and discusses what the latter means for an independent engineering consultant today, in the contexts of duty to the public, relationships with clients, and the intrinsic quality of the firm's work.

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Arup Economics and Planning were commissioned to provide an independent evaluation of alternative options for the development of high speed train services from Valence to Marseilles and Montpellier in the South of France, including options proposed by objectors to the proposals.

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This new university library, as well as housing nearly 200 000 volumes, provides state-of-the-art accommodation for its technology-based learning systems, and a physical focal point for the LJMU campus. Ove Arup & Partners undertook the structural and building services design.

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Ove Arup & Partners led the 'civils' design team for these two new, privately-owned, combined cycle gas turbine power stations — among the first of this energy-efficient type in Britain. Arups' responsibilities embraced structural, civil, geotechnical, environmental, and building services engineering.

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Professionalism...?

John Martin*

Definitions

Professionalism is a dreadful word, but I cannot find a better. The trouble is that not only is it clumsy but it conveys no clear meaning; perhaps it never did. Yet it represents something that I believe to be important; the principles it stands for were part of the reason I, and doubtless many others, chose the job I did as a professional civil engineer.

Some argue that 'professionalism' is not the thing that matters; competence is the issue, they say. But competence generally means having the ability to do something well, and makes no allusion to the nature of what is done — its value, or its purpose or the motive for doing it.

See what the lexicographers make of the word! Longman[1] starts off well enough: 'professionalism; (1) the especially high and consistent conduct, aims or qualities that characterise a profession or professional person', but look at the example they give — 'The professionalism of most school orchestras'! I know school orchestras have come on a bit since my day, but it seems to me that Longman is scoffing. Then go on to look at the meaning of 'profession': '(1) The act of taking the vows of religious community' and so on until eventually '(4a) a calling requiring specialist knowledge after long and intensive preparation (4b) a principal calling, vocation or employment'. They follow that by this example: 'men who make it their profession to hunt the hippopotamus'! No wonder the word has practically lost any meaning, something brought home to me when I was advised not to refer to it in a radio interview because 'the public' would not understand it.

Richard Tawney does rather better. He was a well-known professor of economics at London University in the 1930s and a great writer on social history, and he had this to say in *The Acquisitive Society*[2]:

'A Profession may be defined most simply as a trade which is organized incompletely, no doubt, but genuinely, for the performance of function [...] Its essence is that it assumes certain responsibilities for the competence of its members or the quality of its wares, and that it deliberately prohibits certain kinds of conduct on the ground that, though they may be profitable to the individual, they are calculated to bring into disrepute the organization to which he belongs. While some of its rules are trade union regulations designed primarily to prevent the economic standards of the profession being lowered by unscrupulous competition, others have as their main object to secure that no member of the profession shall have any but a purely professional interest in his work, by excluding the incentive of speculative profit. Business men may cajole the public from every hoarding. But doctors, architects; consulting engineers, and even lawyers are prohibited by their professional associations from advertising, from having any pecuniary interest in the treatment or course of action recommended to their clients, or from receiving commissions. The fees which the more eminent among them charge for their professional services may often be excessive. But they may charge for professional services and for nothing else.'

'The conception implied in the words "unprofessional conduct" is, therefore, the exact opposite of the theory and practice which assume that the service of the public is best secured by the unrestricted pursuit on the part of rival traders of their pecuniary self-interest, within such limits as the law allows. It is significant that at the time when the professional classes had deified free competition as the arbiter of commerce and industry, they did not dream of applying it to the occupations in which they themselves were primarily interested, but maintained, and indeed, elaborated, machinery through which a professional conscience might find expression. 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 the motive of pecuniary gain upon the necessities or cupidity of the individual.'

Rights or duties?

'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 measures of their success is the service which they perform, not the gains which they amass. They may, as in the case of a successful doctor, grow rich; but the meaning of their profession, both for themselves and for the public, is not that they make money but that they make health, or safety, or knowledge, or good government or good law. They depend on it for their income, but they do not consider that any conduct which increases their income is on that account right. And while a boot-manufacturer who retires with half a million is counted to have achieved success, whether the boots which he made were of leather or brown paper, a civil servant who did the same would, very properly, be prosecuted.'

There are two essential ingredients here, in addition to competence. One is the notion that professional advice should not be influenced by pecuniary gain, and the other is the notion of duty to the 'public'. I believe both are vital and both are at risk.

It's curious. To 'do a job professionally' sounds fine, but to speak of 'the professions' and 'professionalism' provokes a bad reaction. Recently the Assistant Secretary General to the Law Society wrote: 'There is a lot of mystique attached to the notion of a professional and one can strip away a lot to reveal some of it to be overblown pomposity'. In 1906 Bernard Shaw had someone say in his play *The Doctor's Dilemma*: 'All professions are conspiracies against the laity', and I have a feeling that Shaw himself meant it.

So the word is unhelpful; the image was spoiled some time ago. But the values it stands for matter enormously. Sir Robert Kilpatrick, President of the General Medical Council, wrote this recently: 'It is largely a matter of trust — when the public go and see a professional, they go on the basis that they trust that individual to give them a high-quality opinion about what should be done.'

Trust

Consider first this matter of the performance of duties or the giving of advice which can be relied upon, because it is not influenced by pecuniary gain. Compare the contractor and the consulting engineer. They both have a worthy calling but there is a fundamental difference. In a contract you define what you want fully and you simply buy it. You may even bargain for it. If afterwards you think you have been cheated, you can sue someone for not providing exactly what you specified. The relationship is at least potentially adversarial from beginning to end, even if you manage to remain good friends throughout. Trust is not a necessary ingredient.

Once the need is a bit more complex, however, some skilled advice is needed. The 'buyer' may have the advisor available 'in-house' or he may not. Whoever he is, the advisor is in a position of trust, for his client or employer depends upon him and depends on his having a sense of responsibility and commitment to the interests of his client as well as to certain objective standards. By definition the client cannot check up on his advisor except by finding other advisors, and so on. Some indeed try and do just that. Such an advisor is the consulting engineer, but it is a fragile position. Once he loses his independence he can no longer claim to be able to offer unbiased and therefore trustworthy advice.

He then owes a duty, not only to his client and to society, but to another, his owner, for this owner will require or will be assumed to require, that his servant will do his best for him. The owner, who may be a group of shareholders or a company selling cement or owning building sites, will want, not unreasonably, to get some return for his investment, whether it be maximum profit, maximum use of cement, or the maximum enhancement of the value of his building site. If professionalism means being accepted as a trustworthy advisor to another, then, under those circumstances, forget it.

Of course the issue is never presented so starkly, and it can be tempting not to notice that it exists. For example we may be invited to join a joint venture with a partner who is owned by a commercial organization. Pretend otherwise or not, we will then be expected to support the interests of our partner and thence his owner, and our ability to offer uninfluenced professional advice to a client may be inhibited.

'... no work can be rightly done without honesty and incorruptibility'.
(VITRUVIUS: 'Education of the architect',
from *The Ten Books on Architecture*, Book One. 1st century BC)

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*John Martin is Chairman of Ove Arup Partnership.

The irony is that when the firm was young and our business generally gave us few opportunities to get near our real client, and limited scope to act as his trusted advisor when we did, then our profession was held, if I remember rightly, in higher regard. I cannot recall being described or even feeling like a 'design contractor'. Now often much further 'upstream' in the flow of decision-taking, with a wide range of the sorts of skills most needed from a trusted advisor to help the client decide what he needs and how to get it, now we find ourselves in a time when professionalism is valued little, and the tendency often is to treat consultants like contractors, the criterion for selection being cheapness, and the scope for making the kind of contribution the consultant should be able to make being severely limited.

Duty to the public

Consider next the duty of a profession to the 'public'. After much thought in my last days at school, when all things seemed possible, I thought that for a fulfilling life one needed the satisfaction of doing service to the community, the pleasure of a creative job, and a decent wage — is there no limit to the ambition of the young? Although there was no first-hand information available I thought that to be a professional civil engineer could offer all that. I was right, it can.

The Institution of Civil Engineers in what might nowadays be called a mission statement refers to 'harnessing the forces of nature in the service of mankind'. Peter Dunican (1918-1989) in the final year of his Chairmanship of Ove Arup Partnership wrote on 'The structural engineer in the service of society'[3] saying: 'But structural engineering is not concerned only with design [...] Design is equally concerned with service, service to the community'. Richard Tawney said 'the meaning of their profession, both for themselves and for the public, is not that they make money but that they make health, or safety, or knowledge, or good government or good law'.

In defining 'the professions, for lawyers', Rupert M. Jackson and John L. Powell wrote this in *Professional Negligence*[4]: 'Practitioners are usually committed, or expected to be committed to certain moral principles, which go beyond the general duty of honesty. They are expected to provide a high standard of service for its own sake. They are expected to be particularly concerned about duty of confidentiality. They also, normally, owe a wider duty to the community, which may on occasions transcend the duty to a particular client or patient. For example, a doctor's duty to prevent the spread of contagious diseases may outweigh his duty to a particular patient. An accountant, certifying the accounts of a firm of solicitors or auditing the accounts of a public company, may find himself obliged to act contrary to the immediate interests of his clients.

Similarly, a barrister or solicitor is under a professional obligation to draw the court's attention to relevant authorities, even if they are adverse to his client's case.'

Often the 'community' is not our immediate client and paymaster, and the priorities of our client might not in our perception be in the best interests of society. As Peter Dunican said: 'There could be conflict here, which in the end only we can resolve for ourselves, both individually and collectively. This issue is very much a professional one [...]'. Nowadays we often have a dual duty, to client and community, and I think part of the attraction of our role is in the challenge we face in resolving the situation. But many will see no conflict at all. 'The customer is always right.' If society believes the professions responsible for the planning and design of the 'built environment' have served them poorly, it will be partly for that reason.

'Aims and Means'

On reflection I realise that the heart of the matter is simply this. If, as Ove put it, work is to be more than just a means to an end, but is to be an essential part of a satisfying life, then the value of one's working life is obviously crucial; one's aims in work are part of one's aims in life. If, then, we are thwarted in aiming for the best in our work, this would be intolerable since it would lessen the quality of our lives. Certainly what is 'best' may not be easy to determine, and ultimately that is a matter for personal judgement if the criterion is to be the satisfaction of a job well done. We are, by the nature of things, constantly thwarted from achieving this illusive 'best'. That is life; but we must not be thwarted from even making an honest attempt at it because other priorities get in the way.

So by 'professionalism' I mean being free to aim for what we believe to be best. Surely we can agree that this is worth striving for?

I write this because I am aware that 'professionalism' is at low ebb and I want to make sure that, while we make the best of the situation we have, we never lose sight of where we want to be, serving client and community professionally. The mood of our society may be against it, and that is at least partly because the professions have failed to live up to their own standards. But eventually, after much damage has been done, good professional advice will be valued again and society will be served by people with skill and sufficient independence of spirit to give honest advice. I hope that by that time there will be enough left to provide it.

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(2) TAWNEY, R.H. The Acquisitive Society. Originally published 1920; reissued Harvester Press, 1982.

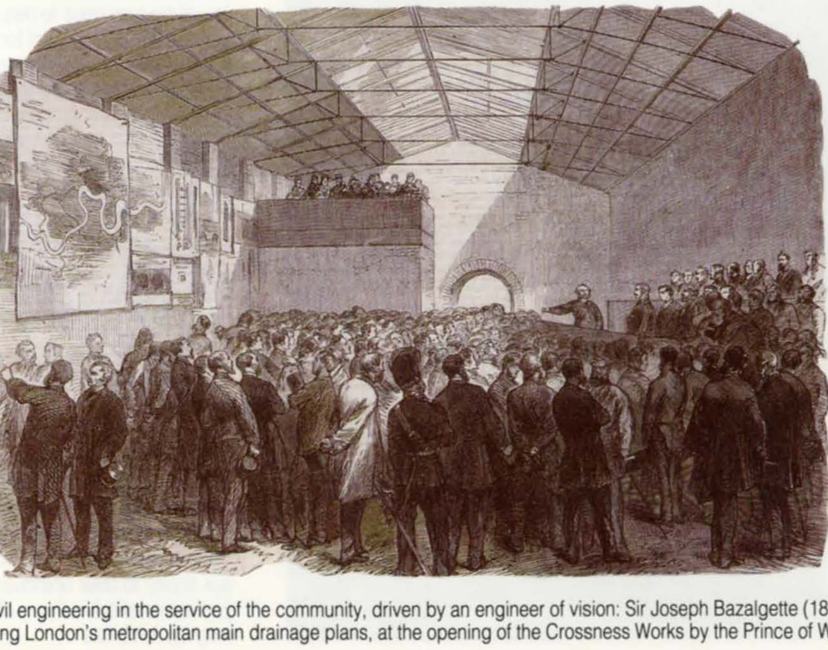
(3) DUNICAN, P. 'The structural engineer in the service of society', *The Structural Engineer, 61A*(10), pp.316-317, 1983.

(4) JACKSON, R.M. *and* POWELL, J.L. Professional Negligence. Sweet & Maxwell, 1982.

Illustrations:

1. 'The architect in Ancient Rome', by Sir Lawrence Alma-Tadema (1836-1912).

2. From *Illustrated London News.* courtesy Mary Evans Picture Library.



2. Civil engineering in the service of the community, driven by an engineer of vision: Sir Joseph Bazalgette (1819-1891) explaining London's metropolitan main drainage plans, at the opening of the Crossness Works by the Prince of Wales, 1865.

Planning high speed railways in France

Mark Bostock
Hugh Collis

In accordance with the national plan for Trains à Grande Vitesse (TGV) in France, French Railways (SNCF) was asked in 1989 to prepare proposals for an extension of the high speed route from Valence, south of Lyons, to Marseilles and Montpellier on the Mediterranean coast. The proposals produced considerable local opposition and a Commission was established under M. Max Querrien in 1990 to consult locally on the route.

1. Protest near Avignon

The route proposed by the Querrien Commission had considerable modifications to the original, but there were still well organized objections to these. The objections were based both on local environmental impact and on concerns that the route bypassed some major towns in the Rhône valley, resulting in fears that the service to those towns would be reduced. Local groups, with the support of local authorities, produced alternative proposals based on upgrading existing lines, some with additional passing tracks and the use of tilting trains to allow higher speeds around curves. In response, the Minister of Transport appointed a College of eight Experts, who were briefed to review the options for development of existing routes or provision of new routes and report to the proposed Public Inquiry.

The College considered six scenarios, ranging from 'do minimum' to 'build the Querrien line'. SNCF were asked to evaluate these alternatives but the College decided they wanted an independent review. Arups' work on the Channel Tunnel Rail Link was widely known and they were invited to enter an international competition to undertake the review.

Brief for the technical evaluation

The brief was to conduct a full review and technical evaluation of the alternative scenarios. The Arup team examined alignments, operations, costs, revenues, economic impact and environmental assessment, with assistance from two individual consultants. The study commenced on 5 August 1992 and the final report despatched to the college on 4 September 1992, with a presentation to the college on 8 September.

Subsequently there was a presentation to representatives of the regional councils and local protest groups. Given the wide scope of the brief but the limited time available, it was essential to study the detail of each aspect only to a level that could ensure robust conclusions, rather than continue to refine technicalities.

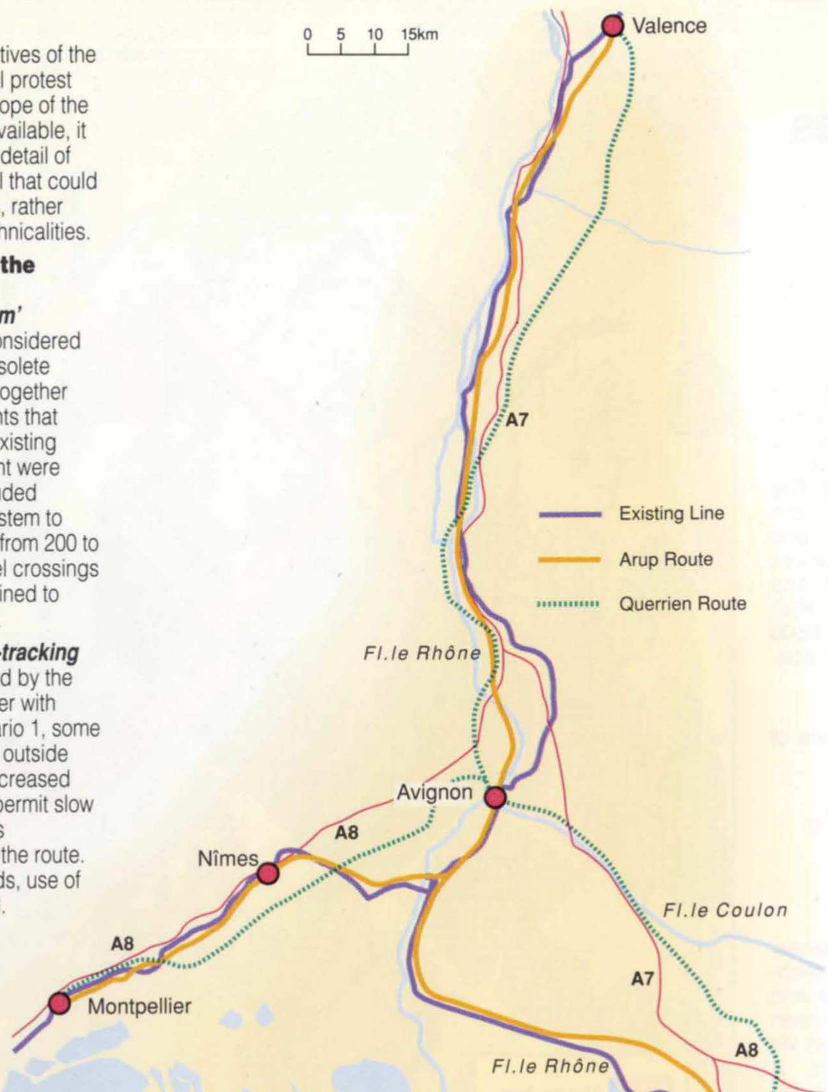
Scenarios defined by the college of experts

Scenario 1 – 'Do minimum'

This reference scenario considered basic improvements to obsolete trackwork and signalling, together with minimum improvements that would be justified on the existing route if no major investment were contemplated. These included renewing the signalling system to increase maximum speed from 200 to 220kph and removing level crossings where speeds are constrained to 160kph for safety reasons.

Scenario 2 – Partial four-tracking

This scheme was proposed by the local associations. Together with improvements as in Scenario 1, some lengths of the existing line outside built-up areas would be increased from two to four tracks to permit slow trains to be overtaken, thus increasing the capacity of the route. To increase running speeds, use of tilting trains was proposed.



2. Location map

Scenario 3 – Full four-tracking (1500V DC)

This scenario envisaged full four-tracking on the existing alignment at the existing voltage (1500V DC), the new tracks generally being aligned immediately alongside existing ones.

Scenario 4 – Full four-tracking (25kV AC)

In this scenario, two new tracks at 25kV AC would run alongside the existing track, generally separated so that the new ones would be on a new embankment, thus easing construction problems and permitting a higher running speed than 1500V DC electrification.

Scenario 5 – New high speed line in existing corridor

This scenario envisaged the construction of a new TGV route generally following the existing transport corridors and diverting around difficult points like towns, with alignment standards sufficient for full TGV speed (350kph) running.

Scenario 6 – The Querrien Route

Results

The results of the study were presented in a framework assessment. Two key parameters were journey time, on which traffic and therefore revenue improvements depend, and cost of construction (Table 1).

As can be seen, the track quadrupling options (Scenarios 3 and 4) are much the most expensive, and do not provide the journey time benefits available from a completely new alignment. These were therefore rejected.

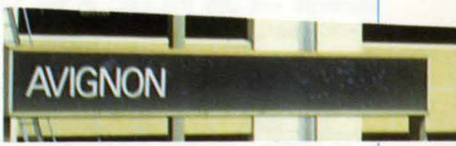
Scenario 2 provided no journey time benefit over Scenario 1, because, in the circumstances, tilting trains could not achieve higher speeds: 1500V DC electrification is limited to 220kph because of the stiffness of the catenary. The passing loops would do little to add to capacity. For a 220kph TGV to overtake a regional train travelling at 160kph, a passing loop approximately 80km long is required. The longest lengths of extra track that could be introduced without affecting urban areas were approximately 40km. A suggestion that capacity could be created by transferring freight trains off the main line on the left bank of the Rhône to the freight line on the right bank also had little effect as, apart from at night, the only freight trains using the main line were those serving private sidings and marshalling yards along the route.

Scenario 2, therefore, only had marginal benefits over Scenario 1.

Table 1: Comparative evaluation

Scenario	Journey time Paris-Marseilles (minutes)	Cost (FF million)
1	234	< 500
2	234	8500
3	230	50 600
4	223	46 800
5	185	32 500
6	180	23 100

The study concluded that the options involving additional tracks on the existing railway were extremely costly and none produced significant benefits, since alignment constraints restricted speeds too severely. Thus a new route was necessary if the benefits of high-speed rail were to be achieved. The Querrien Route (Scenario 6) caused severe noise intrusion in certain very quiet rural areas and the concern about bypassing the towns in the Rhône Valley remained. The alternative route developed by Arups along existing corridors (Scenario 5), permitted TGV services to use town centre stations. However, as it passed through a more heavily developed area, this alternative required more demolition of property and had higher engineering costs due to the proximity of existing roads, railways and built development.



One aspect of Arups' proposal for Scenario 5 that attracted attention was to site the TGV station for Avignon beneath an existing marshalling yard in the city centre, rather than outside the city. This would have involved the Rhône being crossed in tunnel rather than bridged, and would have given better access to the town and improved interchange with local train and bus services. Avignon subsequently asked Arups to undertake further feasibility studies and the town's submission to the public inquiry sought this alternative station location.

Based on Arups' study, the College of Experts recommended that the Querrien Route be adopted, but with increased environmental protection and further examination of the links between the existing towns and the stations on the new line. These recommendations have now been accepted and the Minister approved the route with some minor modifications late in 1993.

Credits

TGV Méditerranée

Client:
Ministère de l'Equipement, du Logement et des Transports.
Consultant:
Arup Economics and Planning
Mark Bostock, Ahmed Bouariche, Jonathan Carver, Nigel Cogger, Ken Cole, Hugh Collis, Gary Hooper, Ed Humphreys, Phil Lee, David Lewin, Alain Marcetteau, Natalie Maynard, Strachan Mitchell, Jim Nyhan, Richard Phillips, Peter Speleers, Paul Tomlinson.
Consultants: Colin Brelsford, Alastair Dick
Photos:
Hugh Collis
Illustration:
Peter Speleers

Avignon Station Feasibility Study

Client:
Ville d'Avignon
Consultant:
Ove Arup & Partners International Ltd.
Ken Cole, David Lewin, Richard Phillips, Jon Shillibeer

Liverpool John Moores University Learning Resources Centre

Steve Burrows
Paul Kay

Introduction
The speed of developments in the field of technology-based learning systems created a need at Liverpool John Moores University (LJMU) — formerly Liverpool Polytechnic — for a Learning Resources Centre (LRC). The purpose of this Centre is to provide both teaching support to academic staff, and learning facilities for students of the Business School, the School of Law, Social Work and Social Policy, and the School of the Built Environment, Art and Design. Over 6600 students will use the LRC in the 1994 academic year.

The brief
The building's function set the two criteria of the brief:

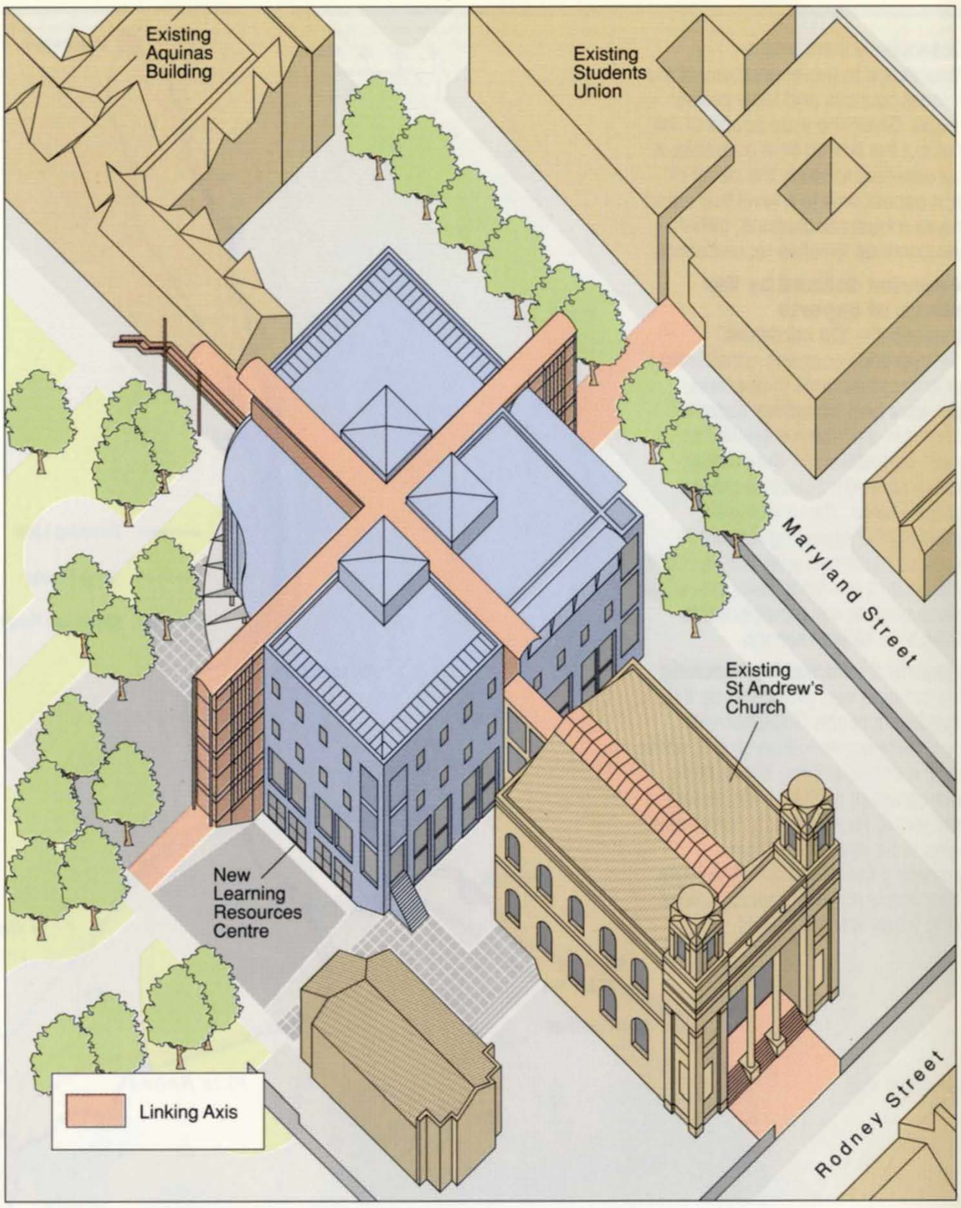
- to create a flexible, interchangeable, responsive development in a changing technology-based field
- to establish a symbolic focal point and meeting place on the campus.

The first criteria required 700 study spaces, 380 of them equipped with information technology terminals to operate courseware and retrieve bibliographical and other information held either within the Centre or accessed via networking to other LJMU resources. A further 100 workstations are provided in the adjacent Aquinas Building Computer Resources Centre. In addition, storage capacity has been created for 190 000 books in fixed and mobile stacks.

In meeting the second criterion, the creation of a physical link to the Aquinas Building and the inclusion of a dramatic focal atrium space in the new building enables the basic planning concept to be achieved (Fig. 1). The completion of the development by landscaping the newly-created inner courtyard and by pedestrianizing Maryland Street in front of the Students Union enables the campus to be fully integrated in both design and function. Austin Smith Lord were the architects and Ove Arup & Partners building and civil engineers for the development.

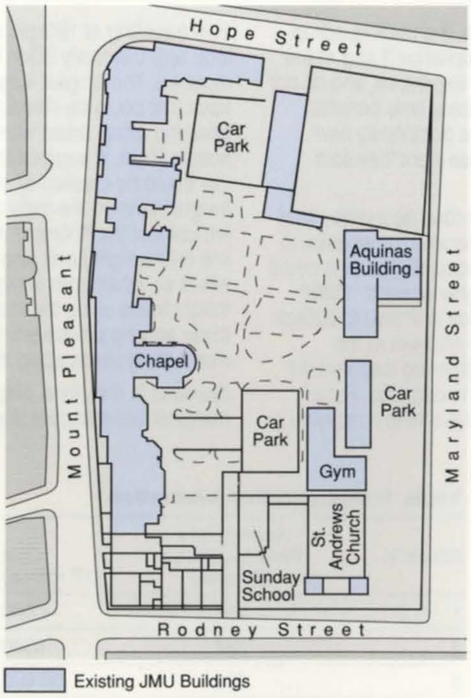
The site
The site (Fig. 2) covers an area approximately 50m x 60m, and slopes down 3m from the north-east to the south-west. Originally occupied by a low rise gymnasium of little architectural or functional merit, it is bounded by roads on all sides. The green space at its heart was in keeping with the irregular morphology of the existing buildings — principally the mostly Victorian former Notre Dame Convent on the west — but at odds with the need to have ordered identifiable links within the campus. It was this need for order that created the building's strong geometrical plan, with 'street' circulation patterns defining zones of accommodation within which there is complete planning flexibility.

Internal planning
The LRC has four floors split into two zones. The upper floors contain bookstacks and quiet study spaces, whilst the ground floor and basement house noisier and more diverse activities, such as social areas, book issue/return and group study.



1. The Learning Resources Centre in context.

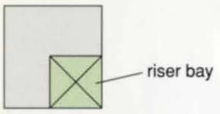
2. Original site plan.



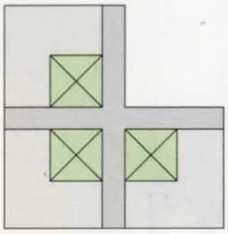
Entrance is via a three-storey glazed atrium wall facing the courtyard garden at the focal point of the crossroads of pedestrian routes through the campus. The entrance quadrant links all floors physically and visually to orientate the users. The study spaces in the upper levels are at the perimeter with increased ceiling height and as much natural top-lighting as possible. Internally, raised access floors and controllable artificial lighting ensures that bookstacks, study tables and VDUs are interchangeable.

At the lower levels, the study areas are dedicated to screen-based workstations. Exploitation of the natural slopes of the site, plus the creation of double storeyheight volumes, eliminates the feeling of enclosure normally associated with basement accommodation. In total, 5700m^2 of high quality accommodation has been created for around £7.5M, including associated works.

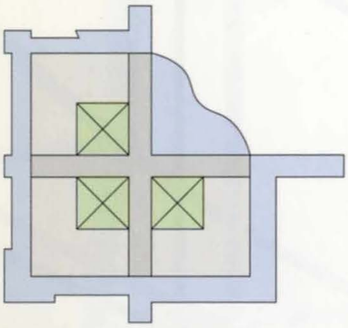
Engineering approach
The element of order established by the LRC co-ordinates a campus formerly at odds with itself. The engineering approach mirrors this concept in that the various engineering disciplines had to respect each other in providing a co-ordinated solution to a building engineering problem. This has been achieved by zoning the building both horizontally and vertically so that the structure and services not only integrate but allow future flexibility. This required discipline from the outset, which benefited both cost and buildability. Such design discipline does not reduce the opportunity to express imagination, however, but complements it.



a. Standard element



b. Built-up block



c. Add-ons to block

3. The plan elements.

4. Glazed escape stair to LRC with existing St. Andrew's Church seen to the left. ▶

The principle was to split the irregular building form down into small regular elements. Within each, vertical distribution is retained in discreet bays. The horizontal plane in each element is repeatable, enabling each problem to be solved only once and the solution then duplicated. Complexities are confined to the perimeter (Fig. 3). It would be easy to dwell on the creative and visually stimulating external features, but it is the standard blocks that have enabled the building to achieve its functional simplicity.

Geotechnics

Ordnance survey maps from 1890 showed little change in land use since the Notre Dame Convent was constructed. The geology indicated that the site was underlain by glacial till over sandstone bedrock forming Keuper basement beds, typically 120m thick. The upper levels of this succession were verified by trial pits and boreholes. Groundwater was shown to be below basement slab level and as a result pad foundations were used, in fresh to slightly weathered bedrock.

Structures

The building contains a variety of structural solutions. Its 7.2m x 7.2m grid enables the standard 14.4m square block to be repeated three times in reinforced concrete ribbed slabs, each block bounded by a 3.6m wide edge strip treated differently in response to the particular requirements of the architecture.Thus the frame is of reinforced concrete from basement to roof level, but with structural steel for the atrium features and the north and south escape stairs, where elegance of form was a pre-requisite of the design. The result is a building with a self-supporting concrete frame bounded by almost free-standing steel and glass enclosures. The detail of the design required careful consideration of both known and anticipated future uses. For example, the basement waterproofing is designed to archive grade because of its potential future use. The ribbed floors can accommodate 600mm wide holes for possible future servicing from above. There are no internal downstand structures to disrupt services distribution in the ceiling void, and the roof standard quadrants have been designed in reinforced concrete to facilitate plant relocation or replacement at a later date. Internally, the areas between the standard ribbed elements are solid slabs, both to enable the ceiling to be sculptured in the corridor zones and to give services distribution opportunities on the main axes. External cladding stability was achieved by using short reinforced concrete walls at 3.6m centres to receive masonry cladding. This removed a trade from the façade work, speeded construction, and eased potential tolerance problems.

The steel north and south staircases are clad in glass blockwork, within a steelframed enclosure. The atrium quadrant has a curved planar glass wall 20m wide by 11m high, the perimeter roofs are in lightweight construction on steel cable trusses, the central roofs are on curved steel sections, and a glass clad steel bridge links the main building into the existing Aquinas Building. Each of these elements is unique in the building and links to the standard concrete frame.

Building services

The services requirements of traditional libraries are well documented, with particular emphasis on natural light, lighting to bookshelves, comfortable environmental conditions, and good acoustics. The LRC fulfils all these requirements and many others, such as extensive data cabling for IT workstations and a central computer room with close control air-conditioning, UPS, and CO_2 gas flooding fire protection system. Overall, the LRC is more like a modern electronic office than a traditional library. One main influence on the services layout is the University's need for flexibility in use of floor space for bookshelves, normal study areas, or IT workstations. This provision will minimize disruption when the use of any space does change.

Mechanical

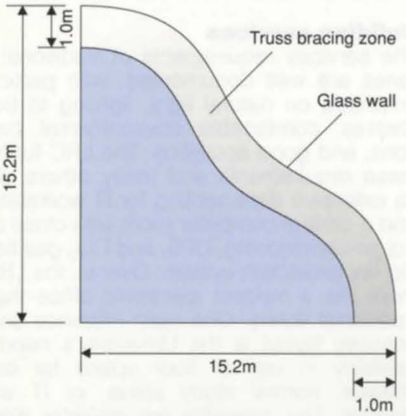
The LRC is deep in plan, but fortunately the main entrance glazed façade faces due north and is not unduly affected by solar gains. The requirement to utilize natural daylight, as against control of solar gain and avoidance of glare problems particularly with visual display terminals (VDTs), was given detailed consideration. The result was to maximize natural daylight in the prime book study areas at the building perimeter and the top floor.

From detailed thermal analyses, which allowed for use of VDT stations, internal summer temperatures in the region of 32-34°C were predicted. Comfort cooling comes via fan coil units in the ceiling void, with mechanical fresh air ventilation from central plant. The system designed to maintain a peak summer condition of 24°C.

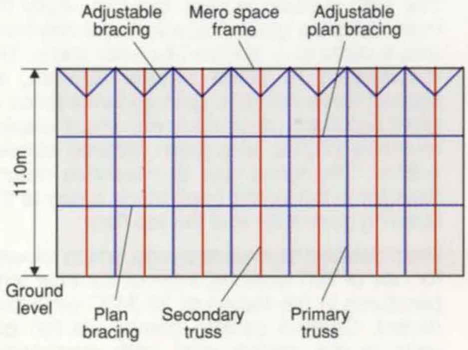
The LJMU LRC glass wall

Structural glazing is now quite a common challenge, the scale of which is growing with the opportunities that advances in glazing technology offer to designers. At the LRC a glass wall was required 20m wide by 11m high and curved three times in plan. The roof quadrant passes over the wall and is supported on a single external column. As this roof is a Mero space frame design, the geometrical complexity of the space frame/glazing junction is enormous and simplification of detail was required to avoid tolerance problem issues being raised on site.

The solution was to use the best characteristics of each element to produce a coherent design that respects their individual natures. Thus the glass performs well in resisting lateral loads, as does the spaceframe roof acting as a diaphragm. The curvature on plan presents potential lateral movement problems due to thrust from both positive and negative wind pressure: situations that require lateral stiffening and vertical support. Vertical trusses were therefore used to span from ground floor to roof level with horizontal diaphragm trusses at two intermediate levels. Adjustment was available at the upper diaphragm level on plan and at each intermediate truss both vertically and laterally. Such adjustments were made before any glass was fixed, only minor additional changes being possible thereafter. This proved a successful methodology and the result was both elegant and buildable.

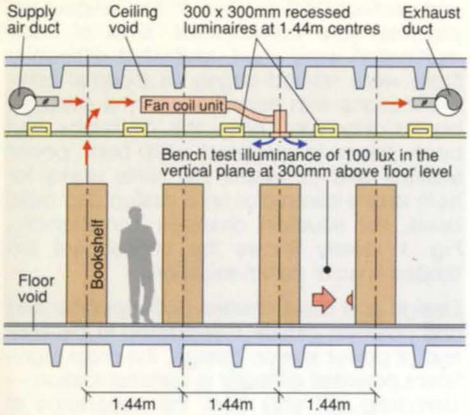


5a. Plan on glass wall.

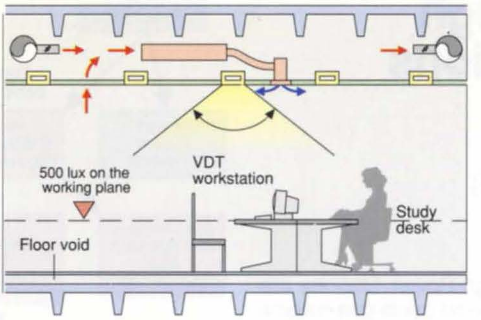


5b. Glass wall elevation.

6.



7. Floor to ceiling section showing bookshelf lighting and mechanical services.



8. Floor to ceiling section showing study area and VDT workstation lighting.

With the large areas of external glazing and to overcome cold downdraughts, compensated heating via perimeter trenchline heaters, finishing flush with the raised floor, was used. This gave maximum use of space, whilst the cover grille selected is capable of taking the point loads from furniture.

As a behind-the-scenes facility to give flexibility, self-regulating water flow valves were used throughout the heating and cooling systems. These eliminated any need for water balancing during commissioning or any subsequent re-balancing of the systems should they be altered in the future.

Building Control requirements were fairly minimal due to the compartmentation requirements being met by the architect. Smoke clearance in the atrium is via high level, pneumatically-operated natural ventilators. A fully addressable fire detection system is installed, with hosereels at all designated escape routes.

Electrical

Many lighting solutions were studied including task lighting, uplighting, luminaires fixed on bookshelves and general overhead lighting. In close collaboration with the architect and University Librarian, the latter was decided upon. The main lighting installation had to satisfy three distinct working environments and applications without the need to relocate or provide additional lighting. These were the VDTs, the work study areas, and bookshelf/reference areas. Each would normally require distinct solutions to satisfy standards of surface illuminance to the working plane, glare, and colour appearance characteristics.

In addition, the following standards had to be complied with: CIBSE Lighting Guide *LG3* for VDTs (1989), the CIBSE Lighting Guide for Libraries (1989), and The Council of the European Communities Directive Relating to Workstations (1990).

The demands of these meant that the lighting design criteria were to be set to achieve:

- 500 lux horizontal illuminance level at desk height
- 100 lux vertical illuminance level at lower bookshelf
- good colour rendering for reasons of colour judgement (CIE Group 1B).
- intermediate colour appearance of the light source (CIE classification, 300K > CCT > 4000K).

In order to be satisfied with the general overhead lighting solution, mock-ups were built at selected manufacturers' premises, comprising two aisles of bookshelves (Fig. 7), and a VDT workstation and study area desk (Fig. 8). The dominant factor of the bookshelf layout was the 1.44m spacing within the 7.2m structural grid. This was reflected in a 'tartan' ceiling grid of the same dimension, which led to recessed modular luminaires being placed on the 1.44m grid in two directions. This allowed bookshelves to be mounted either way in the 7.2m module without alteration.

Alternative recessed luminaires were tested, resulting in a 300mm x 300mm modular fitting being selected using a specially designed nine-cell parabolic louvre. This luminaire fulfilled the design criteria for all three applications and the requirements for flexibility with minimum disruption.

The complete lighting system for the building was controlled through a computerized automatic lighting management control system, taking into account occupancy times and daylight penetration.

IT is a very prominent feature in modern learning resources centres. Consequently, flexible power and data cabling to assist information transfer is extensive. At scheme stage, the extent of associated cabling and the requirement for complete flexibility of all workstations led to a raised floor system being adopted. The power system uses an underfloor busbar installation fixed to the slab at approximately 4.5m spacing. Similarly, a separate data network cabling tray and trunking system, laid parallel to the power busbar system, is provided to accommodate links to terminals, printers and desk top computers.

The whole facility is served from a main file server room which is serviced as a fully fledged computer room with full close control, dual circuit air-conditioning, clean power supplies, UPS, and CO_2 gas fire suppression system. A sophisticated air sampling system within the fire server room provides early warning fire detection.

Conclusion

The LRC started on site in April 1992, and will be fully occupied at Easter 1994. It is a complex building developed around a simple concept and has achieved its aim of integrating a fragmented campus.

In terms of buildability it is a good example of the art of building engineering setting the standards for library accommodation in the 1990s.

Credits

Client:
Liverpool John Moores University
Architect:
Austin Smith Lord
Quantity surveyor:
Walfords
Main contractor:
Norwest Holst
Engineers:
Ove Arup & Partners Steve Burrows, Gerry Eccles, David Hughes (structural), Paul Kay, Paul Entwistle (mechanical), John McGrath, Barrie Leftley, John Waite, Martin Dorward (electrical), Mike Buckingham (public health)
Illustrations:
Trevor Slydel
Photos:
Peter Mackinven

9. Interior showing natural top lighting.

10. Illuminated LRC viewed by night.

Corby and Peterborough Power Stations

Paul Geeson
Gary Marshall

Introduction

Corby and Peterborough Power Stations are amongst the first combined cycle gas turbine (CCGT) power stations in the UK. This type has been predominant amongst new ones built by UK private power generators during this decade.

CCGT technology gives efficient production of electricity from natural gas with much lower levels of pollution and environmental intrusion than traditional fossil fuel power stations. The term 'combined cycle' means the conversion to electrical power of natural gas's latent energy in two separate and distinct steps: the air cycle of the gas turbine followed by the steam cycle. A gas turbine alone will achieve an energy conversion efficiency of around 33%, and a steam turbine from 32% to 38%.

By feeding the very hot gas turbine exhaust gases through insulated ductwork to heat recovery steam generators, combined cycle operation effectively gives two bites at the latent energy cherry, attaining an overall efficiency approaching 50%.

The stations at Corby and Peterborough, some 35km apart in the Midlands, are owned and operated by joint venture private companies. Both were built under turnkey contracts by Hawker Siddeley Power Engineering (HSPE). The total capital cost of each 350MW station was approximately £130M, of which about 15% was accounted for by civil engineering and building work.

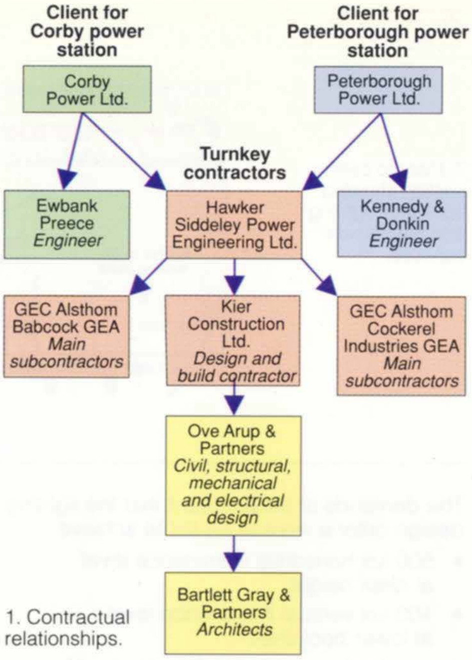
Construction on both sites started early in 1991 and the stations have been operational since October 1993.

Ove Arup & Partners and the architects Bartlett Gray & Partners were first commissioned by HSPE, after a competitive bid in July 1988, to prepare an Environmental Statement and to submit the planning application. Since then this design team, based in Nottingham, has been responsible for all stages of the civil engineering and building works design, including surveys, site investigations, reclamation, and scheme and detailed design of all elements. HSPE engaged Kier Construction as design and build contractor for all civil engineering and building works, conditional upon them employing Arups as designers, and on their appointment Arups' client changed from HSPE to Kier. At Corby there was a separate site reclamation contract, completed by Balfour Beatty Civil Engineering.

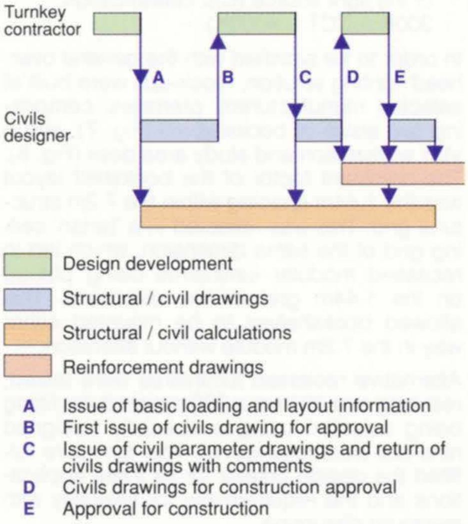
This article makes some general points about design and build contracts, environmental assessment, and working in the power industry, as well as describing some of the technicalities of the two power stations. Because they are similar, features common to both are first described, followed by those aspects where they differ.

Team management in design and build

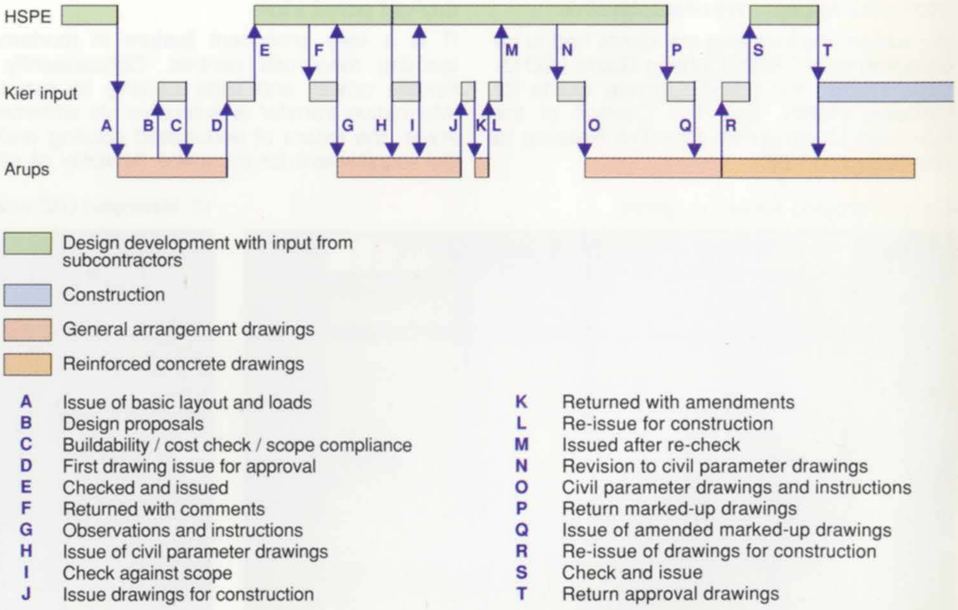
Arups' initial design work directly for HSPE was largely conceptual, and required only a small team with a direct line of contact to the client's engineers. Management during this initial phase largely consisted of calling in and coordinating the work of specialist groups involved with planning, environmental assessments, flood studies, contamination and geotechnical surveys. In this respect the projects were conventional, lines of communication were short, and what difficulties there were related largely to external communications with consultees to the statutory bodies. However, once the decisions had been taken to proceed with both power stations and to award the civils works for both to one contractor on a design and build basis, the situation changed considerably. Fig. 1 clearly shows the consequent extended lines of communication.



1. Contractual relationships.



2. Idealized exchange of information.



3. Actual exchange of information.

Design and build creates both opportunities and potential pitfalls. Considered in the context of power station design, the most significant potential difficulty is communication — stemming not only from the separation of engineer from client but also from the industry's practice in design development. Fig. 2 shows the idealized exchange of information expected between turnkey contractor and civil engineering designer. It is quite logical and sets out to formalize the necessary interactions. However, adding the design and build interface and more realistic responses to each party results in the interactions shown in Fig.3.

From a more positive standpoint, being able to work closely with Kier avoided many potential problems on site. This helped to achieve rapid and high quality construction and minimized delays.

Providing complex foundations and structures for mechanical plant obviously creates important interfaces between different suppliers, contractors and designers. To establish clear responsibilities and ensure sensible engineering decisions, the formal communication route had to be short-circuited. Centralized co-ordination meetings were thus held to enable Arups to speak directly to plant suppliers. Given the strong contractual commitments and the differing priorities of all parties, it is a testament to the mutual respect established that such meetings could achieve useful results.

Design and build is generally considered to be most effective when the work is well-defined and not overly complicated; certainly this renders the separation of engineer from ultimate client less of a problem. Corby and Peterborough have demonstrated that the method can be applied successfully to complex schemes if a high degree of co-operation can be fostered between the principal parties. However, the effect of the interaction shown in Fig. 3 is to extend the design programme and potentially delay the works. In agreement with HSPE and Kier, Arups are assisting a research project at Loughborough University to model the flow of information in a design and build contract and assess the implications of changes. It is hoped that this will provide a useful tool for future projects, as programming constraints are paramount, revolving around fixed dates for power line connection and major plant delivery.

It had been intended to re-use designs and details extensively on the two power stations but, apart from the turbine hall, its annexes, and the turbine blocks, the differences often dictated completely different designs. Work was carried out in Arups' Nottingham, Birmingham, and Sheffield offices, with overall co-ordination from Nottingham. Because of differing programme and approval requirements, the projects were frequently operated independently, the benefits of full co-ordination being sacrificed to the effectiveness of project-specific responses. Highlighted by this situation was the different response of two design teams to inherently similar parts of the scheme. This was overcome on critical elements like the turbine blocks (Fig. 4) by having the same engineers deal with both sites as a sub-group of the site specific substructure design teams.

Main superstructures: Corby and Peterborough

Whilst the layout of both stations is quite different to suit site constraints, the main elements serve the same purpose. The 'power train area' — turbine hall, air-cooled condensers (ACCs) and boilers — follows the same configuration at each site, repeating a previous HSPE power station in the USA. But though the turbine hall with ancillaries is largely replicated on each site, the boilers themselves differ.

Several alternatives for the turbine hall were explored with HSPE during the scheme development phase, including separate structures for the gas and steam turbines. Separation results in more compact buildings dictated by cranage requirements and maintenance lay-down areas. Combining gas and steam in one building means a larger enclosed volume, as the pair of gas turbines determine the width whilst the table-mounted steam turbine dictates the height. Nevertheless, there are savings with shared cranage and the overall sheeting area was not significantly increased. The limited site area at Corby finally compelled the choice to be a combined building, and this design was replicated for Peterborough. The result is quite a large structure, 80m long, 37m wide and over 22m high. Positioning of frames is dictated by main service penetrations and to some extent the ancillary structures for control rooms and water treatment annexe.

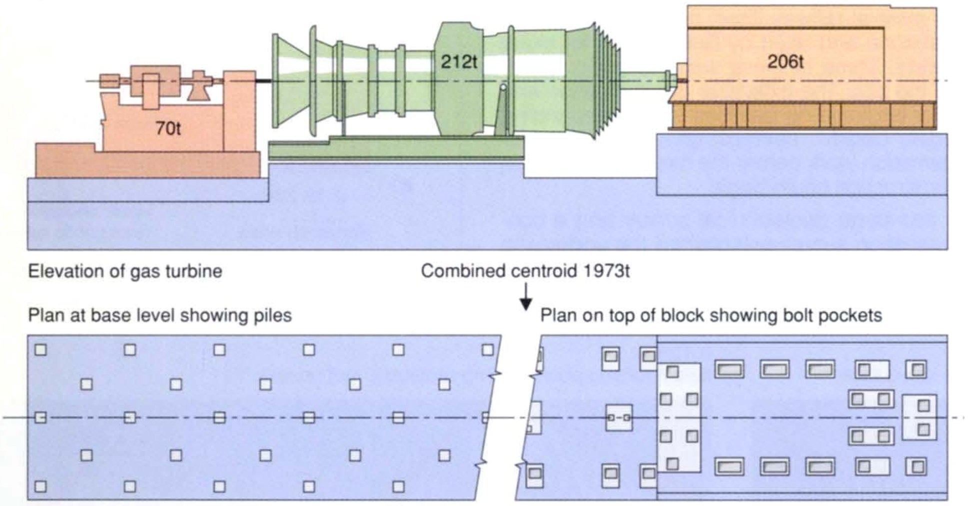
The presence of large penetrations through the gables, to receive steam exhaust ducts and air intakes, led to the adoption of full frame construction throughout rather than braced gables and a roof diaphragm.

Economy in the building frame design was achieved by using traditional lattice-braced columns more in line with the basic philosophy of an industrial structure than the heavy plate girders or concrete columns of traditional power station construction.

The structure is clad with double-skin profiled steel incorporating acoustic linings and filler materials. Panels of the cladding had to be tested to ensure compliance with environmental noise criteria, which resulted in several changes to the original material specification before satisfactory performance was achieved. The turbines and generators have local acoustic enclosures; these reduce the noise to acceptable levels within the hall, though still far above what is desirable externally. A low sound transmission is required from buildings generally to compensate for external plant items, such as the ACC, which are difficult to silence.

Adjacent to the main turbine hall are two local and one central control room and a water treatment annexe. The two-storey central control room is structurally independent from the turbine hall to reduce vibration transmission, particularly from the 60 tonne overhead crane. The auxiliary annexe takes support from the main turbine hall columns but also includes secondary columns to support roof-mounted demineralization and de-aerator tanks, each upwards of 150 tonnes in weight.

The interior of the turbine hall contains extensive pipe racking which is independently founded but stabilized from the turbine hall columns. These pipe racks carry the main high and low pressure steam pipework at high level from each of the boilers to the steam turbine inlets. To make rapid progress on site the main structures were designed early in the programme; thus services co-ordination with plant subcontractors was not possible. Late penetrations and increased mountings on the annexe roof were extensive, resulting in some small structural alterations. In such work, achieving the right balance between structural economy and necessary flexibility can involve equal quantities of foresight and good fortune.



◀ 4. Gas turbine on block elevation.

5. Peterborough turbine hall under construction, showing gas turbine and steam turbine blocks.

▼ 6. Interior of turbine hall at Corby.

Corby

Environmental assessment

As the stations were regarded as clones, at least in the engineering sense, little time was allowed for a comprehensive environmental assessment. Both Environmental Statements were thus similar in content, although some site specific characteristics did emerge. Corby gave rise to issues of contaminated land, visual intrusion, and water supply. The contamination from past industrial use is discussed below in terms of the finally selected reclamation procedure.

There were two concerns about visual impact: visibility of the main flue stacks and the possibility of a steam plume from the assisted draught coolers. The flues were reduced in height somewhat following the dispersion modelling exercise, whilst the steam plume problem was solved by introducing a closed-cycle cooling system. ACCs comprise a series of large fans mounted at high level (7m diameter blades) which force air upwards through inclined banks of radiators. The steam from the turbine is discharged directly into the radiators where it is condensed and subsequently recycled. This change also made for consistency between Corby and Peterborough, where an ACC had already been accepted as a planning constraint.

A secondary study, considering potential effects on Eyebrook Reservoir SSSI (Site of Special Scientific Interest) about 6km north-west of the site, was required when wet cooling was considered. Although the reservoir had been constructed to serve the originally far greater demands of British Steel, it had been used much less since the closure of the steelworks several years ago. The drawdown effects on wildfowl using the reservoir and considerations of the effects on downstream river flows were investigated by a study of historic data on the effects of drawdown on reservoir levels and the populations of wintering wildfowl. Then a physical assessment of habitat change was undertaken, and the correlation of water levels to wildfowl population numbers assessed. It was concluded to the satisfaction of English Nature (then the Nature Conservancy Council) that most species would indeed benefit from the greater wading zone drawdown would cause.

Reports concluded that direct supply from Eyebrook was quite viable. The power station was eventually prohibited from using this supply under the then terms of British Steel's license. Water supply was consequently provided by Anglian Water via a new pipeline along the length of Phoenix Parkway.

Without supply from Eyebrook the use of water cooling became uneconomic and this promoted the change to using ACCs. Offsite disposal of aqueous discharges was split into two streams, with foul effluent and neutralization pit discharge going into the foul sewer, and surface water discharged to the adjacent Gretton Brook. Flow balancing of surface water had been envisaged but upgrading of the ditch avoided this necessity whilst reducing the potential for flooding along Gretton Brook Road. A pipeline was also constructed for incoming oil supplies from a new railhead south of the site. This considerably reduced the potential effect of road-borne oil tankers which would have otherwise been necessary if a long gas outage occurred.

Site preparation

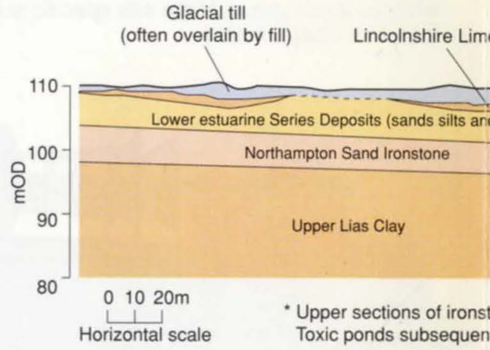
The site was originally split by an access road to a freight company which had to be maintained during construction until a new road was completed. The old access road divided the site into two halves, one taken up by mineral railway lines, the other mined for Ironstone and used by British Steel for slurry ponds. Three of these were wholly or partly on the site. The extensive contamination and poor engineering qualities of the surrounding loose backfill needed comprehensive reclamation work before the main power station construction could begin.

A two-stage geotechnical survey and a contamination survey established the underlying strata, the approximate boundary of the quarry and also the extent and severity of the contamination. In parallel with Arups' investigation, Corby District Council were reclaiming slurry pond 3, which straddled the site boundary; the excavation to clear this extended some 7m below ground level.

Slurry ponds 1 and 2 were entirely within the site. Both contained sludge contaminated with zinc, sulphates, sulphides and toluene extractable matter. Phenol was also present, together with cyanide, plus a high level of ammonia in pond 1. Pond 2 had a significant depth of supernatant water and oil which allowed pontoons to be used for drilling boreholes, whereas pond 1 had a desiccated crust, over which a reinforced stone ramp was constructed to form a drilling base.

From drilling records and recovered samples it was possible to determine excavation levels to achieve the required subgrade strength and reduction in contamination levels.

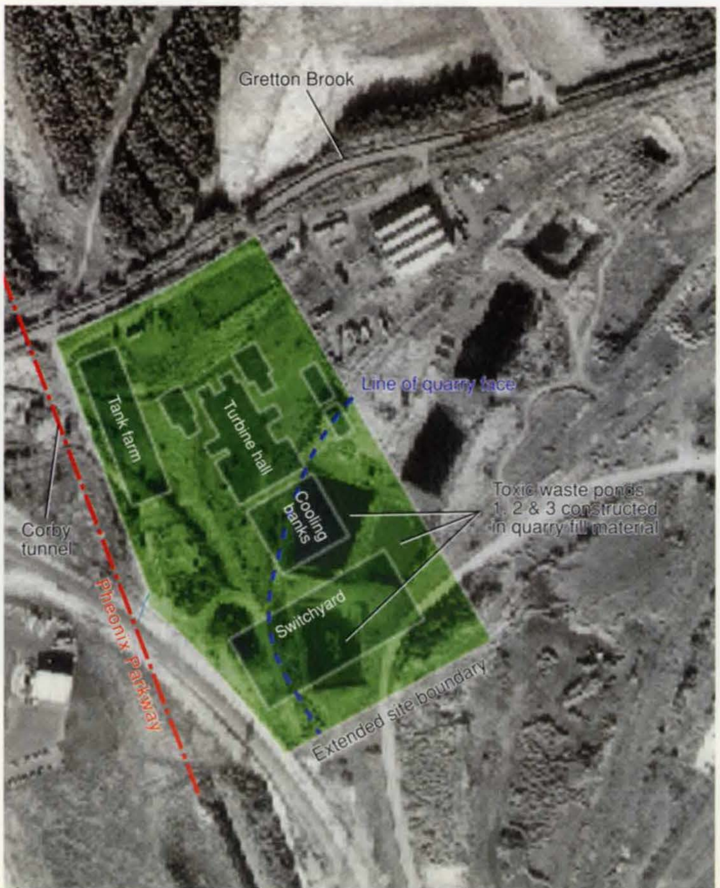
Many options were considered for reclaiming the ponds, the final choice being to remove most of the contamination and place new imported fill. This was enabled by Corby District Council providing a new disposal site on nearby land owned by them, thus avoiding the need for offsite transportation of sludge. The new facility dealt with sludge and solid waste, excavated and carted by conventional plant after the surface oil and supernatant water had been removed by tanker for offsite



* Upper sections of ironst
Toxic ponds subsequen

11. Cross-section through Corby site showing reclama

7. Aerial view of Corby site
showing tunnel and quarry areas and ponds, overlain with site outline.



8. Corby:
steam turbine pour showing protective roof on rails.

9. Corby ponds before reclamation:
pontoon and drilling rig on pond 2 during the site investigation.

disposal. In all, some 100 000m^3 of contaminated material was removed from the site before infilling and subsequent overall capping to provide a working surface. Fig. 11 shows a cross-section through the site.

The need for safety required strict separation of the contaminated site where no smoking, eating or drinking were permitted. Workers entering or leaving passed through washing and changing facilities designed to prevent cross-contamination. Personnel and the cabs of excavators were equipped with gas detection devices and full rescue and respiration equipment was provided.

Substructures

The line of the buried quarry face, and the nearby railway tunnel, significantly constrained the overall site planning. In particular the turbine hall was kept clear of the quarry face which meant that the foundation transition would be encountered only by the ACCs and the switchyard. Although the former transmit column loads of up to 250 tonnes, they are discrete columns on a 10m by 9m grid, which allowed for local piling variations.

Works within the quarried area were liable to inundation settlement of the remaining loose fills with consequent lateral ground strains. Piling here had to be designed to allow for some lateral movement together with negative skin friction from the fill, and the severity of the potential settlement precluded using pad type foundations for the switchyard. The consequences of a switchyard failure on power production are very severe and the risk associated with foundations other than piling was unacceptable.

In the main site area glacial till and estuarine series clays are underlain by Northampton Sand Ironstone over Lias Clay. The Ironstone at 5-6m thick and 7m below ground level offered a satisfactory founding stratum for end bearing and socketed piles. Bored piles between 450mm and 900mm were used across the site with the more sensitive structures on socketed piles. Single 900mm diameter piles, bored through the quarry fill and remnant Ironstone found in the underlying Lias clay, support the ACC columns.

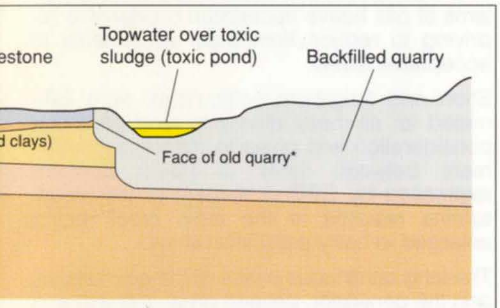
Although the boiler structures are the heaviest elements, with column loads up to 800 tonnes, the main turbine blocks involved the most extensive design work. The gas turbines (Fig. 4) comprise auxiliary turbine and generator sections, all linked by one rigidly connected axial shaft. The capacity for differential settlement is thus very limited. Each block contains 630m^3 of concrete, poured as one to avoid the problems of stop ends. Design problems therefore included soil structure interaction, dynamic design, thermal loads and control of cracking during construction. Dynamic loads result from rotor eccentricities during normal operation and extreme loadcases due to short circuit, faulty synchronization or loss of rotor blade.

The normal running condition is analyzed to ensure that the amplitudes of vibration at running speed are less than 8μm and that the resonant frequency of the foundation is sufficiently removed from the operating frequency as required by *VDI 2056* and *DIN4024* respectively.

Thermal loads on the block are severe, and early on it was decided to use limestone aggregate concrete — benefiting from both its lower coefficient of thermal expansion and higher tensile strain capacity. The block surface temperature can reach 90°c under the exhaust area and 60°c under the plant. Block pouring (Fig. 8) needed careful control, to maintain temperature differentials and to achieve high levels of accuracy. They were poured in the open, then a railmounted temporary protective structure was rolled over them. The concrete surface and formwork were insulated and thermocouples used to monitor temperature at various points near the surface and at the core. A maximum temperature difference of 27°c was recorded — within the 29°c allowance (Fig. 12).

The general principle, adopted as far as practicable, was to allow flexibility for HSPE's design development even late in drawing production stage, without forcing major redesign. This was exemplified in the construction of the central control room basement, which contains switchgear and has cable trenches across a significant proportion of the floor. It would have been quite possible to construct all the substructure in reinforced concrete, but to do so would have made the trench sizes and positions critical; changes would have involved redesign.

Instead, the trenched floor was constructed as a flat slab at low level with duct walls of blockwork and high level slabs cast onto permanent steel formwork. This design allowed early piling and main slab construction to proceed, whilst extensive late changes were made to the internal layout.



tone extracted by blasting and dragline.
tly created by British Steel following backfilling of quarry.

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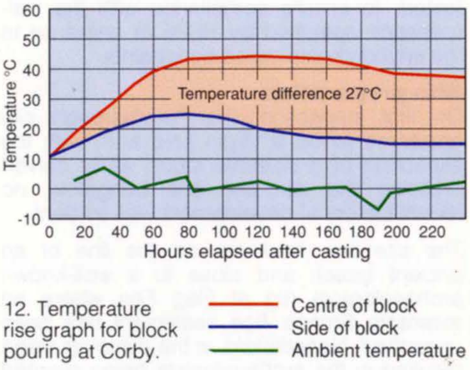
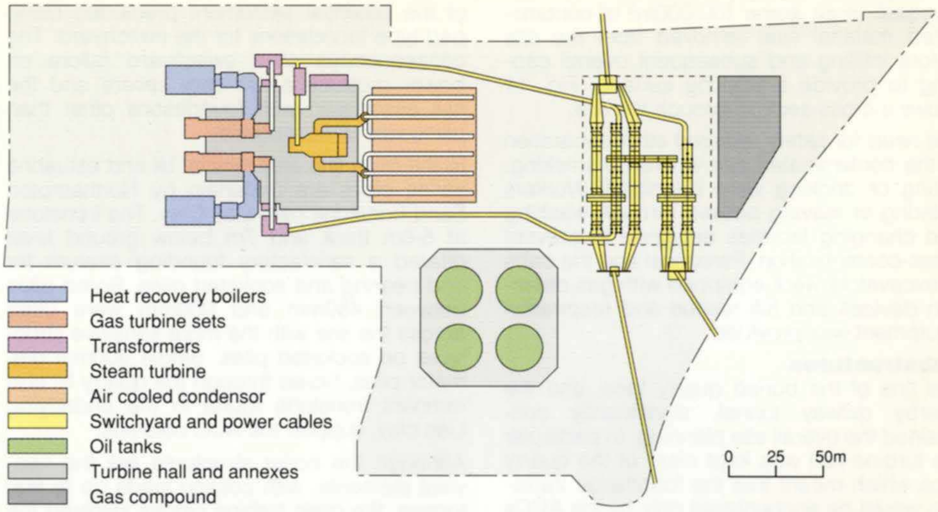


12. Temperature rise graph for block pouring at Corby.

10. Corby:
general view towards ACC.

Peterborough



13. Peterborough key plan showing principal service links.

Environmental assessment

Although many different factors were considered, atmospheric emissions, noise, and archaeology were those closely examined.

A dispersion modelling exercise was carried out for the proposed stacks, and a review conducted for nitrogen oxide (NOX) and sulphur dioxide (SOX) against EC directives current at the time. From these it was concluded that the station would be unlikely to infringe EC air quality requirements. The combined effects of both the Corby and Peterborough plumes were also examined since under certain circumstances they could interact. No problems were observed.

Owing to the location — the edge of an industrial estate on Peterborough's eastern boundary — the baseline noise survey revealed background levels which varied according to nearby activities. Nevertheless, agreement was reached with the City Council and guidance provided on construction noise, as well as an assessment of the plant operational noise levels. The need was confirmed for plant silencing and acoustic cladding to buildings. During design development acoustic panels were set up and tested, to ensure compliance with the performance specified by HSPE in response to the environmental noise constraints.

Site preparation

On first inspection, the Peterborough site appeared to be a virgin field and, with the exception of a sizeable storm water culvert crossing the site and one bungalow, no recent history of development was evident.

The site lies, however, on the line of an ancient beach and close to a well-known archaeological dig at Flag Fen where an extensive Bronze Age settlement has been unearthed. Negotiations at the planning stage resulted in the archaeologists being granted full access to the site for a period prior to development. Most people's perception of digs is of fine painstaking attention to detail over small areas, but the size of this site and the generally well-known horizon for Bronze Age artefacts dictated a major mechanical muck-shifting exercise. Trenches several metres wide and hundreds of metres long, criss-crossing the site, were taken down through the peat to the underlying silty deposits. After all the visible ancient timbers (thought to be foundation posts) had been marked, the wide swathes were covered with hundreds of coloured plastic drinking straws. The timbers, typically up to 1m in length, were usually removed by the archaeologists. The archaeological muck-shift pre-empted the pre-contract enabling works. During this, 120m of 1.6m diameter culvert was diverted to avoid the main power station plant. The peat, between 600mm and 1.5m deep across the site, was removed and replaced by a blanket of imported compacted stone, which raised the site above predicted flood levels and provided a clean and easily trafficked area for power station construction. Principal roads and main drainage runs were also installed.

Ground conditions

A two-stage site investigation had identified the strata succession, and the engineering properties of the drift material were expected to be variable. Recent excavations by the Flag Fen Archaeological Trust on land adjacent to the site had predicted that old drainage ditches and a Roman road might traverse it. These features were proved by the investigation and effectively precluded the use of conventional pad or strip footing foundations at shallow depth. The nature of the drift material in each area of the site dictated whether raft foundations could be used for secondary buildings. One extensive patch of terrace gravels enabled the oil storage area to be founded on compacted stone rafts. For main buildings and plant, the two most viable founding strata were Kellaways Sand and the Cornbrash Limestone, which necessitated piling.

Substructures

For the main turbine hall, a large raft foundation could support all three turbines and the building, but the depth to the Oxford Clay, the highest solid strata, rendered this solution uneconomic compared to the piling options. Smaller raft foundations were satisfactory in some areas where the drift deposits were adequate, but all main structures were identified as needing piles, as were smaller structures in areas where deep deposits of soft silt were found.

The layered strata beneath the site contain no distinct rock head. The Cornbrash Limestone is only some 2m thick at 12m depth. Bored piles could be founded on it, albeit with some construction difficulties, so this was the lowest stratum for consideration. At only about 8m deep, the Kellaways Sands could also provide a viable founding stratum, particularly suited to driven, cast in situ piles, with the induced compaction making good use of this relatively thin layer overlying more compressible clays. In the event the contractor accepted a tender for driven, 275mm square, precast piles. These proved satisfactory in trial pile tests and were used for all elements except the turbine blocks where stiffer 360mm square piles were used. Piling progressed swiftly due to good access and use of a mechanical pile head cropper but problems of pile heave necessitated extensive re-driving to reduce immediate settlements to acceptable levels.

Short and long-term settlements were estimated for all major elements, and particular consideration was given to differential settlement between items of plant. Concern expressed by GEC in respect of the steam turbine resulted in the main block being enlarged to carry peripheral items.

The long continuous shafts of the gas turbine, and the generator, caused great concern and curvature of the block under long-term settlement was considered in detail. The greatest curvature occurs under the exhaust section between the turbine and the generator. Re-aligning the shaft by unbolting and re-shimming the generator is therefore possible, although the necessity for this is not expected before the first five-year major maintenance outage. Concern over pile heave to the turbine block, which could not be fully addressed by re-driving, resulted in a full-scale trial loading test on one of the blocks whilst recording settlements by precise level. The recorded deflections were of the correct order and demonstrated the anticipated deflection curvature.

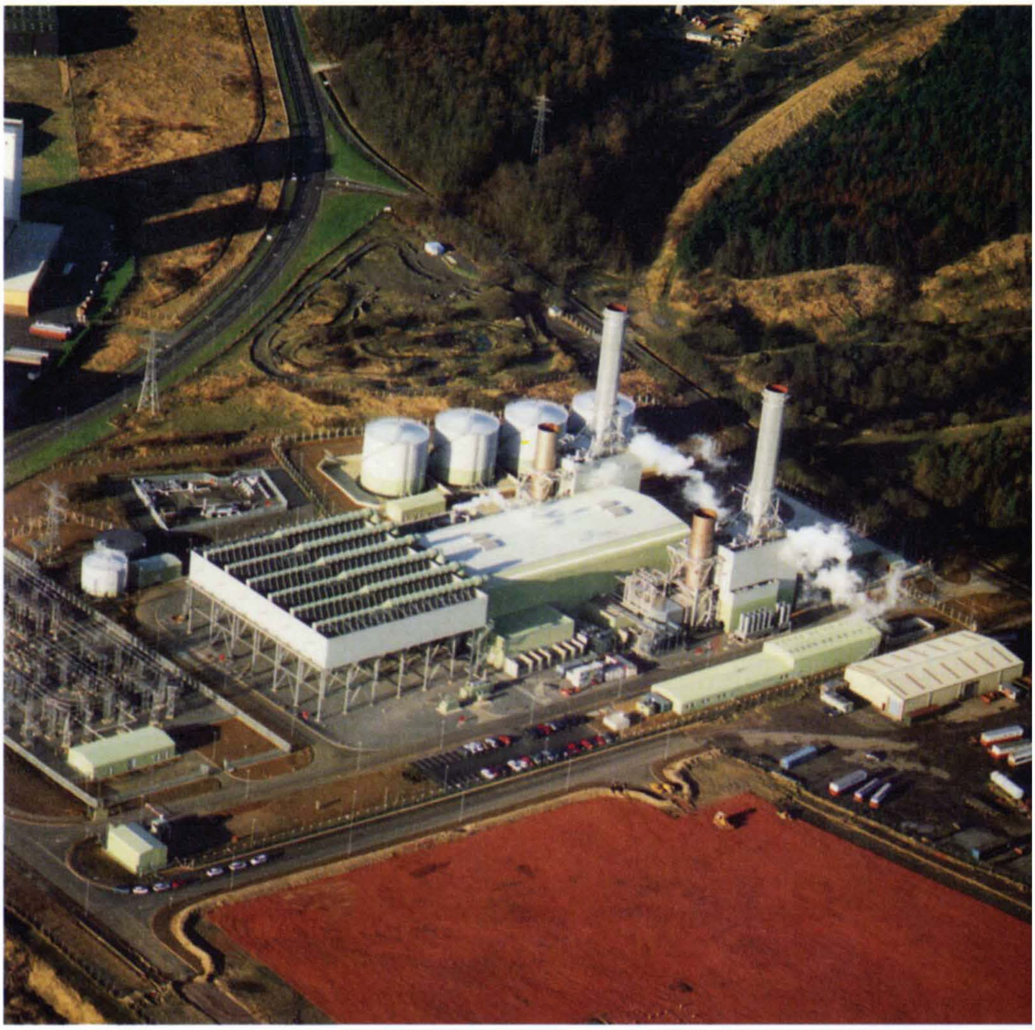
14. Peterborough heat recovery boilers under construction.

Conclusions

These two projects have been significant for Arups in gaining experience in several new areas. The environmental assessments were started only a couple of weeks after the new Planning Regulations, setting out the requirements for Environmental Statements, came into force. The legislation was interpreted and the Environmental Statements completed in less than three months. Other power station Environmental Statements, such as for Bilsthorpe and Sutton Bridge, soon followed.

These were amongst the first few power stations developed immediately after the privatization of the UK electricity industry. Arups have thus entered a UK market monopolized for decades by the CEGB, and hope to build on this experience of the UK power industry and gas-fired power stations in the near future.

Power stations are an extreme example of industrial projects in which civil engineering and building works are entirely subsidiary to the process plant. This puts very particular pressures on the design team, who are constantly squeezed between the requirements to produce drawings for construction and to respond to constantly developing and changing plant requirements. A design/build contractual relationship brings some advantages, but many more potential problems. In these projects, it was the personal commitment and co-operation of individuals from all sides that achieved successful completion of the work on time. Had less positive relationships crept in, the outcome would undoubtedly have been very different.



▲ 15. Corby.

▼ 16. Peterborough.

Credits

Client and turnkey contractor:
Hawker Siddeley Power Engineering Ltd.
Design and build contractor:
Kier Construction Ltd.
Architect:
Bartlett Gray & Partners
(*now* Richard Ward Architects)
Engineers:
Ove Arup & Partners John Duncan, Paul Geeson, Sue Armstrong, Gary Marshall (management), Steve Cliffe, John Read, Gordon Thomson, Duncan Powell, Vinh Tran, Dave Thompson, Dave Sibbit, Suresh Tank, Bridget Allwood, Samantha Williams, Roger Pickwick, Chris Webb, Andrew Anderson, Damien Friel, Jean Bordier, John Corbett, Wayne Charles, Bryan Rogers, Darren Paine, Gary Thomas, Peter Thompson, Liz White, Craig Brittain, Erica, Seddon, Alistair Edwards, Peter Terry, Diane Sadleir (structural/foundations),
Alan Turner, Robin Lee, John Roberts, Adrian Collings, Fred Engman, Hussain Torkpour, Abir-al-Tabar (geotechnical), Paul Johnson, Paul Tomlinson, Justin Abbott, Janice Turner, Simon Hill (environmental),
Peter Court, Carl Wilkinson, Neil Robbie, Martin Howell, Colin Magner, Wayne Powers (electrical /mechanical),
Geoff Griffiths, Chris Evans, Joe Nunan, Andrew Davies, Andrew Lloyd, John Stowell, Steve Dunthorne, Colin Whewell (civil),
Des Killingworth, Iain Clarke, Sue Ridler (industrial/acoustics),
Jo Douglas, Carol Scott (document control)

Illustrations:
1-4, 7 (montage), 11-13: Trevor Slydel.
5: Mark Enstone.
6, 10, 14: Peter Mackinven.
7 (photo): Hunting Aerofilms.
8: John Duncan.
9: Robin Lee.
15, 16: Photoair Group.

Kaiser Permanente Medical Campus, Fresno, California

Alisdair McGregor
Peter Lassetter

1. Phase 1 MOB and mall. The latter has expressed columns and beams at the two lower levels.

Introduction

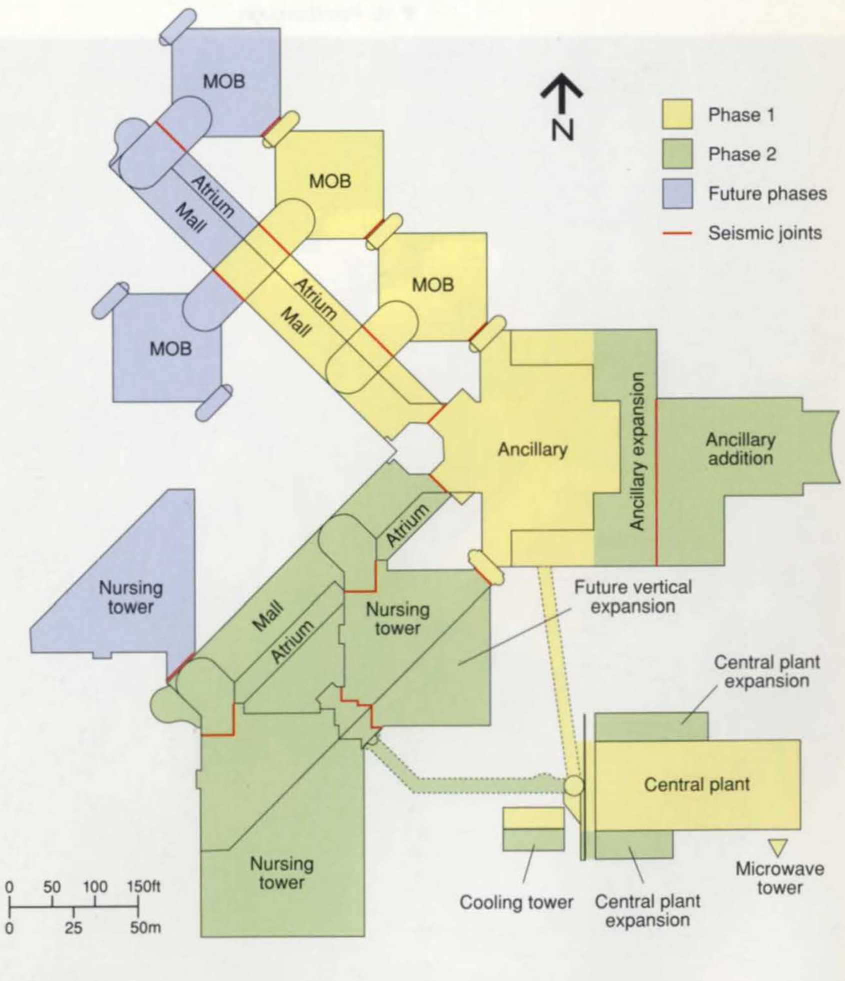
Fresno, in the southern leg of the hot, dry California Central Valley, is one of the fastest expanding cities in the USA. Kaiser Permanente, the largest health maintenance organization in California, needed to respond to Fresno's rapidly increasing local membership, as well as the changing focus in modern health care toward considerably enhanced out-patient facilities. The goals for the project were defined as:

- earliest possible occupancy of medical office buildings (MOB) by 90 doctors
- earliest reasonable completion of ancillary services building
- provision of spaces easily adaptable to rapidly changing health care trends and procedures in the future
- a masterplan for the Campus providing for easy expansion and growth, and allowing rapid response to an uncertain membership growth rate
- cost-effective design.

Phase 1 began design in 1989, and construction was substantially complete in 1991. At that time a second phase of the masterplan was started, and is currently under construction. The architect, The Ratcliff Architects, the contractor, Schaal/Lechner Inc., and Ove Arup & Partners as building engineers, were all reappointed for the Phase 2 works.

Architecture

The complex is set on a 15ha greenfield site (Fig. 2). Phase 1 includes two clinical MOBs, an ancillary services building, and a linear support building or mall as a connecting element, along one side of which the MOBs are located. There is also a freestanding central plant building, serving the complex through a utility tunnel. The MOBs are modular, four storeys high, with an operational model of 12 providers (doctors) per floor. The MOBs accommodate Urgent Care, Optometry and Ophthalmology, Urology, Cardiology and



2. Site plan.

Family Medicine. Spaces in the ancillary services building include a seven-suite surgery, out-patient and in-patient recovery, radiology, emergency, clinical lab, physical therapy and Administration.

In Phase 2, a second mall was attached to the ancillary services building together with two four-storey nursing towers, one able to be extended vertically, each block being planned on a 24 bed-per-floor module. The second mall is designed to accommodate further towers. The bed towers include a 26-bed Labor & Delivery Unit, a 12-bed Critical Care Unit, five 24-bed modules, a cafeteria and support spaces. The malls feature two-storey linear atriums, providing circulation at the ground floor and natural light to spaces within, such as the pharmacies.

The ancillary services building also was expanded in Phase 2, horizontally as well as vertically, to create additional surgery and radiology suites and an emergency department. The expansion was done without using seismic joints, because they would have run through the middle of radiology rooms which had been enlarged. A seismically separate ancillary services building addition was then added where seismic joints would cause no inconvenience.

The MOBs and nursing towers were turned 45° to the malls to gain a dense packing of space while allowing view, light and air to all perimeter rooms and still preserving privacy. Courtyards were created between the building modules and the malls, with public access from the latter. The physical space complements the Medical Center's state-of-the-art technology and has strongly contributed to the owner's ability to recruit high calibre staff.

Project management

In any fast-track project, management and communication play a crucial role. Many programmatic changes were incorporated through design and construction without compromising the scheduled opening date of Phase 1. The project was able to absorb these changes for the following reasons:

Design:
The building services were laid out in a logical manner allowing tap-ins for additional duct and pipe branches with minimum disruption.

Integration:
The co-ordinated structural, mechanical and electrical design allowed the air, hydronic, and power systems to have expansion capacity designed in.

Teamwork:
There was close co-operation between Kaiser's management team, the architects, the engineers, and the contractor. All worked together to anticipate potential problems and so avoid them.

In California, hospital designs are reviewed by the Office of Statewide Health Planning and Development (OSHPD). Their review typically takes 10 months before a permit is released. The schedule-critical MOBs, however, if separated from hospital functions, needed only to be reviewed by the City of Fresno, typically a two-month process. Early on, therefore, seismic joints were located to separate different building usages in order to minimize the amount of building reviewed by OSHPD.

A fast-track approach to construction was developed with the contractor during design. His construction schedule was used to split the Phase 1 documents into nine agency review packages, and five bid packages. The strategy was successful: Phase 1 was completed on schedule and on budget. The Phase 2 documents were split in a similar fashion and construction is currently on track.


3.
Phase 1 MOB from interior courtyard, looking north.


4.
Linear atrium in Phase 1 mall.


5.
View from mall to nurses' station.


6.
Phase 1 surgery suite.

Structure

To enable rapid and economical construction, a steel-framed structural system was chosen. Floors are lightweight concrete fill on metal decking, spanning 8ft (2.44m) to structural steel beams and girders, in turn supported on steel columns.

Lateral stability is provided by special moment-resisting frames around the building's perimeter, where the general internal column spacing is halved to approximately 15ft (4.57m), to provide additional stiffness to the lateral system. Bracing systems were considered in order to reduce cost further, but the impacts on internal flexibility if they were placed inside the building, and on later expansion if at the building's perimeter, were thought too intrusive for the small cost savings involved. Foundations are generally cast-in-place shallow reinforced concrete spread footings. At the seismic moment frames, some drilled piers were used to resist uplift.

The central plant building, a single-storey steel frame with a metal roof deck, has a slightly different structure. Lateral stability is provided by simple concentric bracing in one column bay at each of the building's perimeter elevations. It was initially felt that the perimeter bracing would compromise future expansion, so the maximum possible size of the central plant building was calculated, assuming the site was completely developed. It became clear that the metal roof decking would be able to span seismic shear as a diaphragm clear across the full width of the largest envisioned building. When the central plant is expanded, new braces will be erected at the new perimeter; and also the existing (and now internal) braces unbolted and removed. This solution is substantially cheaper than providing a welded moment frame for such small seismic shears.

All buildings were analyzed laterally using the ETABS computer program. The distribution of seismic joints and phasing breaks the complex into the following structures: two MOBs, two malls, the ancillary services building, the ancillary expansion, the ancillary addition, two nursing towers, the central plant, and the central plant expansion. Base shears ranged from 0.036g for the MOBs, 0.062g for ancillary, 0.085g for the towers, to 0.155g for the central plant. The towers had mass irregularities, vertical irregularities, and non-orthogonal lateral systems due to their triangular shape. This triggered a dynamic analysis of each of the structures, from a site-specific response spectrum provided by the owner's geotechnical engineer.

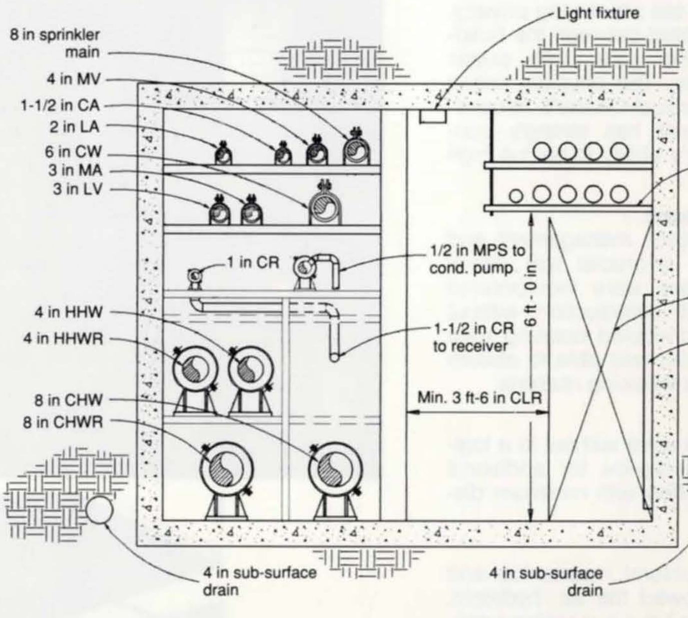
The maximum probable earthquake had an 80% likelihood of not being exceeded in 100 years, assumed 5% damping, and had a peak horizontal acceleration of 0.12g. The maximum credible assumed 10% damping and had a peak acceleration of 0.29g.

Generally, lateral drift was kept to just under the limits allowed by codes. Because the MOBs and towers were turned 45° to the mall, the seismic joints separating the structures were short. However, the joints between the ancillary services building and both the mall and ancillary addition ran the full width of the building. Analysis showed that it was cost-effective to limit drift of the ancillary building and the mall to 50% and 75% of code allowable. The extra expense in structural steel used to stiffen the lateral frames was more than offset by the cost savings that were made by reducing the width of the seismic joints.

Central plant and utility tunnel

The major design parameter for the central plant was to make the future phases of hospital expansion as simple as possible without building more than necessary in Phase I. The solution was to locate the equipment rooms on either side of a central distribution corridor: boiler, chiller, and pump and compressor rooms on one side; generator and switchgear rooms on the other. The pipe headers and equipment were all laid out so that equipment could be simply expanded outwards, with the walls moved to whatever location the next phase required.

The services tunnel from the central plant to the ancillary services building has piped services on one side, data/telecom cabling on the other (see Fig. 8), and electrical conduit along the ceiling. A second tunnel runs out to



7. Section through utility tunnel.

8. (left) Phase 2 tunnel connecting to central plant building.

9. Central plant building from the west in June 1993, showing bolt-on frame for Phase 2 expansion. The cooling tower is in the foreground.

10. East corridor looking north on first floor of south nursing tower, Phase 2, under construction November 1993. Pressed metal studs, with insulation and then gypsum board, are used for partition construction.

11. Phase 2 nursing towers under construction, September 1993, viewed from south east. Part of the Phase 1 ancillary building can be seen on the right.

12. Phase 1 ancillary building from the south; ancillary expansion and addition under construction on the right, Phase 2 nursing tower on the left (August 1993).

11

the Phase 2 wing. There was much discussion with Kaiser and the contractor about the relative cost of the tunnel and alternatives such as direct-buried. In the event, the tunnel provided many operational benefits and received positive comments in the Post-Occupancy Evaluation (POE). It allowed the MOBs to be connected into the central plant and made operational, while construction of the ancillary services building continued over the top of the tunnel. Medical gas lines were extended to the MOBs after Phase 1 was opened, without any disruption to the occupied floors. Running the primary distribution route under the building also meant that the first floor ceilings were less congested, allowing greater ceiling space for the Radiology Department. Beyond the ancillary services building, piped services continue in a trench which can be accessed by crouching. The trench stubs-out beyond the MOBs with capped-off pipes so that future MOB modules can be added with minimal disruption to the hospital.

Energy conservation

The utility company, Pacific Gas & Electric, has been offering a series of cash rebates for energysaving construction for several years now. The use of variable frequency drives, high efficiency motors, supply air temperature reset, and high performance glazing, achieved PG&E's targets, netting about $60 000 in rebate for the owner, in addition to the annual savings in energy costs.

1in (25mm) diameter high-efficiency fluorescent luminaires, electronic ballasts, and occupancy detectors for light switching were incorporated in Phase 2. For this phase, which is predominantly hospital occupancy and so exempt from the Energy Code, the performance of individual components became critical. Providing new, high efficiency cooling towers for the whole project netted almost $100 000 which, together with annual energy savings, enables the towers to pay for themselves in three years.

Cooling system

Chilled water is generated by five centrifugal chillers with a total capacity of 1520 tonnes (5350 kW) using R134a as a refrigerant. Financial rebates from the utility company made it cost-effective to provide three cross-flow towers operating with a 6°F (3.3K) approach temperature to cool all five chillers. These new towers not only reduce fan energy consumed by the towers, but improve the efficiency of the chillers by supplying cooler condenser water.

Heating system

Hot water is generated in four gas/oil-fired forced draft boilers with a total output of 17 600 MBH (5200 kW); heating water is distributed by variable speed pumps. Mandatory limits for nitrous oxide emissions were enacted by the San Joaquin Valley Air Quality District during construction. The two Phase I boilers had flue gas recirculation packages added, whilst the two new boilers have newly developed low NOx burners.

Air systems

The MOBs have variable air volume (VAV) systems with plenum ceiling returns. The ancillary services building has constant volume (CV) systems for all areas except Administration, which is served by a VAV system. After discussion with the state code checkers, the operating rooms were allowed to have two-position terminal boxes so that the room air change rate could be dropped from 20 to 10 per hour when not in use. The nursing towers also have CV systems to comply with OSHPD regulations.

Controls

All major HVAC and plumbing equipment is controlled or monitored by a modular direct digital control (ddc) system. Individual room temperature control is pneumatic. The use of ddc terminal boxes was investigated during design development but was estimated to cost an additional $60 000-80 000. For Phase 1 the 'host' station located in the central plant provides colour graphics of all systems with current status and setpoints. In addition, trend logs on any measured parameter can be generated.

Electrical systems

The distribution equipment and most of the step-down transformers are located in the central plant. Total sizing of the main high voltage switchgear is 8MVA to accommodate all foreseeable growth. Unit substations are used to step-down the voltage to 480V for distribution within the central plant and to the ancillary services building. The MOB, being farther away, gets power at 21kV, with a local pad-mounted transformer to step-down to 480V.

All main feeders are metered electronically and the information is sent to a computer in the engineer's office. Instantaneous readings and long-term trends can be viewed on the computer screen or printed out.

Four 700kW diesel generators provide emergency power, with a series of automatic transfer switches used to subdivide the emergency system into Life Safety, Critical, and Equipment branches.


9


10

12

Conclusion

Phase 2 is now well into construction and is due to be completed in October 1994. Subsequent to the Fresno project, Ove Arup & Partners were appointed by Kaiser Permanente for the design of the new 450-bed Santa Clara Hospital, and a new MOB plus remodelling of the hospital at their Martinez campus.

Credits

Client:
Kaiser Permanente
Architect:
The Ratcliff Architects
Structural and services engineers:
Ove Arup & Partners Peter Lassetter, Alisdair McGregor, Peter Balint, Jack Howton, Eric Ko, Jerry Frias, Alla Lightman, Jimmie Smith, Willie Batenga
Contractors:
Schaal/Lechner
Illustrations:
1, 3-6: Jane Lidz
2: Trevor Slydel
7: Michael Hoffmann
8: Eric Ko
9-12: courtesy Schall/Lechner

Evolution of the panorama lift

Roger Howkins*

A number of recent projects on which Arups have worked as lift engineers raise some fascinating issues about the future. Those presenting the most interesting lessons have included:

- The International Conference Centre, Birmingham
- Triton Court, London
- Block H, Euston Centre, London
- Lloyds of London
- Bracken House, London
- Expo '92, Seville
- 123 Buckingham Palace Road, London

and currently:

- Golden Square, London
- Finsbury Pavement, London.

The clear lesson from all these is that owners and passengers want a very different kind of lift: for security (in a rougher world), for travel safety, for efficiency of use, with environmentally appropriate design, and for the simple pleasure of the journey.

Lifts in 2020

How far have we travelled towards such a destination? What has changed in the last 100 years of lift design? What is going to change in the next 25 years? Figs. 1-5 demonstrate how cab design has evolved from the turn of the century to the panorama lift of today — and on to some version in 2020 which will seem even more open to today's eyes. Fig. 6 similarly indicates how the controls have evolved, both in the cab and at the landing, converging on some form of smart card. Information technology is already making a significant impact on lift design and this will continue.

The microprocessor has changed the way control systems operate: the old copper and carbon contactors on slate boards are now rare. An old-timer would have as much difficulty diagnosing faults on a modern processor-based controller as would today's graduate in maintaining air gaps and dressing contacts. But the old-timer going into today's lifts would be able to recognize most, if not all, of the equipment and techniques being employed. Admittedly we have glass cabs and finishes (considered modern), but every generation has had its trends.

The question could soon become: can a lift company provide lift cabs, lobbies, and hoistways with total glazing — and keep visually intrusive elements to a minimum on the landings, in hoistways, and fitted to the cabs? We can look into the future, say to the year 2020, for the next generation of panorama lifts — as seen from a good design viewpoint.

Rethinking lift design

Lift companies rarely employ conceptual designers to transfer architects' ideas into working detail drawings without employing the well-worn phrase 'using our standard equipment'. If there is to be real progress in lift design, with the service, efficiency, and appearance being improved, all aspects of current lift design should be questioned from first principles.

Who in their wisdom (back in the early days) decided on the magical ratio whereby a building's lift provision *has* to be capable of moving *17%* of the building's total population in *five* minutes, or decreed that *30* seconds is the optimum waiting interval for quality lift service? Who decided how cab floor area equates to number of passengers? (It has been suggested that originally it was the area taken by passengers' feet in horse-drawn carriages! This is now virtually engraved on tablets of stone, worldwide — with minor regional variations.)

Of course designs undertaken from 'new' first principles must be safe, and the safety of users, lift mechanics and inspection personnel not compromised. This is not to say that all components, fixtures and fittings should be under-engineered, or that there should be confrontation with those devising standards. Far from it.

All vertical transportation professionals know that lifts the world over are reasonably and consistently safe (in terms of journeys per day), although some countries have better records than others. Most of the accidents do not happen to the general public, but to mechanics and inspectors who probably short-cut safety procedures or skip maintenance. The main components have performed reliably over the years.

Let us look at some of these and see if they have a place in the 2020 lift.

Safety gear

Ever since Elisha Otis demonstrated his safety lift in 1853, most passenger-carrying lifts have been equipped with a safety gear. What function does it really achieve? As a control device, in conjunction with the overspeed governor, it monitors speed and movement, and, in the case of gear or rope failure, it stops the lift from crashing down the hoistway. Is it really needed now? In the early days of lifts — with suspect quality ropes and gears — yes.
But now?

In the days of early aeronautics, all passengers had parachutes under their seats in case of engine or structural failure, 'just in case'. The airlines no longer consider parachutes necessary for passenger safety.

Why? Because of advances in design and reliability. Perhaps this remnant in lift design, virtually from the Industrial Revolution, can also be dispensed with? Or should it still be 'just in case'?

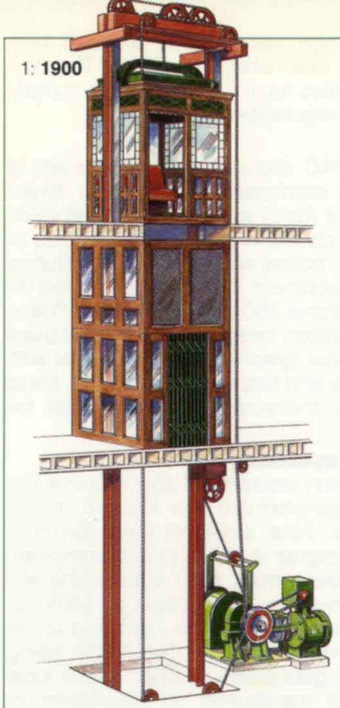
Overspeed governor

The majority of lift installations at present include a flywheel mounted at the top of the shaft, encircled by a rope whose other end is attached to the lift cab. If the lift speed exceeds the design maximum substantially, the rope and a breaking mechanism bring the cab to a halt. If the need for the safety gear is successfully eliminated, this assembly, the overspeed governor, also becomes redundant: electrical overspeed can be successfully monitored by use of speed transducers.

Guide rails

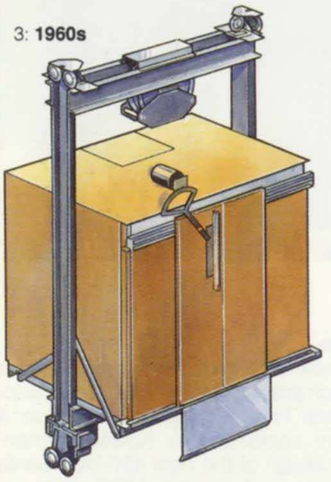
By definition, these guide the cab up and down the hoistway and provide something to be clamped onto, when the safety gear is activated. Because traditionally they have to stand excessive force, due to safety gear operation and loading imbalances, the traditional rail is a steel T-section. However, if the safety gear were removed, the T-guide would become redundant. In its place, a pretensioned cable could be incorporated,

1: **1900**

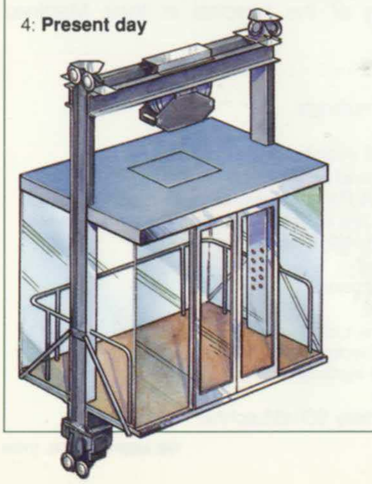


2: **1930s**

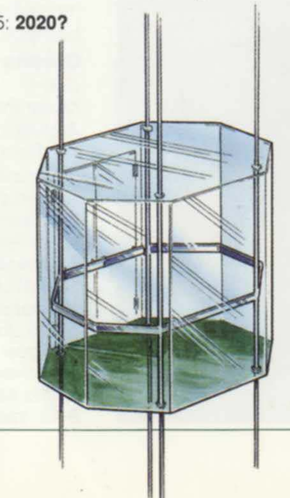
3: **1960s**



4: **Present day**

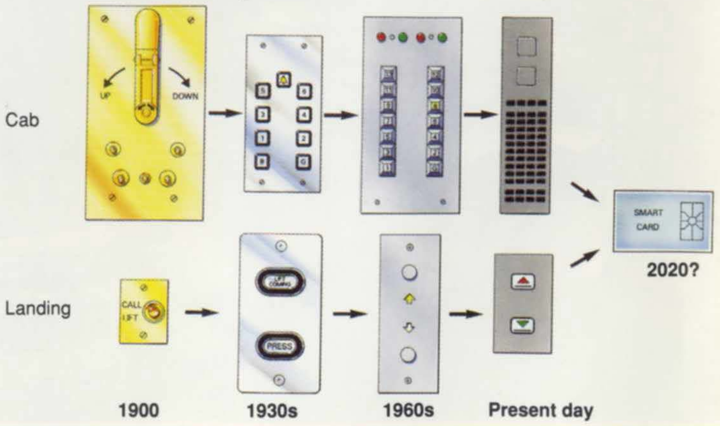


5: **2020?**



1-5. Evolution of cab design.

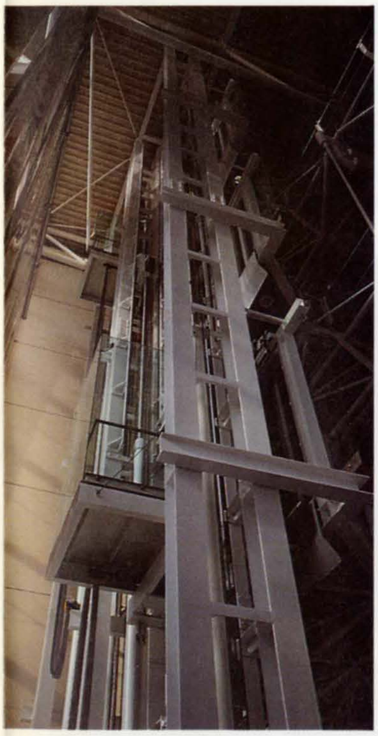
6. Evolution of cab and landing controls.



**Roger Howkins is a senior lift engineer in Arup Research & Development.*

7. Top of atrium climber lift at Triton Court, 1984.

8. Lift at UK Pavilion, Expo '92, Seville, 1992.



with the cab kept in its correct location in the hoistway by the means of an electrical field, around an eye shoe. This would also eliminate the need for guide rail brackets, secondary steelwork, and structural supporting frames — with enormous cost savings. The lift structure would be lighter and leaner, and the well-designed panorama lift would become a reality.

Cab sling

Today, heavy sections of steel wrap around the cab like a gigantic safety cage. What does this achieve, especially if the safety gear, overspeed governor, and guide rails have been eliminated? The answer is very little. All that is required is a way to attach hoisting ropes, to withstand possible buffering and to support the passenger loadings and attachment of eye shoes.

Lift cab design

Major materials advances have been achieved recently and could be incorporated today in cab design by the adventurous. Bulky, architecturally-obtrusive components are still considered necessary by lift companies (to demonstrate to passengers that their safety is in strong 'hands'), but not by all the engineers, architects, and building designers who are paying the lift company to produce and manufacture to *their* design concept.

Panorama cabs in 2020 will have total visibility without resorting to heavy fixings. Car lighting will be by fibre optics and the traditional operating panel will be relegated to the museum of the black arts, as has the lift attendant's cab operating switch. However, workmanship will have improved significantly when bespoke panorama cabs are a requirement, not a luxury.

Door/operators

Major changes will have occurred in the design of these mechanisms, whether they are over or under-driven. The use of air line couplings will become the clean and safe method of door drive. There will be no car door operator as we know it today, just a simple air line connection engaging the doors at each landing to impart horizontal or vertical movement, with redesigned safety mechanisms incorporated to protect the lift user. Gone will be the heavy door linkages and skates. Smooth, clean lines will be required on doors and operators.

Controls

Gone too will be the days of 'white knuckle' rides, when lift travel was 'an experience'! Passengers, owners and engineers will require specific ride comfort criteria to be set and achieved in terms of vibration levels, acceleration, rates of change of acceleration, and noise levels. Otherwise buildings will become unlettable.

By 2020, 17% five-minute ratios, 30-second waiting intervals (or similar) should be historical relics; new standards will be adopted. Perhaps this will reduce the numbers of lifts required in buildings!

The old-fashioned 1990s lift control algorithms are based upon minimal waiting intervals with no expense spared in human cost. The passenger is subjected to unpleasant lift journeys just to achieve the 17%/30-second standard requirement. 2020 control algorithms will analyze each destination requirement and program the most energy-efficient lift to answer the destination request — not what is the nearest car, etc., to achieve the shortest waiting time. Thus will be born the true green lift control algorithm — not the token gestures being adopted in the 1990s. Destination requests will be by the use of smart cards issued to every lift user in the building, whether worker or visitor. Each person will have to verify his/her card's validity while passing through the building security system. This process will also only allow access to floors cleared for that particular user. If the passenger tries to exit on an unauthorized floor an alarm will sound.

The advantage of the smart card is that you will not have to remove it from your pocket, bag or wallet for verification. The card reader will be able to verify validity without swiping or physical checking. Thus the 2020 lift cab can be buttonless, with a reader embedded in the ceiling or other convenient location. The landing calls can also be activated by the smart card and will verify your desire to travel up or down or to those floors permitted by your level of security clearance.

Security and terrorism will be major considerations in all 2020 buildings, not just government, commercial, and research establishments. Terrorism will be a major lift safety issue worldwide and all individuals and companies will have to be aware of the fanatical element within the community. Lift systems will be prime targets for terrorists unless the frontiers of security and lift technology are developed hand-in-hand and not as separate incompatible systems.

Hoistway information

Information regarding each lift's location will be by transducers imbedded into car cills and landings, giving precise information on the lift status by means of fibre-optic data control cables to the master control system in the lift machine room.

Wiring and conduits

Traditional methods of wiring and conduits will be relegated to reference books as, it is hoped, most elements traditionally requiring electric power in the cab, landings and hoistway will have been eliminated. With no electric door operators or car buttons, is there any requirement for heavy trailing flexes? They are never seen by passengers in transit but are most unsightly for those waiting on landings.

Fixed charging modules will transfer power from landings to cab when the lift stops. This will enable cab lights, control and information devices to be maintained between floors. The landing smart card call stations will use fibre-optic data control cables to transfer signals and information from these local stations on lobbies to the master control system in the lift machine room.

Drive

Pressures being expressed in the 1990s by environmental groups and national bodies will mean that the 2020 lift drive system is likely to be energy-efficient, clean, and totally recyclable. The 2020 drive system will use man-made materials for gears, drives and structural components. The drive motors will be smaller because of weight reductions of cabs, and of course the elimination of safety gears, cab slings, door operators, and cab information systems.

continued ▶

9. 10.

9. Lift cage for the Golden Square project being assembled. Uniquely (to date), the lift door mechanism is situated at the base.

10. Completed lift as it will appear at Golden Square.

Earlier versions of this article also appeared in *Elevator World*, March 1994, and *Building Services*, April 1994.

Illustrations:
1-6: Fred English
7: Ove Arup & Partners
8: Reid & Peck
9: Roger Howkins
10: Courtesy The Halpern Partnership

Evolution of the panorama lift
continued

Environmental factors
2020 lifts will be environmentally friendly in manufacturing costs, installation costs and running costs. Penalties are likely to be imposed on companies who are not 'green'. Technical specifications will require that we know the amounts of manufacturing pollutants that are being dumped into our environment when producing a tonne of material. Cheap but environmentally dirty materials may well be outlawed. Heavy additive mineral oils will be replaced with vegetable-based oils. Natural woods will be sourced only from renewable stocks; exotic rare trees will be preserved in their natural habitat, just as animals have been in the 1990s.

Lift companies' corporate activities on green issues will be a major factor when making decisions. Green policies of engineers and designers will foster new technology, allowing companies to invest in research and development and reduce the current mass destruction of our planet.

Medical
Research will have shown the medical effects on a person whilst travelling in a lift. Whole body movement is something that affects everyone, and in the 1990s there are real problems with the medical effects of lift travel. They only occur in a small proportion of lift users, but this doesn't mean they should be ignored, as they won't go away. The smart card can hold this individual medical information. The lift control can adapt to individual needs on acceleration, cab brightness, strobe effects — even change the colour of glass to suit individual medical needs, or automatically inform reception that the intending passenger requires escorting, without the possible embarrassment of revealing phobias.

Specification for the 2020 panorama lift
The objective at the beginning of this article was to identify what would be needed (or not needed) in lift cabs, lobbies and hoistways with no visually-intrusive steelwork, brackets, guides, or components. There seems no reason to doubt that, 25 years hence, intending lift travellers will only see clean, open, glazed hoistways, and that lift passengers will be aware merely of a glass enclosure whisking them up the atrium hoistway in comfort ,without vibration or noise, and with no visible means of support, guidance or operation. Lift design continues to present a fascinating mixture of problems: everybody has strong opinions on the subject, especially while they are waiting! It has always involved electrical, mechanical, and structural engineering. We now see the influence of more recent preoccupations of environmental awareness, along with those of utilizing new materials and information technology, converging on the pursuit of modern ideas of space and transparency.

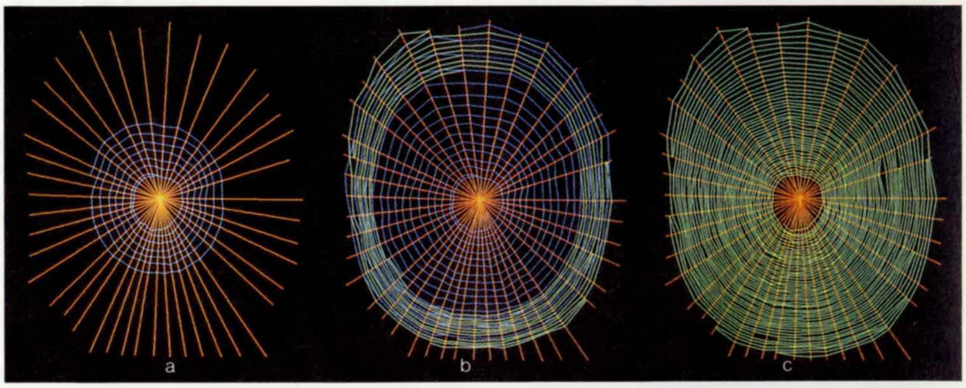
Studying spider webs: A new approach to structures

Lorraine Lin*

Initial research
Progress in architecture and engineering can come from unexpected sources. Millions of years of evolution have produced the spider web — an extremely efficient, natural, lightweight structure that has evolved with a clearly defined function: to resist load while minimizing both material and construction time. An interdisciplinary research project, begun by Peter Rice, between Oxford University zoologist Dr. Fritz Vollrath and Ove Arup & Partners has been focused on unraveling the mysteries of the web of *Araneus diadematus* (a common species of garden spider) — the properties of its silk, its geometry, prestress distribution, and relationship with the environment.

Spider silk is over 400M years old. Present-day silk is a very strong biopolymer (breaking stress 1300MPa) which can absorb up to 100 times the energy required to snap steel. The silk is sensitive to the rate at which loads are applied. This 'viscoelasticity' means that sudden lengthening of a thread creates a large unstable resisting force. If the new length is maintained, the tension settles down over time to a lower equilibrium force. Thus, viscoelasticity has two advantages: (1) it reduces the amount of pretensioning required in an 'in situ' web; (2) it maximizes the kinetic energy of impacting prey absorbed by the threads. This special property of the silk is an example of the web's ability to react to loads, be it the next meal in the form of impacting prey or the swaying branches of its attachment points.

Properties
The silk's versatile elastic properties depend on whether it is wet or dry. A stiff skeletal structure formed by the radial threads is composed entirely of dry silk, but the spider fully exploits the material's increased elasticity when wet: spiral threads are spun from the same silk but covered with a special 'glue'. This coating serves two functions: (1) to provide the stickiness required to entangle an insect, and (2) to draw ambient moisture from the environment. Water absorbed by the glue forms a cylinder of fluid around a capture spiral. This cylinder grows in size until it becomes unstable at a critical diameter, and breaks into a strand of droplets. These droplets act as 'windlass' mechanisms, rapidly reeling in and out the capture spirals under loading. The driving force is the surface tension of the water. The result is a superelastic spiral thread that can contract up to 5% of its original length without sagging, then stretch over four times its original length without snapping. This is an important feature, which prevents the formation of holes in the web caused by rupturing or sticking together of the threads. Thus, by incorporating these natural mechanisms and a combination of softness and stiffness in a web, a spider is able to maintain an effective net for capturing prey even in strong winds.

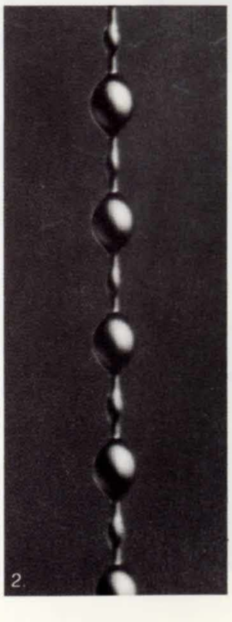


1. Construction sequence of a web.

(a) Stiff, highly-stressed radial threads (red) are constructed in a near perfect plane.

(b) Stiff spiral threads (blue) are placed, starting from the centre. These threads are stressed tightly, providing intermediate stability and scaffolding for further construction. They also affect the prestress distribution by pulling the radial threads towards the hub. Then, the spider laboriously constructs the capture spiral threads (green), beginning at the periphery. These spirals are placed with zero prestress force, but are covered in glue. As the glue absorbs ambient moisture to produce droplets, the capture spirals tighten up.

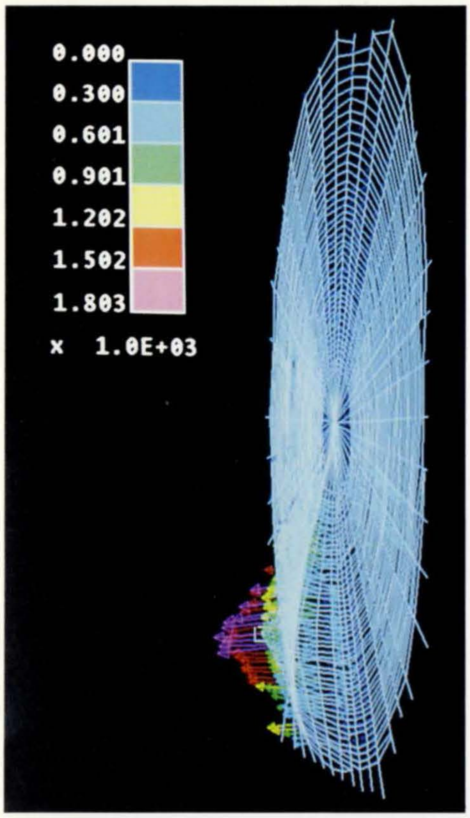
(c) Finally, the spider eats away the highly stressed scaffolding threads, releasing the radials to create the desired prestress distribution. The web is usually consumed by the spider to regain the silk's protein, as well as gain water.



2. A strand of droplets on a capture spiral magnified 100 times. Each droplet has a diameter of about 50 microns.

3. A single droplet placed on a glass slide showing the reeled-in spiral thread magnified 300 times. Each droplet acts as a 'windlass', driven by the surface tension of water.

**Lorraine Lin is a structural engineer with Ove Arup & Partners, currently on secondment to Renzo Piano Building Workshop, Genoa. This paper is dedicated to the memory of Peter Rice, who together with Sir Jack Zunz, Tom Barker, and Arups' General Development Fund, made this research possible.*

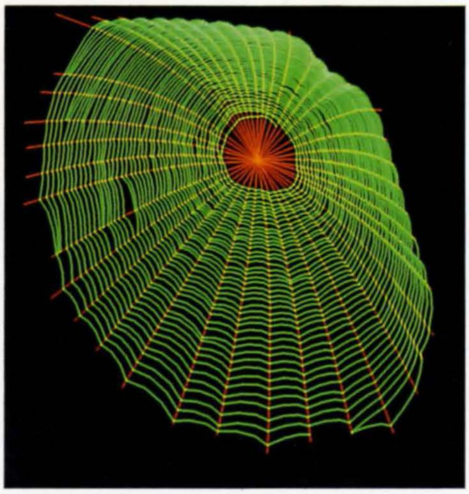


4. Velocity plot (mm/sec) during impact of a web with a fast-moving and, on a relative scale, massive 'insect'. Webs have evolved to respond rather than to prevent deflections.

Resistance to loading

From the perspective of a web, a hurtling insect is equivalent to a guided missile. The 'strategy' adopted by the orb-web after 180M years of evolution, is to respond to geometric deformations rather than prevent them. A planar web is nature's answer to a form that requires a minimum amount of building material for a given projected area. However, straight cables are unable to resist perpendicularly applied forces. Thus, the threads of a web provide resistance to loading only after they have been activated by deformations. This is all done in a controlled manner: the spider delicately and precisely tunes the prestress forces in the various threads, determining the magnitude and location of the greatest deformations.

The lightness and clarity of the stone arches in the Pavilion of the Future in Seville was achieved following the same principle. The façade was designed to behave in a similar way to traditional stone arches, not as precast concrete elements post-tensioned together. A certain degree of movement is permitted between the 'blocks'. These deformations activate the appropriate resisting forces in the prestressed cable system depending on the loading. Under self-weight, the prestress of the semi-circular cable is applied uniformly through the arches. However, under unsymmetric loading, 'hinges' can form between the blocks. The movement of the stone causes discontinuities in the cable beneath. This change in shape redistributes the forces applied to the stone, providing strong restoring forces underneath each hinge to oppose further movement.



5. A web billowing in the wind. Controlling the air resistance of a web is a matter of balancing the desirable feature of aerodynamic damping during an impact with the danger of a web blowing away in high winds. The spider compensates by building its web parallel or 45° \to the primary direction of the wind.

For the first time, the tools of the structural engineer are being applied to the spider web. A customized version of OASYS Dyna3D, a computer program used to understand the behaviour of structures, has been created incorporating the unusual non-linear viscoelastic properties of the silk. Analysis shows the natural occurrence of a distinct hierarchy of the structural elements of the web. This results from the large difference in prestress between the radials and spirals, and the use of wet and dry silk. The same concept appears in the design of the Pompidou Centre, Paris, as well as often in nature, where the primary, secondary, and tertiary members are well articulated.

It appears that the advantage of such a system is that it provides greater certainty in its structural behaviour under loading that is always random. It becomes clear which members are load-carrying and which stabilize, thus reducing the *range* of the loading envelope for each member, allowing a lighter, more efficient structure.

The future

Natural structures must always be considered in the context in which they have evolved. Scale and function are two important issues which must be addressed. However, the value of the ideas and insight provided by the study of natural structures into new untried systems remains undiminished. In the future, there will undoubtedly be: (1) Intelligent systems that *actively* respond to loads by the choice of appropriate geometry and materials; (2) Optimized three-dimensional structures shaped and oriented to minimize the effects of the forces of nature; (3) Buildings constructed of biomaterials that are extremely lightweight and strong. Research on the web of *Araneus diadematus* contributes to all three of these lines of development. Interestingly, spider's silk, as well as many similiar materials which have not been readily available in the past, are on their way to being biosynthesized.

The goal is understanding nature's forms and the processes she employs to arrive at her solutions — which have both architectural and structural elegance. Only then can we intelligently apply nature's concepts to human creations.

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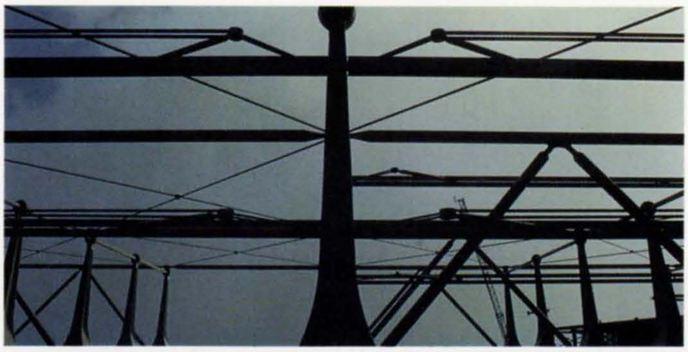
Illustrations:
1, 4, 5: Computer drawings: Lorraine Lin
2, 3: Micrographs © Fritz Vollrath
6: Renzo Piano Workshop
7: Alistair Lenczner

Applications of the web principle



6. Structural hierarchy in the Pompidou Centre (Architects: Piano and Rogers).

7. The stone arches of the Pavilion of the Future for Expo '92 in Seville, Spain. Similar to a web, the lightness of the structure is achieved by designing for deflections rather than preventing them.

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