the architecture of bridge design

Edited by David Bennett

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Foreword

Alexander Reid
Director General, RIBA

Bridges are wonderful examples of design, but a bridge is also a powerful metaphor of the design process.

Bridges are all about connection, and they are all about communication.

Design too is all about connection. Connecting the needs of the client to the constraints of time, cost and materials. Connecting present need with future need. Connecting the creative vision to the reality of construction and use.

Design is also about communication. About understanding the client need. About explaining the options. About drawings and designs which communicate intention to the construction team. And good designs communicate their logic to every passer-by.

Stuart Mustow
President, Institution of Civil Engineers

At its best, a great bridge can satisfy the need for movement and delight the eye in a fusion of utility and beauty. At its worst, it can be brutally unimaginative and a permanent irritant to the aesthetic feelings of those that use it. To the cynic, designing for beauty is expensive but to take this view is to miss the possibilities of beauty in the simplicity of good design.

This conference is to be welcomed as a way of opening up these issues.

Contents

Welcome and Introduction

Peter Hartley, Chief Executive, DHV (UK) Ltd

Why should DHV (UK) Ltd hold a bridge conference now? There are many other well established forums for discussing such matters. However, we believe that there is a need to improve the aesthetic quality of bridge design and this conference will enable the subject to be debated properly.

Traditionally, architects have had little involvement in bridges and other civil engineering projects and, we believe, do not look on these as significant potential areas of work. We are aware of the increasing interest in the visual impact of all types of civil engineering, not only those related to bridges. This interest has been expressed during many of our informal conversations with clients, such as the Highways Agency, contractors and other consultants. We therefore need to involve architects in this type of project. How do we excite an architect about a bridge?

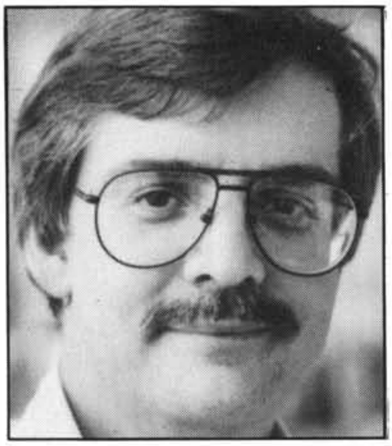
Will our clients pay more for a more attractive structure? Our approach must be cost effective; this sometimes causes problems as attention to aesthetic detail may require greater resources. Our own interests lie in improving our design and the quality of the final product, thus offering better value for money to our clients, possibly in terms of life cycle costs, and so winning more work. Understandably, our clients also seek to commission aesthetically pleasing structures, particularly as the general public is increasingly well informed and demands higher standards for any structures that impinge on the environment.

Do civil engineers have any aesthetic instinct? Traditionally this has only played a small part in their training. One important aspect of this conference is to discuss how we can improve the training of our engineers and their ability to work more closely with architects to achieve improvements in their aesthetic design of projects.

Finally, the conference is part of a process to remove the "DHV who?" question. DHV (UK) is part of the international DHV consultancy, which employs some 2,500 consultants worldwide, over 300 of whom are in the UK. The DHV Group is one of the top 20 engineering consultancies in the world.

I hope that you will find the conference both stimulating and enjoyable, and at the same time that we can all take this necessary and interesting debate a few steps further.

"Lipstick on a Gorilla"



Ken Shuttleworth

Sir Norman Foster and Partners

He is a director of Sir Norman Foster and Partners in charge of the practices work on bridge design, amongst many other challenging commissions.. He was responsible for all aspects of the design of the Hongkong and Shanghai Bank from inception to completion.

In 1994 he received an Honorary Doctorate at De Montford University. He is also a columnist for 'New Builder' magazine.

"Bridges are fantastic pieces of architecture, they have the power not only to grab the imagination and uplift the spirit, but to thrill and take your breath away.

Bridges are definitely architecture, they are not just structures. The good ones, like the Maillart bridges are engineering and architecture working in harmony. The bad ones like the Brooklyn Bridge in my view are just dead handed engineering with no architectural thinking.

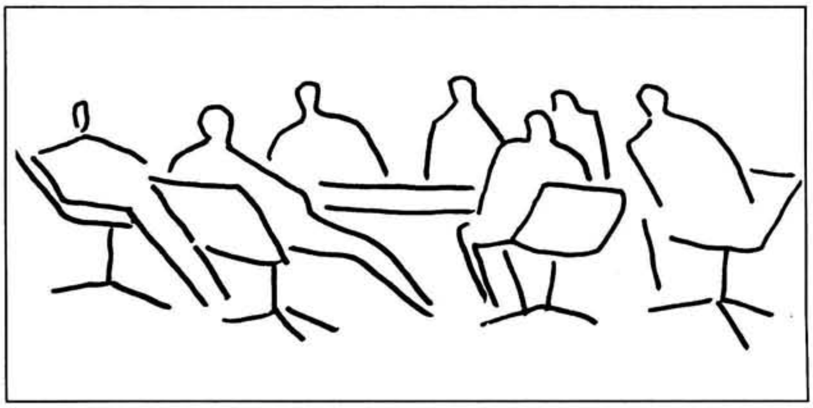
The best examples are where architects and engineers combine their talents to bring visual judgement and engineering together, to produce good bridge architecture".

On a building, even a really big building, the architect is king. On a bridge, even a really tiny bridge, the engineer is master and the architect chooses the lamp posts. Why is this? Why is there such a colossal difference in the way projects are organised? Why is it seen that there has to be a difference?

For me as an architect, the advantage of us working on the design of a bridge, is that we bring a fresh approach. We encourage new thinking, challenge preconceptions and force engineers who have been designing bridges in the same way for years, to think again. More often than not an engineer will look at a solution for a bridge within a familiar and existing framework of ideas. Our advantage is that we don't bring any preconceptions to bridge design as we haven't done any before! This is our greatest strength. We at Sir Norman Foster and Partners are able, as in all our designs, to think a problem through from first principles rather than start with the last design we did and work forward. Our training and the way we approach design means we do have the ability to start afresh on each and every project.

And yet I don't think it matters who is king. What matters is a working relationship between individuals from different disciplines who respect and trust each other. Working together where engineers and architects change hats is a joy on any project. When a creative team who really get on with each other, sit around the table, it is difficult to tell which discipline each one represents.

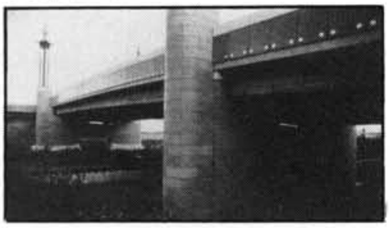
Where the ideas come from, or whose idea it was in the first place is not important. However it's critical that everyone identify's with that idea and really believe in it.



Currently the design of bridges polarizes who does what, with the engineer pulling the strings. In many cases engineers object to architects having any sort of say at all, in what a bridge should look like. That would be OK if what was produced looked really good.

However, the fact remains that many bridge designs are ugly, crude and nasty and is a concern to us all. They seem insensitive to their location and often totally out of scale. It gets even worse when decoration and motives are added on arbitrarily. This simply highlights the mistake - you can't hide or disguise a bad bridge by adding knobs to it! Its visual appearance has to be considered from the outset. Its a question of scale, proportion and rhythm. Adding fake decoration is like putting the lipstick on a gorilla.

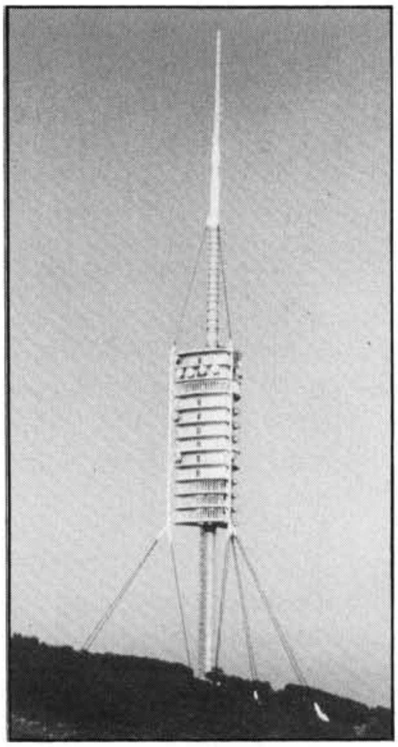
Architects' training in design, makes them constantly aware of the aesthetic implications of their design decision. Engineers tend to have little training in this aspect and therefore are not sure how to consider aesthetics in their design thinking. However, there are exceptions.



Road bridge, East London

When we designed the Barcelona Tower with Tony Fitzpatrick and Chris Wise of Arup's, we asked ourselves what is the most minimal structure? What is the least amount of material we need to build with? One suggestion was a concrete funnel because that's what was done before. Another idea was that it must be a flag pole with three cables. That idea caught the essence of the structure. The design developed from there and it didn't change much from the first sketches. The skill was in coming up with the minimalist concept and one which had the power to capture the imagination.

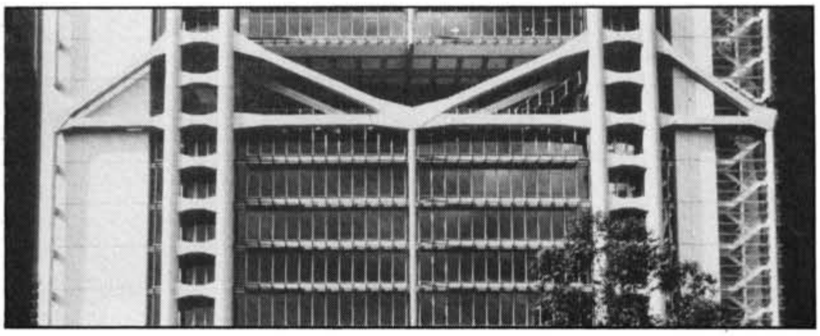
For me, being involved in bridge design is a natural evolution, and a progression of the building architecture we produce. Our buildings tend to have structural expression, which reveal the method of support and the constituent parts. We have a good understanding of structural form and a good relationship with structural engineers. For us it would be easy to evolve a working method to work with bridge engineers. On some projects we could be the lead consultants and on others they could be. It doesn't really matter who leads, what does matter is the end result. Many of our building projects are designs with bridging ideas.



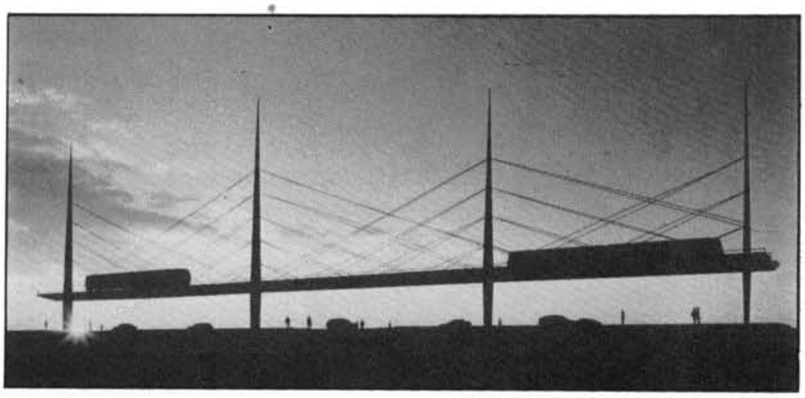
Telecommunications Tower, Barcelona 1992

The Hong Kong Bank for example is very like a bridge. It has 25,000 tons of steel - the same as the Sydney Harbour Bridge, and spans 80 metres. It may not be the simplest of structures nor the most obvious architectural solution, yet it evolved as a scheme by rigorous analysis of the building problem, the people needs and banking requirements. It was a true integration of architecture and engineering synergy.

HongkongBank Headquarters, Hong Kong 1986

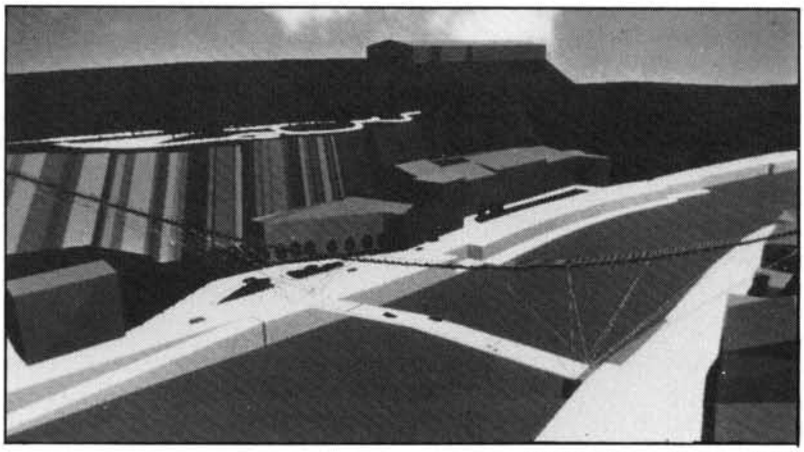


We have since progressed onto bridge projects in Rennes, Millau, Spandau, Lyon, Bordeaux, Sweden and Oresund. The method we adopt is exactly the same as we do on any other project. For each one we start from scratch with a blank sheet of paper, we structure a team of architects and engineers who really get on and brainstorm our conceptual ideas. Let me give you some examples of our work.



Viaduct, Rennes, France 1990

On Rennes Viaduct we evolved with Chris Wise of Ove Arup and Partners a system for the viaduct which touched the ground at only a few points to minimise the environmental impact. We used parallel cables to support the bridge elements from masts which tapered to a fine point and create markers in the city.

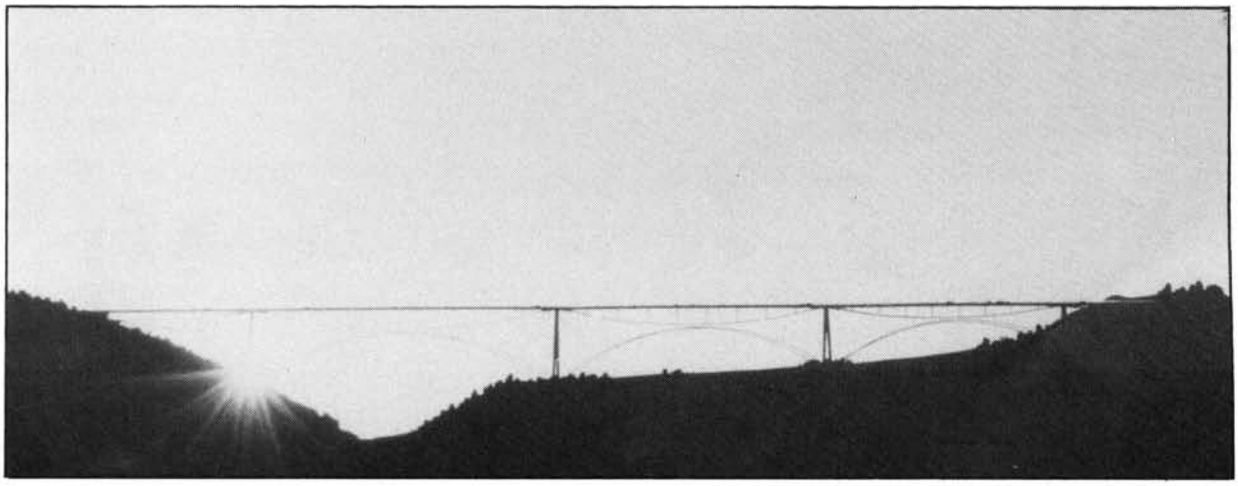


Bridge, Lyon France 1990

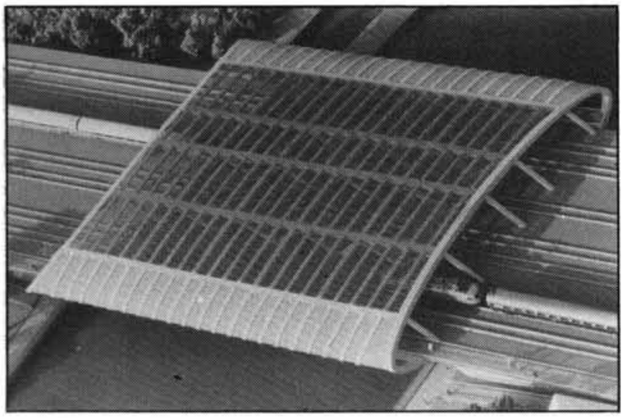
On the Lyon Bridge scheme we also evolved with Chris Wise a scheme for 2 bridges, one above the other. Our idea was the high level foot bridge should be an exciting experience. So we used the natural shape of a catenary from one cliff top tied to the next, and cables from the geometry of the road bridge below to stop it wobbling from side to side. This produced a sinuous exciting foot bridge snaking across the gorge.

On the Millau bridge the highest Road Bridge proposed in the world we evolved a scheme with Tony Fitzpatrick and Angus Low of Ove Arup's to touch the landscape in only 3 points. With equal spans 270 metres above the riverbed. The scheme used a very light net of cables which stabilised the whole bridge and provide a fine screen to see the valley through.

Bridge, Millau 1994

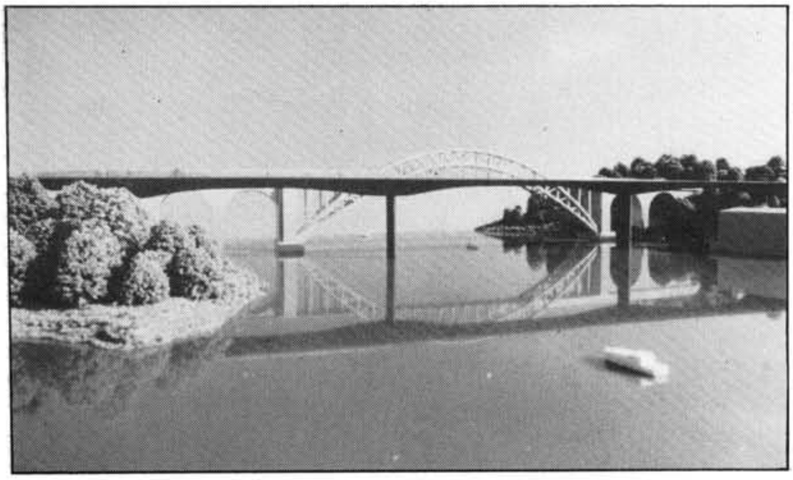


On our scheme for the Oresund Bridge we designed a scheme with Rudolph Bergerman and John Webb of Acer of twin giant arches which lean together. It provided a gateway to the Baltic.

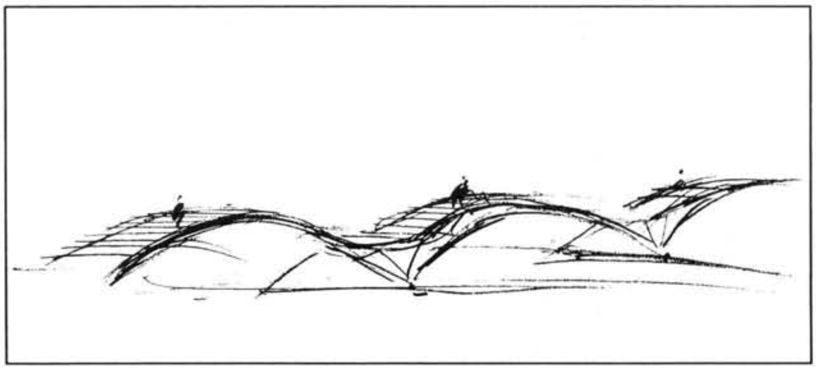


On the Spandau Bridge we evolved a scheme with Chris Wise of Ove Arup's to use the sound proofing of the railway as the structure and designed a flattened tube to span across the river. The cladding and structure became integrated.

On the Arsta Bridge in Sweden we designed a scheme with Tony Fitzpatrick and Angus Low of Ove Arup's an incredibly restrained bridge of equal 84 metres, spans with a sculptured deck profile. The scheme is minimal and elegant to defer to the existing historic bridge which has significant local importance. The bridge design is a rusty red colour to reflect Swedish Heritage.



Our proposal to link the new Tate at Bankside at the City of London over the Thames was to make the footbridge like a cliff top walk. The bridge gently undulating allowing rest stops along the way.



Who are today's Master Builders?

Jørgen Nissen

" ... have you noticed that some buildings are silent, others speak and yet others (but they are few) sing? It is neither their use nor their appearance that make some come alive or force others into silence; it is the talent of their master builder or the favours of the Muses. " (Paul Valéry: "Eupalinos, the architect")

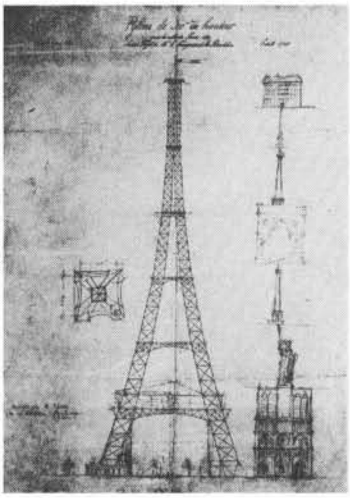
So it is also with bridges: a few sing - and may even by some be called architecture. But all bridges are engineering structures. In some countries they express it differently: bridges are *ouvrages d'art* in France, and *Kunstbauwerke* in Germany.

The talent of the master builder is now to be found amongst many 'master builders', who are separated by discipline or by function. And some are involved for only part of the whole process from inception to completion, from dream to realisation. We are now engineers or architects, or we are clients or planners or designers or builders. Whatever we are called, we all contribute to the final form of the bridge but in different ways and to different degrees.

And so it is also with other engineering structures. The form of the Eiffel Tower is based on a rational design by the brilliant Swiss engineer, Maurice Koechlin. The architect Stephen Sauvestre added the decorative arches at the bottom and other ornaments to this design. The contribution of anonymous engineers from Otis was crucial, as the success of the tower depended on the efficiency of the lifts. But we know it rightly as the Eiffel Tower; it is the accomplishment of Gustave Eiffel as *entrepreneur* - as developer, constructor and engineer.

At the time of construction, the tower was criticised by the *beaux-esprits* for its severe appearance. Later, the modernists objected to the architectural decoration because it concealed a pure engineering form. Today no one would think of changing the tower. It has become one of the best known symbols in the world; once a symbol of engineering, now of Paris.

Kylesku Bridge, Sunderland
Fitting the road to the landscape
Architect: Georg Rotne



The Eiffel Tower
Koechlin's sketch above
The final form below

What are bridges?

Bridges are structures. They should be *firm* and feel secure and built to last. For me, a good bridge expresses the essential properties of the materials from which it was built and the way it was built with honesty, clarity and free of superfluous detail.

But bridges are more than structures, they have a *function*. Most bridges are part of a larger scheme; a road, a railway, a waterway or whatever, and the way in which the bridge structures are integrated into the whole project and the environment in which it is placed, matters just as much as the form of the structure itself.

And bridges must *delight* as well as fulfill their intended function efficiently. If they are to be decorated then it should be honest decoration that supports rather than obscures the form of the structure. But the appearance cannot be separated from the engineering; it is the engineering.

Working with architects

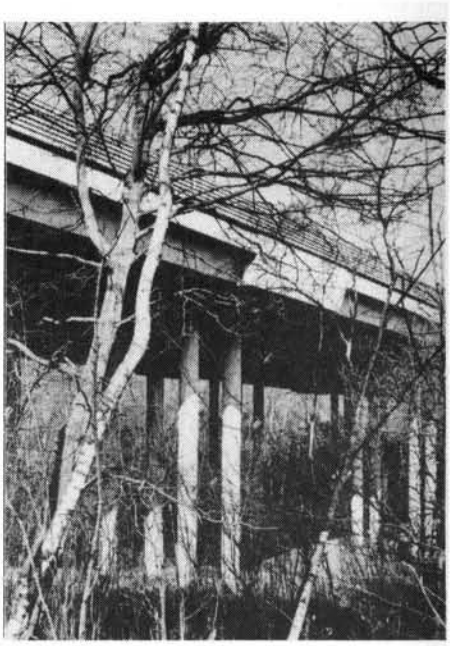
We started doing serious work on bridges in Arup some 30 years ago. We involved architects in our work from the beginning. We had by then worked with architects on buildings since Ove Arup started the practice and had learnt to understand how we, as engineers, can play a creative role in the design of buildings; and sometimes in creating architecture.

Designing buildings is only different from designing bridges in detail, but not in principle. It involves many skills and relies on teamwork. We had learnt to work in teams; to integrate contributions of many skills, and to understand that the whole project matters more than the part, even our part. And that the team must have a leader who understands the whole design process and how the industry works. For buildings the leader is usually the architect and for bridges it is the engineer.

We worked with the architects we had worked with on buildings. They were not tame architects, but architects with an interest in bridges and a commitment to bridge design.

It took time to build up our relationships. We worked alongside each other rather than remotely. We learnt from each other and to understand what we could each contribute. As we became bridge engineers they became bridge architects; some even joined our bridge group for a time.

We found that architects have a vital contribution to make, not as wilful aesthetes and beautifiers of engineering concepts but sharing in the whole design process, involved from the beginning when the first ideas come forward and throughout as the design evolves and becomes firm. And taking part not just to offer solutions but to ask questions, to challenge values, assumptions and conventional wisdom, and to give us confidence when we experimented.



Berry Lane Viaduct, M25
A forest of columns in the woods
Architect: Ulrich Plesner

Kingsgate Footbridge, Durham
Unity of structural concept and construction method
Architect: Yuzo Mikami

But bridges are engineering structures

Bridges are structures just as buildings are, but engineering considerations have a much stronger influence on bridge design. Engineering is rational and objective and some, even some engineers, believe that there is a unique solution to all problems. Everything else being equal, all engineering works would thus be identical with little variety or room for surprise. If one also believes that pure rational forms are inherently beautiful, what rôle is then left for imagination let alone for involving architects?

Everything is never equal. Design has a rational and an irrational part. Understanding is as important as knowledge. When knowledge does not suffice, the designer must use intuition and synthesis to reach a balanced design. Technology is necessary, as a help and a tool but also as an inspiration. Ove Arup put it well: "Engineering is not a science. Science studies particular events to find general laws. Engineering design makes use of these laws to solve particular problems. In this it is more closely related to art or craft; as in art, its problems are under-defined, there are many solutions, good, bad or indifferent. The art is, by a synthesis of ends and means, to arrive at a good solution. This is a creative activity, involving imagination, intuition and deliberate choice.".

As engineers, we do in fact have plenty of space to adopt individual positions; not as formal stylists but in choosing an attitude to our craft.

The wider team

Bridges are not designed in isolation, they are designed as part of an industrial process with many different players from concept to construction, including a few authors: clients, planners, designers, contractors.

While designers are clearly central to the design, both clients and constructors influence what the designer does and particularly what he can do.

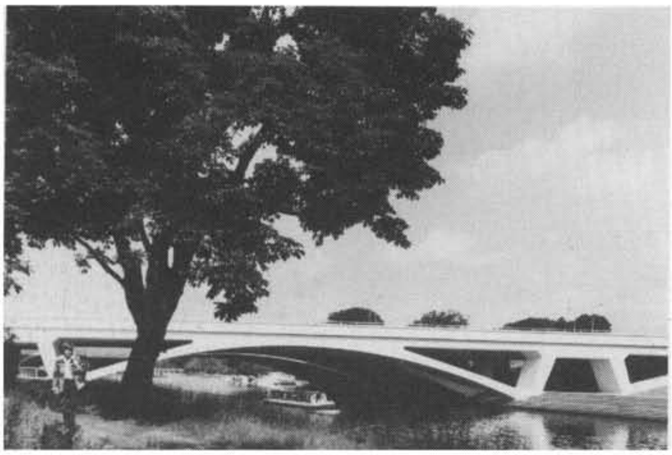
Our clients are our patrons. They are often public bodies and therefore decide why a bridge is built and increasingly they have a say on how; by setting the design criteria, the procedures and the processes that are to be followed. Clients can have an important influence on whether the right balance is achieved between firmness, utility, delight and cost. Their aesthetic feelings can be a secret determining factor on decisions apparently dictated solely by questions of cost and efficiency.

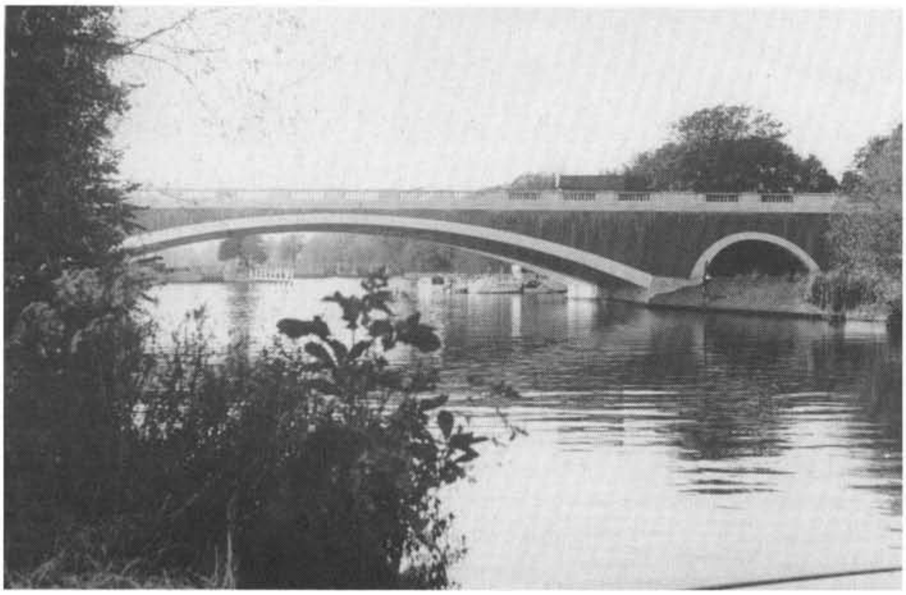
But not always. Even some of Robert Maillart's clients thought his bridges hideous. "I am sick of these pastry-work bridges" was the way the leader of one local body expressed his views. But they were built across remote Alpine valleys, where they were cheaper to build than other types and comparatively few people would see them anyway!

Construction is crucial. The way a bridge is to be built must be considered at the design stage and has usually a fundamental influence on the design. Construction technology contributes to the vocabulary of forms that designers can use, and bridge designers need to understand the process of fabrication, construction and erection. In design and construct contracts, designers and constructors work alongside each other. Many fine bridges have been designed by such teams.

We need to explore and innovate to continue to produce good bridges, and not be too inhibited by precedents. The construction industry has an enormous investment in the status quo and can often use good arguments to resist new methods. Contractors must be given opportunity to develop new methods of construction. This implies taking risks. They can best do so if they are able to plan ahead with confidence. German and French contractors developed important new construction techniques in the 60's working to long term programs set by their Government.

Runnymede Bridge, M25
Twinning Sir Edward Lutyens' bridge
Architect: Sir Philip Dowson





The industry

The civil engineering industry is mostly concerned with public works, which are often commissioned by engineers, mostly designed by engineers and always built by engineers. The industry would seem to be led - some would say dominated - by engineers and perhaps somewhat divorced from its ultimate customers, the public: users and observers. We run the risk of becoming inward looking - because we have nowhere else to look. We do of course need to respond adequately to the demands for better quality and amenity that our post industrial society is not able to communicate to our industry adequately.

I worked once in a team with an architect, a landscape architect and a sculptor on a competition entry. The brief was "to demonstrate a collaboration between architects and artists on a project for the built environment". The sculptor said at the outset: "You are professionals, you know how to design and how to build. Don't look on me only as an artist. I am also a professional. My profession is to bring humanity into the built environment. I am a professional human being."

It was enjoyable and interesting, and they gave us a prize. We worked not only to a "client's" brief, but we felt that we worked in a more direct and focused way to the public; - to society.

"....it is the talent of their master builder or the favours of the Muses...."

Today's master builder is a team of 'master builders'. Many talents are brought together on any but the simplest projects. For a good and strong design to emerge, the team must include not only good designers but also creative and sensitive managers. Teams are only successful when the members of the team have respect and understanding for what the others do. Barriers between disciplines can be broken down by team members working alongside each other, rather than remotely.

Second Severn Bridge
A construction strategy as the design strategy.
Architect: Georg Rotne

The Øresund Link between Denmark and Sweden
Tying it together
Architect: Georg Rotne

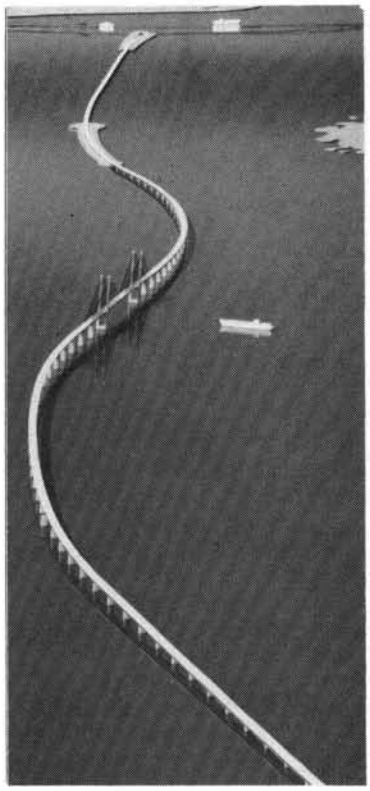
A bridge project usually takes long to complete. The design takes form early in the process and it is important that it survives the later stages. Designers need to be involved throughout. Designing is sometimes about taking risks and clients and contractors should be equally committed to the design for the project to succeed.

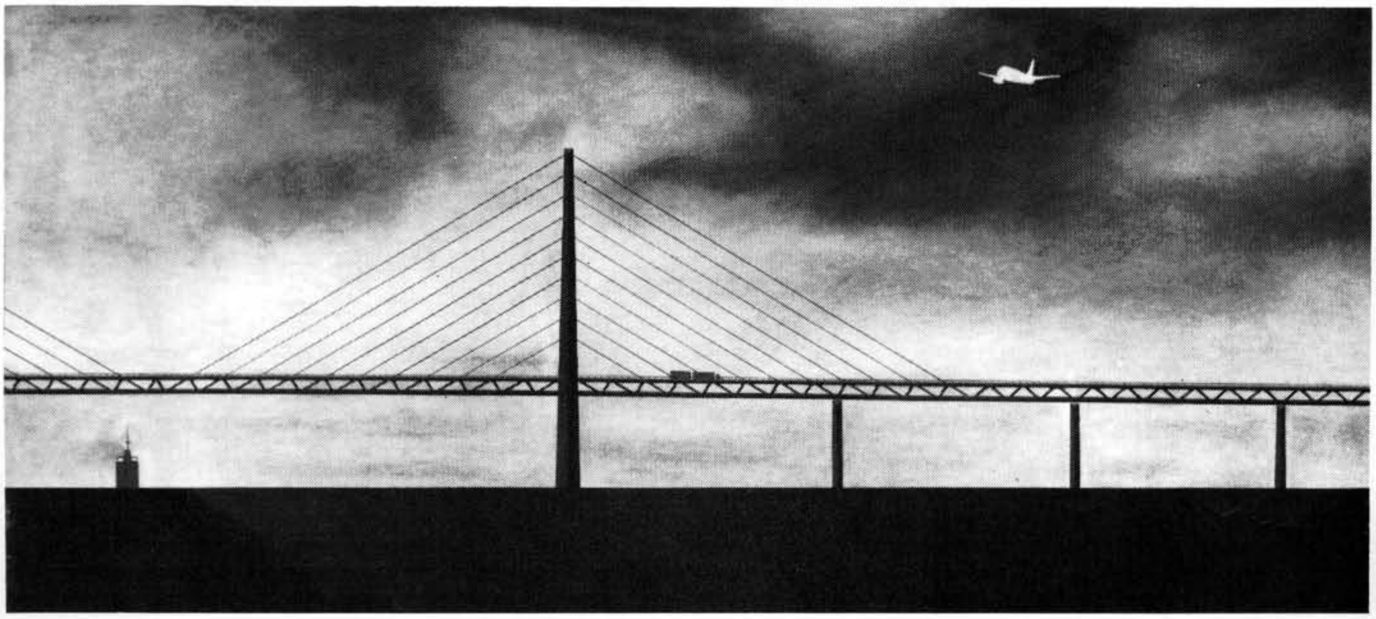
The process should be designed to encourage an open relationship between all parties, but some relationships become contractual eventually, with lines drawn between client or designer or constructor. Traditionally designers provide continuity on projects, first as the client's advisor and later as his agent. But they are somewhat remote from construction. In design and construct contracts, some designers work closely with the constructors, whilst others advise the client. But the continuity has been broken and there is a danger that the overall design responsibility will be divided. There is no simple answer, the right process will depend on the circumstances of individual projects.

Whatever the process, everybody involved in it needs to be committed. We get well designed bridges only if all the parties want it:

"It may be that a more skilful and humane use of engineering depends on a more knowledgeable response to its poetry." (Arthur Drexler on "Twentieth Century Engineering" at MOMA).

Jørgen Nissen is a civil engineer He is a graduate (in Civil Engineering) of the Technical University of Copenhagen - where he was taught that all real problems have a rational solution, and (in Economics) of University of London - where he was taught that problems are more interesting than their solution, and that the answers can easily be found "at the engineering level". He has been involved in engineering design, particularly of bridges, for 30 years. He joined Ove Arup & Partners in 1962, was made a director in 1977 and has been on the main board of the Partnership since 1984.





WHO SHOULD DESIGN A BRIDGE?

WJR Smyth
BA BAI FICE FIStructE

Consultant
Ove Arup and Partners

Engineer

When I was about sixteen I was much struck by a photograph of Maillart's Val Tschiel Bridge in J.M. Richards' *Introduction to Modern Architecture,* and this played a large part in my decision to study engineering at university.

At the time when I saw the picture I knew nothing of structures, it was the appearance of the bridge which attracted me. When I had already been in a design office for a year or so, I bought a copy of Max Bill's book *Robert Maillart,* containing a photograph of the Salginatobel Bridge which made an even stronger impression. When I saw that picture I did have some knowledge of structure and my reaction to the bridge was more complex, but it was still largely based on the fact that I immediately responded to its appearance. The reactions of most people to bridges, at any rate those who are not engineers, are also largely based on appearance. Most bridge engineers also pay at least lip service to it. So why are they not prepared to take more trouble to produce bridges which look good as well as doing all the other things which bridges are supposed to do?

As far as we know Maillart designed his bridges without the help of an architect, and Billington, who is owed a debt of gratitude for all the information he has unearthed and published about Maillart, has used this to argue that it is not necessary to have architects involved in bridge design. He has used selected works of Maillart and Eiffel and a few others to create a new category which he calls *Structural Art*, by which he means beautiful structures designed by engineers. I do not see this as a particularly useful category. The fact that there have been some engineers who have designed attractive bridges without the help of an architect does not mean that all engineers are capable of so doing, as one only has to look around to see.

Of course one can also see by looking around, that the number of architects who can design attractive buildings is limited. There are also some bridges where an architect has played the major role in design, and these are not always satisfactory either.

There are (at least) two ways in which not to design a bridge. The pitfall which architects fall into is to decide on the appearance before they know enough about all the other factors which are important. The engineers' pitfall is to design the bridge taking just all those other factors into account and assuming that the appearance will take care of itself. If you set off firmly down the wrong path you may never get back

Salginatobel Bridge
Completed 1930
Designed by Robert Maillart and built by Prader & Cie. A.G. for the Canton of Graubünden, Switzerland
Since this old photograph was taken the trees have grown up around the bridge and it can no longer be seen as a whole, except in close oblique views

to the right one, so we need a point of view which takes all the factors into account right from the start.

A bridge is one thing and all its qualities are inherent in it. Engineers are trained in analysis, and some of them seem to confuse analysis with design, but design is something very different and analysis is only one tool (although a very important one) on the way to achieving a satisfactory design. Architects mostly have a much better training in design but do not normally have the necessary technical background or understanding to design bridges. Engineers and architects who have an understanding of bridges and are able to work well together can make very powerful teams for designing them.

Any substantial modern construction is designed by a team. There may be individuals who provide leadership or inspiration and there may be individuals who take the credit (not necessarily the same ones), but the design is almost always the work of a team. In the case of a building, the people who take the lead are most often architects, because sorting out the brief and planning the building and integrating the work of the other designers fall most naturally into their field, and they should have the best overview of the whole. In the case of a bridge the lead will generally fall to the structural engineers for similar reasons. There may be special situations where an engineer may take the lead on a building, or an architect on a bridge; this must depend on the particular circumstances, and these are exceptional cases.

During the first part of my career I enjoyed working with architects on buildings, and as a designer of bridges in the last nearly thirty years I have tried to work with architects whenever possible. It takes time to learn to work together and it also takes time to understand the nature of bridges, but there are great advantages in having a team which contains people who look at things from different angles and bring fresh and unconventional ideas, or just ask awkward questions. It helps to avoid getting hidebound, people learn from each other and, in a team which is working well, it is often impossible to say who thought of particular ideas, because they emerge from the to and fro of discussion. Where it is possible to say, the idea doesn't always come from the quarter you might expect.

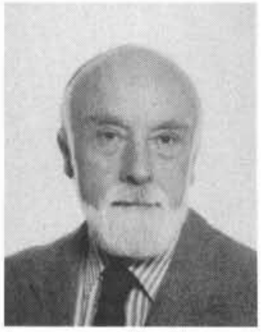
Engineers and architects also learn from each other. I know more about why things look good than I did when I started. Some of this is due to looking at bridges and other structures, some from thinking about particular problems, and a great deal from working alongside architects.

When I first saw the picture of the Salginatobel Bridge I didn't try to analyse why I liked it, I just knew that I did. Now I can make some sort of rationalisation for my feelings:

- *The way it fits its site* — the arch springing across the steep sided gorge and the approach viaduct on the shallower slope at one side.
- *Its unity* — the consistency of character and the way in which the structure of the approach viaduct carries on across the arch, so that it is not possible to experience the bridge except as one thing, *approach viaduct* and *arch over gorge* are words used for analytical purposes, but the bridge is a unity.
- *The shadow line* under the cantilever of the deck, which stops either side of the hinge at the crown, because the cantilevers of the deck and from the bottom of the arch are connected by a thickening around the hinge.
- *The detail* — for example there are semicircular holes in the parapet whose purpose is to act as scuppers, draining water from the deck; however there are more of them than are functionally necessary, and they provide a visual rhythm to the edge of the bridge, when seen from nearby.

There are other things which are not immediately obvious, but which add to the pleasure of looking at the bridge when they are known. The bridge was designed to be built on the lightest possible falsework. The flange at the bottom of the arch was built first and then worked in conjunction with the timber falsework to support the rest of the arch while it was being built. This is typical of Maillart's attention to construction.

The quality of the bridge arises from the fact that it is a highly tuned engineering construction designed by a sensitive designer, who was also an intelligent and intuitive engineer, and responsive to its site in both technical and aesthetic senses. The design emerges from the site, as do those of most, maybe all, good bridges.



After graduating from Dublin University, Bill Smyth worked for Ove Arup and Partners from 1948-1950, and also from 1959-1991. In 1965 he became the first head of Arups' highways and bridges department, and worked in the field of bridge design until his retirement. He has written the draft of an advice note on the appearance of bridges for the Department of Transport.

Bill Smyth

The Art of Engineering

Robert Benaim, Bridge Engineer

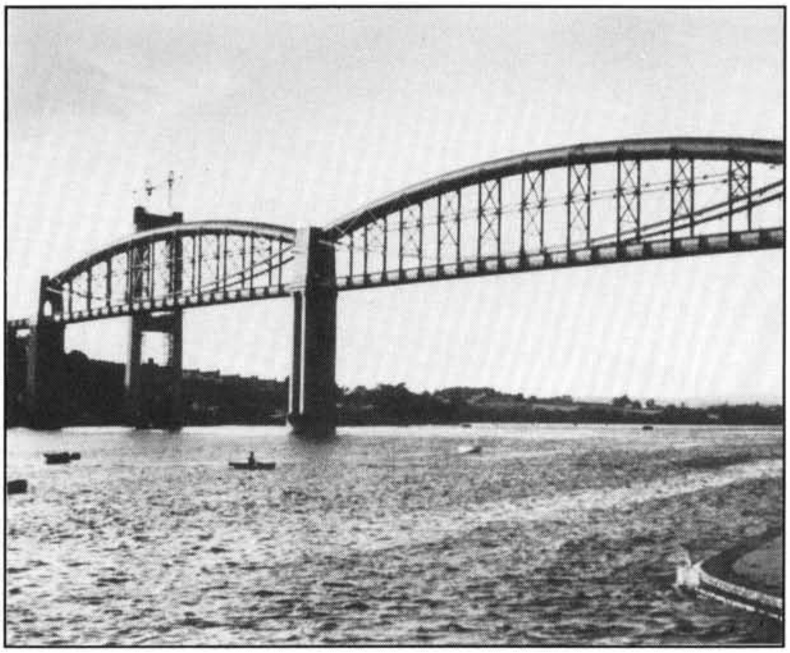
"I believe that all structures must be buildable, economical in materials, and that even the most mundane engineering structure is capable of an elegant solution".

Having spent six years in France as a Senior Engineer for STUP/Europe Etudes and eleven years at Ove Arup & Partners as Senior Engineer and subsequently Project Director, he has applied these principles to form his own Award Winning Practice, Robert Benaim & Associates, set up in 1980.

Whether in town or in the country we are surrounded by civil engineering structures. The majority are relatively small scale, with a lesser number of medium sized viaducts and river crossings. Unfortunately, many of them have been inadequately designed and detailed. As a result, their appearance is sometimes inelegant and they are weathering badly. Frequently this poor appearance is linked to deficient engineering design, and some of these structures are requiring excessive amounts of maintenance and repair.

However, in recent years the standard of aesthetic design of these smaller structures has improved. It is probable that a significant number of designs do now benefit from some architectural advice.

There are relatively few major bridges in this country. They are potentially the showpieces of our industry, and we expect of them the highest standards of design. Whereas some are superb, others represent lost opportunities.



River Tamar Bridge :
I K Brunel 1853
(R.B. Vickery : AA)

The industry is currently debating what should be done to improve the appearance of bridges. It has even been questioned whether civil engineering structures should remain under the control of engineers, or whether an architect should be the lead designer.

Economy of Structure

It is not obvious that architects' training equips them for bridge design. Most architects are probably unaware of the different quality of engineering which a bridge requires as compared with a building. The importance of construction engineering, the design problems associated with exposure to the elements, the issues of articulation, durability, maintenance and access for inspection make the design of a bridge quite different to that of a building. Also, the economy of the structure, which is relatively unimportant in a building, is paramount in a bridge. Thus the design debate between the architect and the other professional disciplines which determines the final appearance of a building is quite different for a civil engineering structure.

Buildings are designed for a relatively short life during which they may well be reclad or otherwise changed in appearance. It is quite normal that they should reflect changing fashions in style.

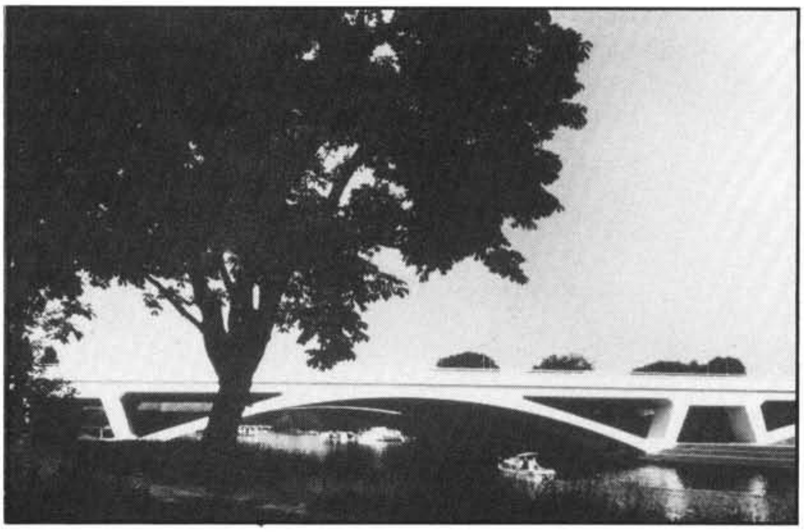
Bridges are designed once and for all. Not only will they be with us for many decades, they will outlast any current architectural fashions. If well designed, they represent the current state of technology, and are continually evolving as our understanding of structural action and materials progresses.

Aesthetic Eye

Small urban structures usually have little scope for expressing design and require certain civic qualities. Their scale, finish, detailing of street furniture and control of rainwater run-off, are most important.

Engineers are not currently trained to consider these civic aspects and the design of small structures would almost certainly be improved if suitable architects or architectural technicians were used as advisors as a matter of course.

However, engineers must remain in charge if we are not to see structures which havelost their engineering logic, and



Runnymede Bridge
(R. Benaim)
Ove Arup & Partners 1978

have not gained any genuine architectural merit.

On larger bridges, there is much more opportunity to express the way in which the structure works. These bridges provide the greatest challenges to the skill, knowledge and experience of engineers.

The art of engineering depends on a deep and intuitive understanding of the way in which forces flow, of the engineering properties of materials. The quality of this art depends on a readiness of the engineer to consider every project from first principles, to continually re-visit his design, to fully understand the way in which each element of the structure works, to remove all superfluous material, to strip away all elements of fashion and cliche and to understand in detail how the structure is to be built. Ideally he would define all the methods of construction and even design the falsework himself.

This knowledge, and this effort of research and refinement does not automatically lead to a structure which expresses the engineer's understanding and insight. Such expressiveness requires a further quality of aesthetic judgement. It is only when technical excellence and courage to revise combines with aesthetic judgement that one obtains a truly outstanding engineering structure.

The role of the architect should be to assist the designer to consider points of view with which he may not be familiar. He may also challenge the engineer to justify his preconceptions, and prompt him to research problems from first principles, if he has not already done so. Such a modest and restrained contribution can be very creative.

No Quick Fix

For decades, our civil engineers have not been required to perform. The quality of their designs, both technically and aesthetically, have not been challenged, and have not been major factors in their appointment. As a result, bridge design, which should be the pinnacle of engineering excellence, has had difficulty in attracting and retaining the brightest and most creative talent.

Competition of engineering ideas should be reintroduced into the commissioning and tendering process. This may be done by holding design competitions for engineers, by encouraging alternative designs, by re-visiting designs once they have been let and by encouraging design and build contracts.

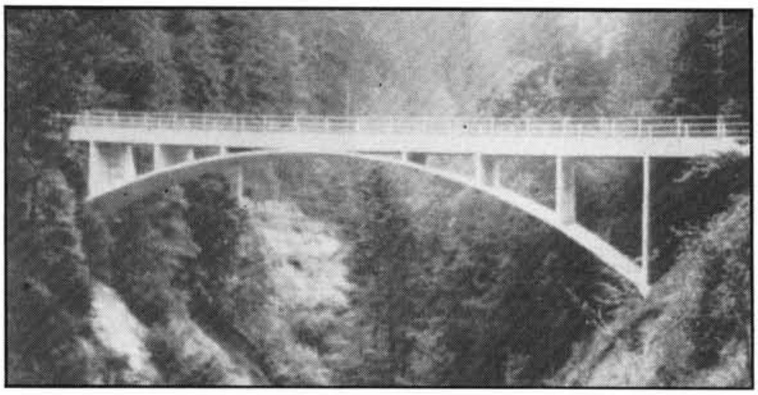
If extra money is to be allocated to improve the appearance of bridges, the greater part should be allocated to the substitution by the engineer of expressive structural forms for cheaper, inexpressive forms, rather than spending it on elaborate finishes, or on non-structural decoration. Does anyone look at Maillart's parapets?

Engineering students who intend to become designers should have architectural training. This would make them aware of the civic and architectural dimensions of their work and prepare them for discussions with architects and planners. For the most talented, it will also give them confidence in their aesthetic judgements and give a new strand to their development as designers.

Central and Local Government need to see themselves as patrons of engineering art. They need to make it clear that they require designs of high engineering and artistic quality, and that this matters in their appointment of engineers.

However, the essence of any changes must be to improve the quality of the engineering. The improvement in appearance will follow.

Quick fixes, such as putting architects in charge of the design of civil engineering structures, will only further diminish the engineering profession, and lead to a deterioration of standards rather than the improvement sought.



Schwandbachbrucke :
(R. Maillart 1933)
(Samuely Collection :
Architectural Association)

PROFILE

Alain Spielmann

Bridge Architect

by David Bennett

Influences

He is the first to acknowledge the considerable debt he owes to the many outstanding bridge engineers he has worked with and learnt from. He confesses to taking inspiration from great bridges of the past, particularly those designed* by Eiffel, by Maillart, by Freysinnet and from contemporary designs by Fritz Leonhardt, by Auguste Arsac, by Christian Menn, Jean Muller and Nicholas Esquillan, to name but a few.

His spiritual influences include the words of Loos and Jorn, the works of Mancoba, Verlov and the COBRA Group.

He is a dyed in the wool Renaissance man with minimalist tendencies, who believes in the Classical order of scale and proportion, with a modernist eye for colour and texture.

Background

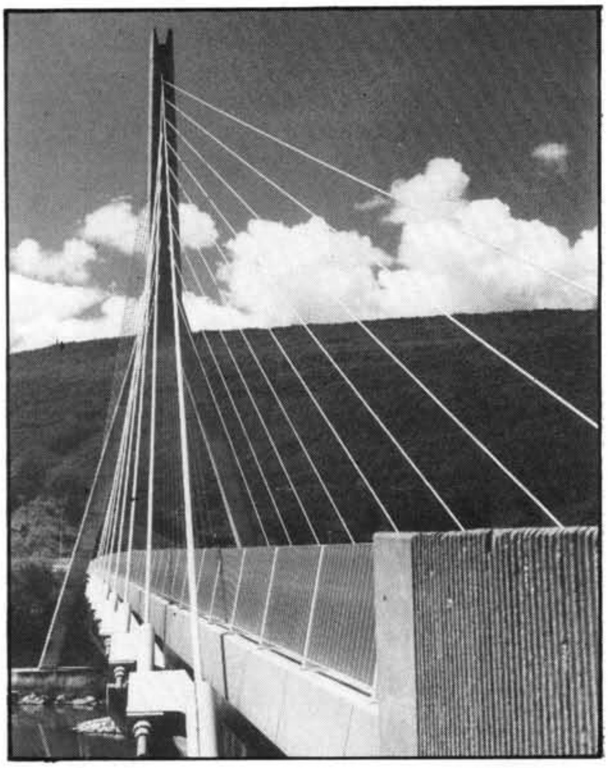
Worked for Bandini Architects for 10 years. Designed and supervised construction of offices, houses, and hospitals for many years, but was the only architect in the practice who took on all the bridge work.

After experiencing the work of Nicholas Esquillan for the Abidjan Bridge, his interest in bridges became an obsession. In 1977 he set up on his own as Alain Spielmann, Architect. His first bridge under his own name, was the Roquebilliers Viaduct in Cahors, which he won in competition.

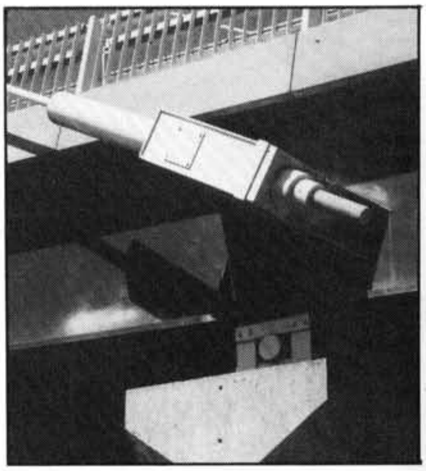
He has since designed over 60 bridges, mainly in France, and entered designs for more than 100 competitions. He has used a wide variety of bridge structures to express his architectural style. From cable stayed, to steel arch, to concrete segmental arch, to bow string, to box girder to suspension bridges. It is an eclectic choice, but then we are dealing with a rare talent .

He has won numerous national awards for his bridge designs.

"The Architecture of Bridge Design"



"The imagery and conceptual possibilities of a bridge fascinate me more than any other structural form. The architecture of the design can't be tackled by rigorous calculation or Newtonian principles alone. We must also draw from conceptual experience, from the location of a bridge to order the design process."



Is it by chance that so often the technical side of bridge construction is preceded by a lengthy introduction on the aesthetics of the design?

It is generally true, in my experience, that if the functional and technical side of the bridge design dominates the end result, it is not easy to design with aesthetics in mind. The two approaches to design are not identical.

Mindful of the limitations and shortcomings of pure, utilitarian design - which suggests that one type of bridge construction has one precise function and one basic form - I see the vocabulary of bridges offering a broad range of forms, rich in unexplored possibilities.

But how do we make our choice? How do we adapt the structure to its site and environment? What are the parameters to guide us to the right options?

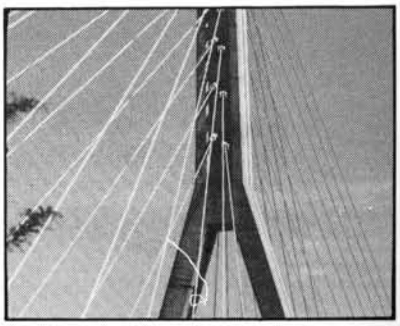
Making the right decision is a combination of economy in construction technique, bridge aesthetics and the material choice - a choice which will stand the test of time.

Seysell

I discovered to my happy surprise that architect and engineer collaboration can lead to pleasing results. A certain elegance was achieved with this humble bridge, particularly the choice of paint colours to highlight the geometry of the cable fan, the depth of bridge deck and handrailing.

Seysell was important to me in the early development of my cable stayed bridge designs. It was the prototype for the Isere and Pas Du Lac bridge concepts, some years later.

A bridge has a great capacity to astonish and to surprise. Like walking into a cathedral, a bridge makes an immediate and lasting impression. That first effect of wonder and awe furnishes a complex impression on the onlooker of aesthetic pleasure, intellectual curiosity of the design and a sense of well being in the stability of the construction.



A bridge is a path to cross, by foot, by car, by rail, by sail.

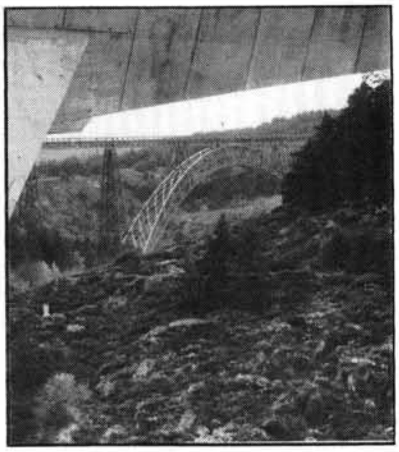
It is also a statement of an age, of man's achievement of how we have progressed in overcoming obstacles. A bridge therefore has more than one purpose. It plays a role in our environment which must be taken into account, today even more than before, if we want to create good design.

Celebrated bridges like the Pont Neuf, Rialto Bridge, Ponte Vecchio with their niches, cornices, shops and secret passage ways are multi-functional and inspire joy and pleasure to all who see and use them.

Good bridge design can tickle the imagination! Look at the Bridges of Paris, at Garabit, at Tolbaic, at Valentre. These bridges and many others are the source of popular stories, myths and legends about a by-gone age that has become "inseparable" from the structures themselves.

At Valentre was there any truth in the legend of the Cahors devil? Why did the architect design a marquette of the Cahors devil and place it high up on the Tower? Was it there to ward off evil spirits, lurking on the bridge?

Accentuating the different parts of an old bridge, using colour, can be a useful aesthetic. Vezinnes Dannemoine bridge dates from the

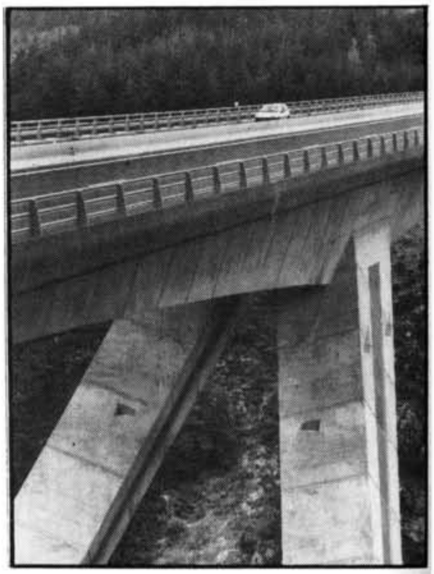


A75 Clermond - Ferrand Viaduct at Garabit

The pier supports for the glued segmental arches of Garabit are tapered and splayed, to present intersection parallels with the 144m, main span. The modelling and rendering of the pier legs were sculptured to create the drama and tension of a ski jumper, just before lift off.

I put some battens in snow, and studied the interplay between the angle and split of the pier legs and its relationship to the length and curve of the span, to help achieve good visual harmony.

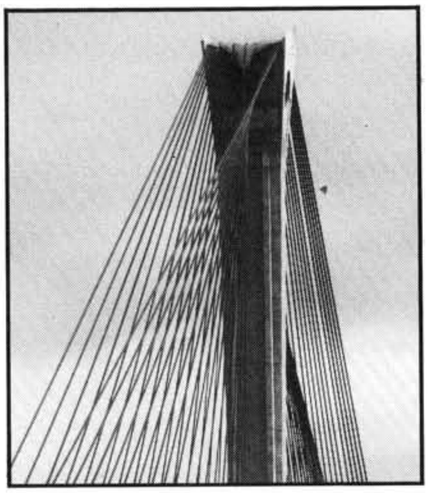
There are also flutes formed on the outside of the uprights to lighten the appearance. Green slates were cast on to the outside faces, to contrast with the grey, "as struck" finish of the concrete .



end of the 19th century. We repaired the existing brick arches and added a decorated lattice frame work to widen the roadway.

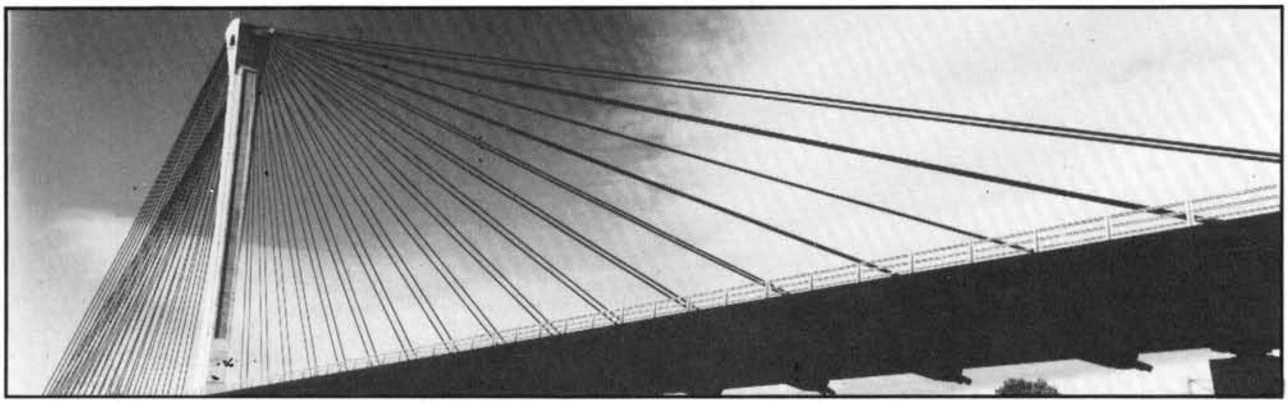
Some older bridges, handled carefully, have a certain irreplaceable charm. As bridge designers we must get to know them, to appreciate them and to restore them with passion.

The mystique of a bridge can't be stuck on as an afterthought, it has to be an integral and discrete part of the design - its lifeblood.



To span the breach is the operating function of the bridge. To reveal the site is the aesthetic objective of the design.

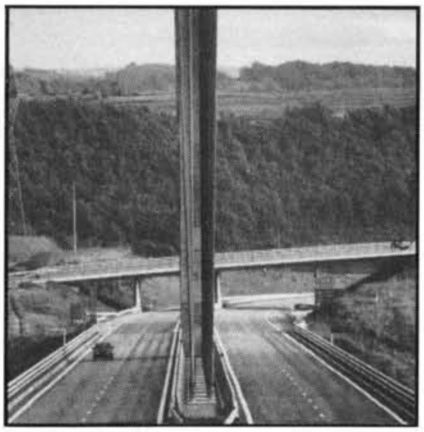
A bridge is judged by its "lines", by the symmetry of its shape, by the proportions of its span and piers and the feeling of "lightness". A building is judged by the "mass impressions" of its different volumes, proportions, section sizes, openings, storey height, walls and windows .

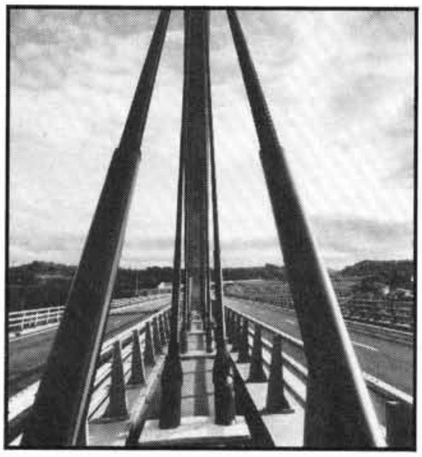


Pont Isere, at Romans

For both the Isere and Seysell Bridge I have been inspired by Jean Muller's Severin Bridge, and translated and transposed those principles in my early design ideas. As I grew more certain in design, striving closer to the minimalist statement, I modelled Isere's single pylon just like a tulip in bud, widening the top to ease the cable pathways.

The underbelly of the bridge deck was curved, the leading edges profiled in black channel sections, to create the sleek aerofoil lines I wanted, to give the appearance of the wing of an aircraft.





Bridge architecture is not building architecture, it is as different as painting with watercolours, to painting in oils.

Not everything in the mind of design can be explained rationally. It is healthy that some part of inner experience and intuitive understanding is left to hypothesise and for individual discovery. Nothing can be worse than to shut off further possibilities, lock the present to the future, with inflexible rules on bridge aesthetics.

A design is not there to seduce or fascinate egotistically, it must seek the truth in the aesthetic of design and to capture the heart of its intrinsic beauty .

These thoughts take their meaning from the many bridge structures that I have built and I have seen. They are the result of inspiration, crossed by a thought, that is then imprinted on a structure .

Le Pasarelle Du Pas Du Lac

It was more than a question of bridging a collection of rail tracks over the SNCF station at Pas Du Lac, or spanning a major dual carriageway, the NI0 and the Avenue des Pres. It was also the link between the commercial centre of the town to the residential quarter of Pas Du Lac, on the other side.

The span length of 187m and clutter of the rail tracks below, made a cable stayed footbridge, the most practical option. The pad foundations for the central cable mast were installed in the spaces between pairs of tracks. Those for the road way supports, micropiled in the hard shoulder, between the N10 and station car park.

The 2.5m pedestrian walkway is sheeted in steel plate overlaid by a carpet of red impregnated resin felt. The metal sheeting is supported on a framework of parallel beams and transverse secondary beams. By night, the walkway is flooded by the light of neatly arranged lighting standards, running the full length of the structure. The brightness and shadows on the walkway, give the illusion of an alley way.

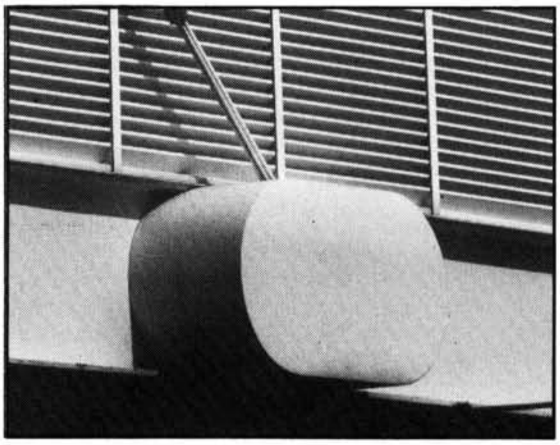
A feature of the bridge is the high sided, white slatted panels each side of the walkway and the eye catching smoothness of the cable housing, running along the outside of the bridge deck. The high sided panels provide shelter for pedestrians from the strong winds that funnel along the open rail tracks.

How can we begin to reconcile the full weight of mere words like the tension of lines - multi-functional bridges - beauty rediscovered - to inspire great design?

For me it is not a question of simplicity in design to achieve lightness, but looking for that purity, that essence and that tempo of the structure, to enrich a concept in its own light.

Looking is learning and seeing is believing.

It brings together complementary elements which speak to the eye and touches the spirit of the observer.



THE AESTHETICS OF BRIDGE DESIGN

Fritz Leonhardt and Holger S. Svensson

Prof.Dr.Ing. Fritz Leonhardt
Founding partner of Leonhardt, Andrä and Partners, one of the leading bridge design consultants in the world. He pioneered work on many steel beam and cable stayed bridges.
As well as a distinguished career as a bridge designer, he has lectured widely and publishes extensively. He is the author of the most celebrated book on bridge aesthetics, "Bridges"
He has received many honours and decorations from several countries, including an honorary doctorate from the University of Bath, and the Gold Medal of The Institution of Structural Engineers in London.

Holger S. Svensson
P.E., P.Eng., CEng MICE, MHKIE
Managing Director of Leonhardt, Andrä and Partners, he has specialized in all aspects of bridge design and construction, all over the world. He is particularly experienced in the design of cable stayed bridges.

"The design of good looking bridges does not happen by chance, nor does it exclusively depend on some elusive "feel" which is only given to a chosen few.

Constant conscious examination of existing bridges to find out why they are beautiful or ugly educates aesthetical awareness. Aesthetic guide-lines can help to find a good shape or to check the shaping of bridges.

Important aesthetic criteria are: clear structural statements, good proportions, order, compatibility with the surroundings including colouring, and, above all, simplicity."

There are good looking bridges which contribute favourably to the appearance of a city or a landscape, which are admired by many people. *(Fig.1)*

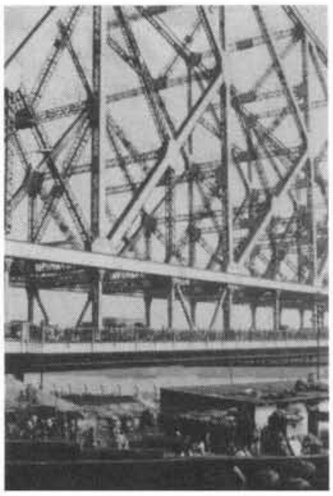


Fig.2: Howrah Bridge, Calcutta
"An ugly bridge, a confused structure of brutal scale"

There are ugly bridges which disturb the environment, which many people wish had never been built or could be demolished. *(Fig.2)*

Why is one bridge beautiful and another one ugly? Many people argue that one cannot agree about taste and that beauty is in the eye of the beholder. This is a superficial answer. It is an answer from people who have never given thorough understanding to aesthetics.

It is a fact that the majority of people will judge one particular building in a group to be beautiful and another one

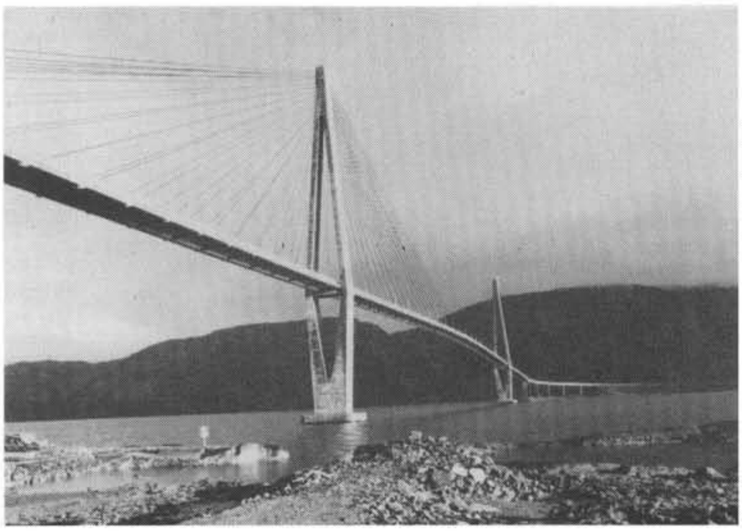


Fig.1: Helgeland Bridge, Norway "A good looking bridge"

to be ugly. Buildings or other familiar objects have, therefore, aesthetic values which have a common effect on man. The impact of this effect or aesthetic value depends on the sensitivity and sensibility of the individual.

Fig.3: Kaisersteg, Berlin
"A mixture of different systems leads to difficulty for good shaping"

Perceiving Beauty

Aesthetic values can be perceived consciously or act in the subconscious field. The competence of judging aesthetics, which we call taste, develops only by repeated evaluation, weighing of consciously perceived values, and by training in visual appreciation. Therefore, taste requires self-learning and self-education.

The formation of taste or the competence of judging aesthetic values has been severely neglected in our materialistic age, with the result that much ugliness has been built which now begins to disturb us. This is especially true for many big cities with their slum areas and their modern mass housing quarters with monotonous tall buildings in the sad grey colour of concrete. People living in such areas, cut off from nature, become sick. It is not so much physical sickness but starvation of their soul causing all kinds of psychic disease. Some get frustrated and withdraw in depressive resignation, others become aggressive or even turn to crime. Many famous sociologists and behaviourists have stated the fact that ugly living quarters and an ugly city environment are a hot-bed for crime.

Protests arose against the ugliness of many modern city quarters, against some products of modern architecture especially against the style which is called 'brutalism'. But protest turned also against the growing destruction of our environment by traffic facilities, highways, freeways with their grade separation structures, and traffic noise. Large groups of citizens joined in such protests. In Germany, we even got a new political party - die Grünen - (the Green) who mainly aim at the protection and improvement of environmental qualities.

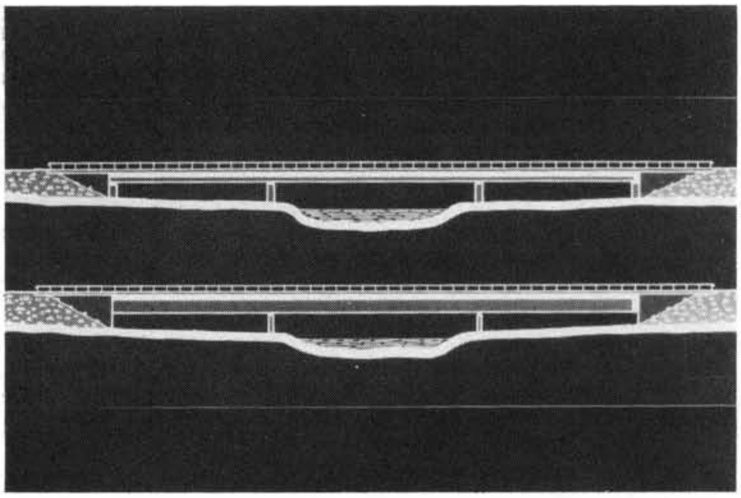


Fig.4: Three span beam
a: slender beam on strong piers - good
b: deep beam on narrow piers - bad

Lack of Education

If we trace the causes for such negative results then we must admit a lack of education in those fields which affect the psychological health of human beings. It is mainly a lack of education in aesthetics and ethics which belong closely together. But architects and engineers are not the only professions which are responsible. Almost the whole of society, especially the owner builders, the clients and cost consultants are culpable. It is the materialistic orientation of our motives this century which has made the tender flower of beauty thirst to death and rendered unable to recognize and appreciate values of aesthetic qualities.

Lack of education can only be overcome by educational efforts. However it may take a long time to change from bad design, to good design practice. Our hope is that we become aware of the necessity of such education. That is a good starting point.

Bridges belong to the built environment. If we recognize the value and the importance of aesthetic qualities of the built environment, then it is necessary to make every effort to design bridges resulting in a pleasing appearance.

Aesthetic Guide-lines

In order to reach this goal, one must first analyse why one bridge is considered to be beautiful and the other one to be ugly. If we ask this question, then we find guide-lines which are not only valid for bridges but also for buildings of all types, of which the beauty is generally acknowledged, independently of cultural differences. We shall try to formulate such guide-lines for the aesthetic design of bridges.

"Choice of a clean and simple structural system like a beam, a frame, an arch or a suspended structure. The bridge must look trustworthy and stable"

A mixture of different systems leads usually to difficulties for good shaping. and confusion to the observer. *(Fig.3)*

The often heard opinion that a structure which is statically correct, will simultaneously be beautiful is however not valid if the following qualities are not included:

"Good proportions in all three dimensions between the structural members or between length and depth of bridged openings"

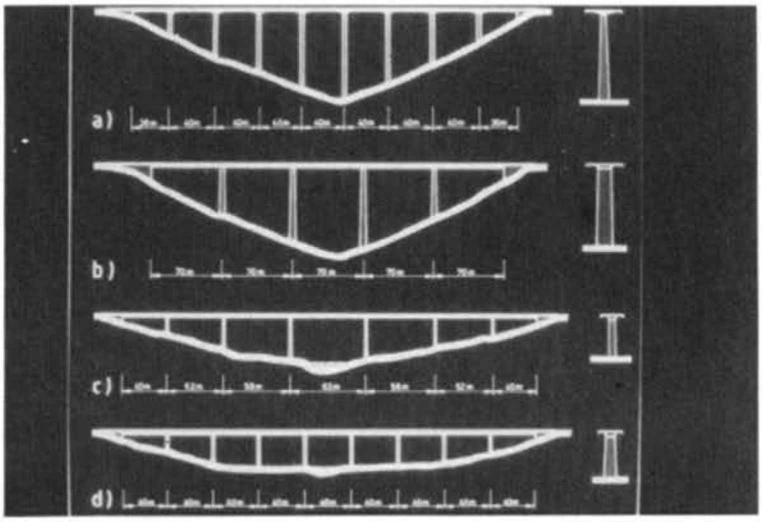


Fig.6: Relation between Valley Slope and Bridge Layout

a: Deep V-shaped valley, slender piers closely spaced emphasize height

b: Deep V-shaped valley, good to use tapered piers with uneven number of large spans and no pier in center

c: Shallow valley, flat openings with varying spans, is harmonious

d: Shallow valley, identical and small spans, look stiff

Fig.5: Gemünden Railway Bridge, Germany

"Good proportions in all dimensions"

There must be good proportions between height, width and depth of a bridge in relation to the size of the bridge deck structure itself. There must also be good proportions between the spanned structure and the carrying piers, between the span-length and the depth of the beam; and between bright and dark surfaces due to light and shadow. Good proportions must also be created between the masses of the structural members, between abutments, piers and superstructure. *(Fig. 4 and 5)*

What are good proportions? This needs a definition. There are many good proportions. The choice may depend on the question if, for a bridge high above a valley, the floating impression shall be emphasized or if, for a bridge crossing a river in flat country, the impression of length shall be emphasized. *(Fig.6)* Good proportions are like harmonic accords in music.

"Good order of all the lines of edges of a structure which determine the appearance. One should limit the number of directions that cause unrest, confusion and worried feelings"

For instance for the transition from straight lines to curved the curvature should steadily increase like in a second order parabola. *(Fig.5)* Good order must also exist between the proportions which have been chosen for a structure. Symmetry is an approved means of order, if the conditions are favourable for symmetry. A certain rhythm and repetition of equal elements belong to good order. Monotony should be avoided by interrupting many repetitions with different rhythms of elements creating asymmetry. *(Fig.7)*

"The compatible integration of a structure into its environment, into the landscape or the city"

This is especially important with regard to the scale of the structure compared to the scale of the surroundings. *(Fig. 8)* A very long span with rather deep massive beams is not at all in harmony with an old town with small houses or with a pretty small river valley.

"The choice of the materials has considerable influence on the aesthetic appearence"

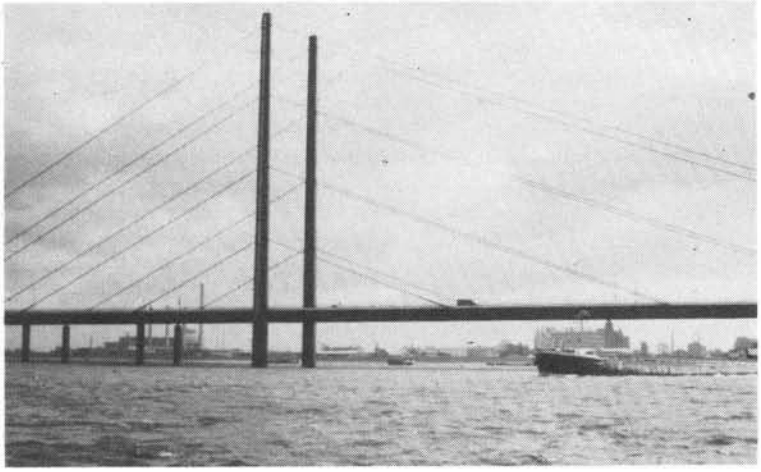


Fig.7: Knie Bridge, Dusseldorf
"Good order with minimum number of direction"

These guide-lines - tentatively formulated - shall not be considered as strict rules for designing. Design shall always begin within individual freedom for intuition and imagination. Good designs still depend on the gifts and talents of the designer, on his sensitiveness towards aesthetics and on his training in visual appearance. The guide-lines can, however, serve for self-analysis, as a critical faculty for checking the design, especially with models, which can help to highlight aesthetic mistakes. Pleasing appearance is usually the result of such critical analysis, leading to improvements, step by step, until harmony is obtained.

For heavy piers and abutments, stone masonry is often preferable to regular concrete. For truss bridges, steel looks lighter than concrete. The same is true for pure tension members like stay cables and hangers.

The surface texture of materials should be chosen depending on size and function of the bridge elements. For large areas of abutments or piers, rough surfaces will be suitable. For slender beams a smooth but not glossy texture, will be opportune.

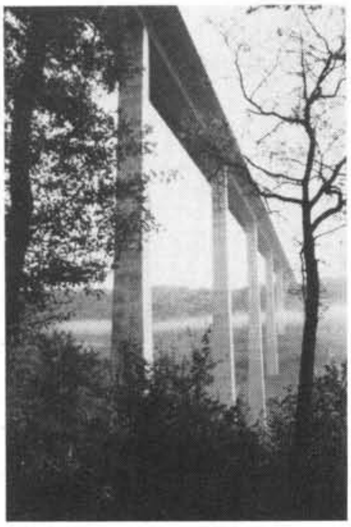


Fig.8: Kocher Valley Bridge, Germany
"Compatible integration of structure into the invironment"

"Simplicity and refinement of the pure structural shape is important"

All additions like ornaments, decorations or architectural extras should be avoided. The shape of a bridge is only mature if nothing can be left out. *(Fig.9)*

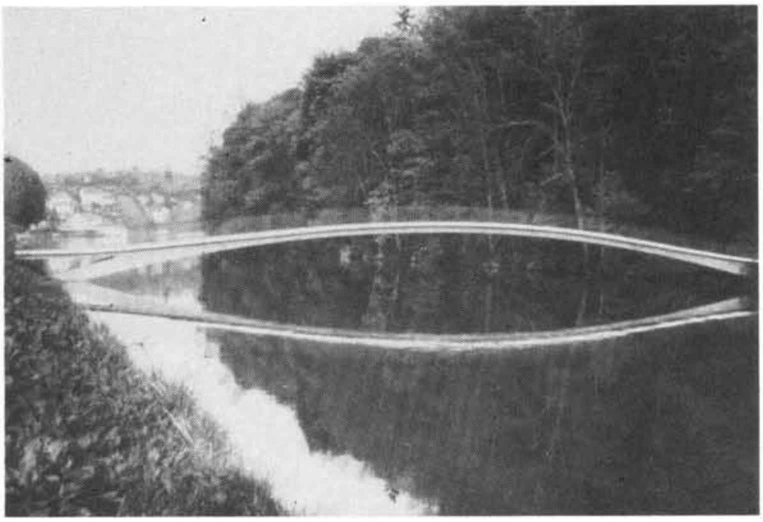


Fig.9: Pedestian Bridge across the Enz River, Germany
"The shape of a bridge is mature, when nothing else can be left out"

"An important element for pleasing appearance is the colour"

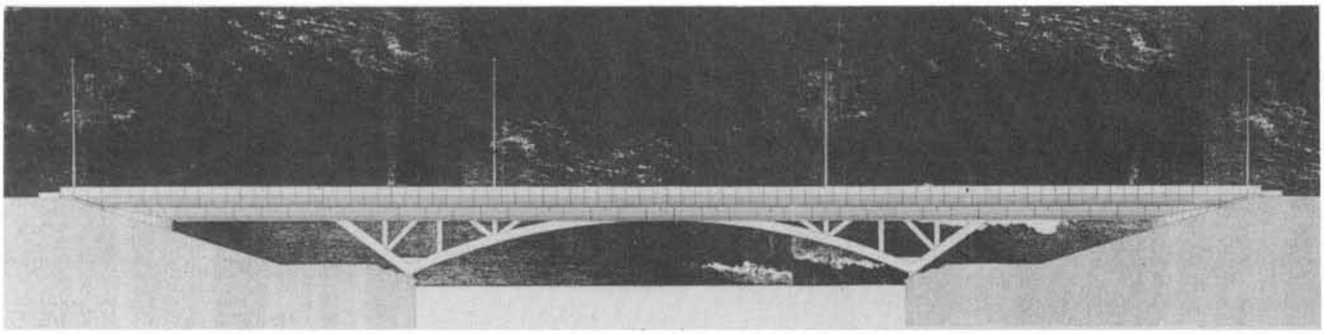
Natural colours of masonry or painting of the bridge structure in harmony with the surroundings can enhance a bridge. Principally mineral colours should be chosen because glaring, loud chemical colours - especially in the shape of abstract ornaments - are only disturbing and spoil the bridge appearance.

Beauty can in no case be secured by direct application of the rules. The designer must be willing to work for it, maybe with the assistance of good friends who possess good taste and sensitivity for beauty, especially if he recognizes he is not gifted with such vision.

MOVING ON

Initial Design of Proposed Third Bridge at Runnymede

Peter Ahrends
Ahrends Burton & Koralek
Architects



In the Beginning
Symbolically the concept that is embodied by the word 'bridge' is surely one of the most powerful and evocative in the vocabulary of our experience. The high flying movement of 'sailing' eloquently but safely across a chasm, a waterway, a crossflow that lies below, is both profound and deeply satisfying. To make connections where none exist and to reach out and over to the other side lies at the very heart of our imaginative and adventurous natures. In designing any bridge (like a young child placing a stick across a puddle) we enter the territory of making delightful crossings; in doing so we make fundamental gestures that speak and occasionally sing beautifully about ourselves, our society.

Brief
The brief for the design of the new Runnymede Bridge that forms part of the current M25 proposals between junctions 12 and 15, was not simply to get the A30 diversion safely from A to B across the Thames near Egham. Nor was there anything unusual about the technical brief related to the span, the traffic volumes or any other typical engineering function of the bridge.

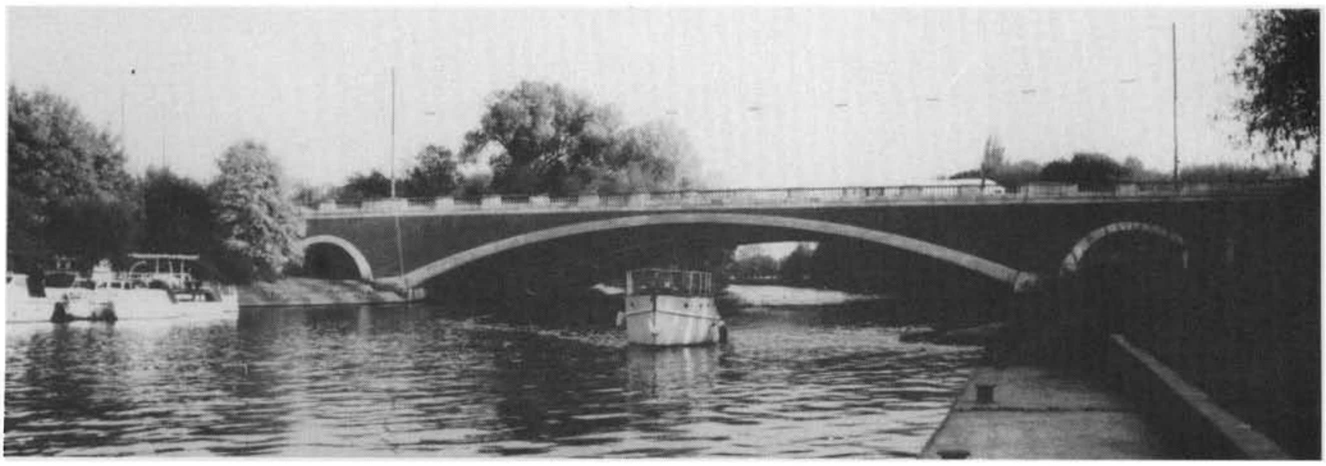
More unusual was the site-specific nature of the problem and the contextual significance of designing a bridge at Runnymede in relation to the two existing bridges. In this account of the design process I shall outline and illustrate how these conditions and constraints were viewed and interpreted by the various parties and how their attitudes interacted, during the design period.

Early Influences and Thoughts
In designing a bridge we reach forward to touch the future as, with our feet on the ground, we rub shoulders with our past, the place that we come from.

It is difficult, especially with hindsight and post-hoc rationalisation, to cast one's mind back to the influential and complex patterns of thought that intermingled during the formative stages of design. However, in this case, certain issues were clear at the outset.

The Runnymede site is unusual not only because of the historic connotations and the natural beauty of this typical English riverside scene close to the built-up edge of Egham, but importantly, because of the presence of two fine existing bridges

1 The Lutyens Bridge
The First in line



2 The Arup Bridge
which made a kind of twinning

which are to be joined by the presence of a third, a newcomer. With the addition of the proposed new bridge this group can be seen to be a family of bridges; a family that will share a number of common characteristics whilst having different types of construction and, notably, different forms of expression.

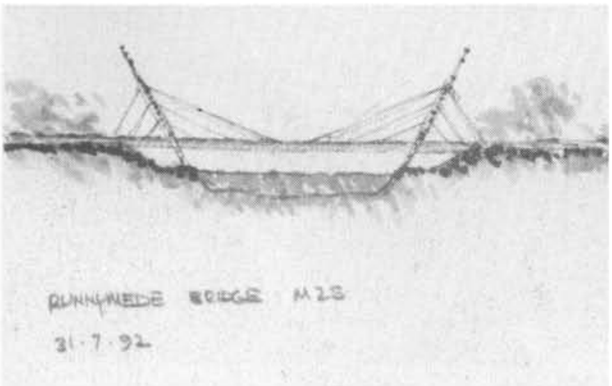
The first bridge, designed by the architect Lutyens is a steel arch which was clad with warm red brick facings and stone dressings. It was completed in 1960 and later strengthened to meet more demanding engineering standards. *(illustration 1)*

The second bridge formed part of the original M25 construction programme and was designed by Ove Arup and Partners as a set of arched white concrete frames and was completed in 1980. *(illustration 2)* Sensibly, this bridge was set apart from the Lutyens bridge by a gap of several metres. Not only did this assist with the new design and construction programme, but it served to maintain and respect the design integrity of each bridge whilst, importantly, allowing daylight to shine through the gap to illuminate the river and towpath below.

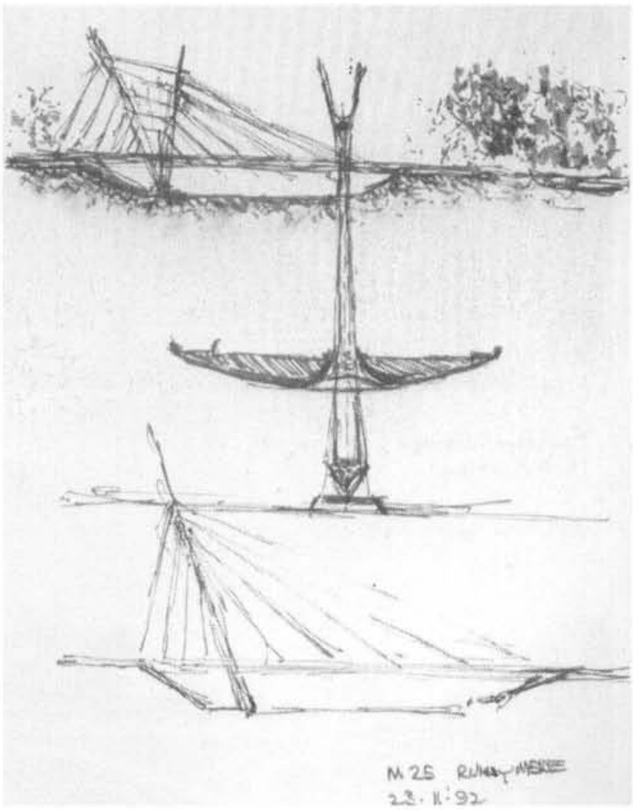
Given these alternative idioms in which the Arup bridge had unashamedly, but quietly, established its own modern identity, the question became - what should the options for the third bridge be? In phrasing that question I wanted to identify aspirations that would guide and inform our design proposals in addition to satisfying the normal technical and budgetary requirements. Several intentions grew in my mind and these served as guidelines during the developmental stage of design.

- I would follow the earlier precedent by establishing a gap between the new bridge and the existing Arup neighbour. Indeed, why not go even further by separating the structures of the eastbound from the westbound lanes of the new deck by introducing another gap. Eventually this strategy was also applied to the new footpath structure in order to separate that element from the adjacent traffic-bearing deck, environmentally a hostile neighbour in relation to the pedestrian crossing.

  It was important that the profiling of the underside of the bridge deck should be subtly curved, in monocoque form, in order to



3A Cable stay solution



3B Other cable stay solution

present the thinnest and lightest edge to the sky. Not only would this admit as much light as possible to the river below but upward reflection of light from the surface of the water would thereby become a significant factor in the appreciation of the bridge when seen from the towpath. Just as one clear strand of the history of modern architecture is rooted in the exploration of light - its significance in relation to spatial and formal configurations - so should such issues influence the design of this bridge in reaching out for a 'lightness of being'.

- From this baseline I felt that the bridge should be seen to be clearly and progressively modern and that, in the lineage of this family tree, there should be an identifiable sense of *moving on*.

  The group of structures should be seen to develop from the earlier bridges with their expressions of brick, stone and concrete, to modern interpretations of the use of steel.

- Finally, I was looking for a dynamic simplicity of form that would reinforce and celebrate the interaction of the points that I have made above.

The Waiters Fingers
Several options were considered and for the purpose of this text I will separate those that were presented to the client from those that were considered only in sketch form, in discussions between architect and engineer.

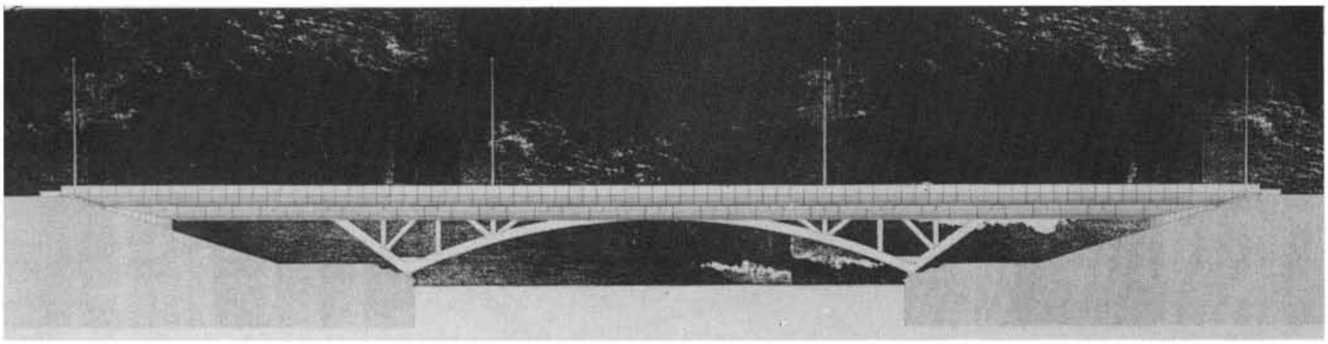
I had considered a cable stayed solution, which we dismissed for three reasons :
(illustrations 3A & 3B)

First, there was a doubt as to whether the structural masts and cable stays would be acceptable to the Heathrow airport authorities in relation to possible radar interference.

Second, the engineers thought that there could be little or no justification for the use of a cable stay solution in this position.

Finally we felt that this solution, so evidently athletic and dynamic, would appear to be too self-assertive and dominant in relation to the forms of the earlier bridges. In other words the quiet relationship between mother and father might be somewhat disturbed by the decibel ratings of a rather boisterous teenager.

The clearance distance above the waterline was required to be no less than the existing bridges. This proved to be a



5 Articulation of the elements

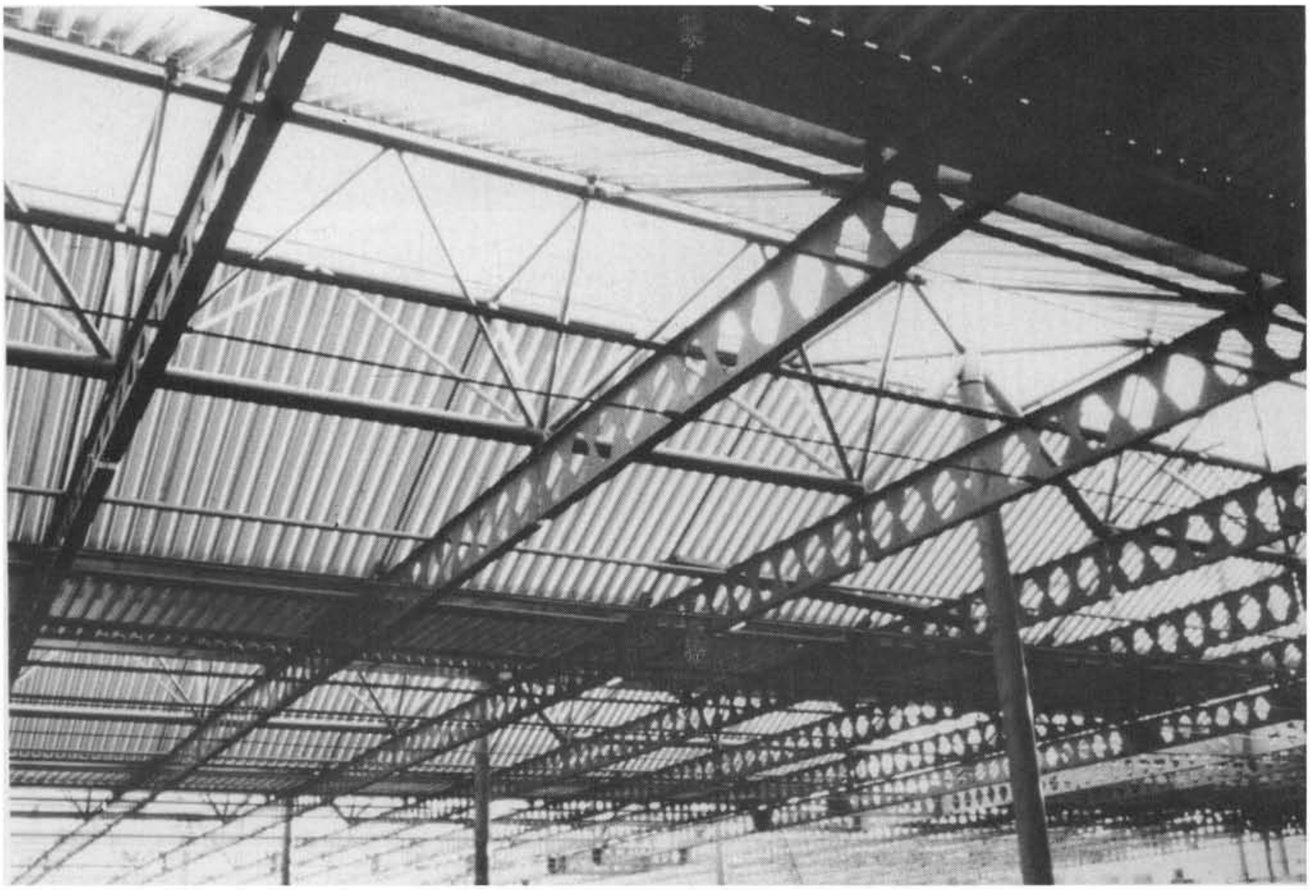
considerable constraint in relation to the structural depth available for the bridge deck. Three options were considered, each being a structural variation on a more or less constant deck form.

The first was the simplest proposal in formal and geometric terms. The two curved forms of the deck structure, whose monocoque characteristics (at least seen through my eyes), should have the inherent stiffness to span between two sets of inclined main struts in the form of an inverted tetrahedron. Frank Lloyd Wright's memorable early 20th century description of a *waiter's fingers holding a tray* had come to mind. Equally the decks should have the capacity to cantilever outwards from the primary support structure to the leading edges, to include the asymmetric loading of the pedestrian footpath. The scheme was developed, drawn, modelled in sketch form and presented to the Department of Transport, now the Highways Agency.

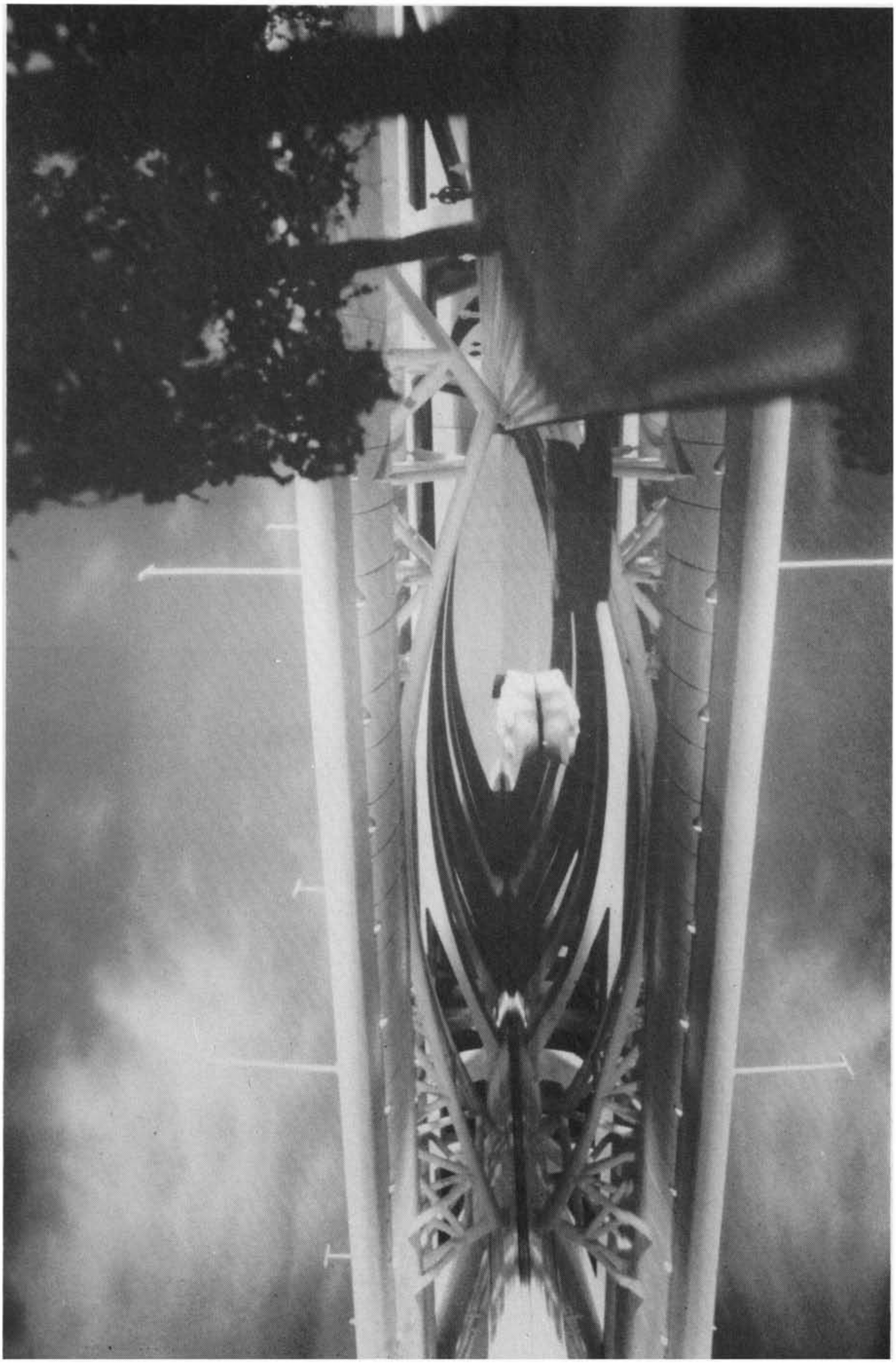
At first the client, the Highway Agency, seemed less than convinced that this was the optimum solution. The underlying concepts were thoroughly argued and supported but some doubts remained. These included the inability to resist boat impact, the structural efficiency, and the buildability of the structure. In addition, the cost of the solution had to be very carefully considered.

Our thoughts turned to an alternative, a simple arched structure which we developed to a similar stage of presentation. It was my turn to feel a lack of conviction about this solution. The design lacked some of the formal tension that had been evident in the earlier option - a dynamic between the expressed primary elements and the monocoque decks. It became obvious that another move was called for.

Interestingly, the third and final option was typical of more general ABK design preoccupations which concern the celebration of the significance of structure through the medium of daylight. For instance, the structural scheme for the Cummins Engine plant in Shotts (1980) highlights this point. *(illustration 4)*



4 Daylight and the Cummins roof



6 The arched spine as primary structure

Balance and Hierarchy

We proposed a more complex triangulated arched frame serving as a spine of the structure situated in the daylit gap between adjacent decks. *(illustrations 5 & 6)* Cantilever struts extended outwards to establish a stiff zone in each monocoque on both sides of the centre span. The dynamic tension of formal and structural interaction was once more re-established. The elemental characteristics of the parts became clear within an order of balance and hierarchy. Formal gestures and engineering checks seemed synonymous - one seemed to reinforce the other.

In character with the gap that we had designed between the deck structures we introduced a second minor interval; a safe gap between the edge of the road deck and the footpaths. Cantilever beams established the separation and made the connection; happily this formal separation brought with it an unforeseen bonus. For it was at this stage that the services provision for mains gas and telecom cables became greater than had been foreseen. These elements were properly accommodated within the aerofoil section of the walkway structure *(illustration 7)* to enable free access for maintenance, independent of the road structure. A good arrangement in relation to safety and traffic flow.

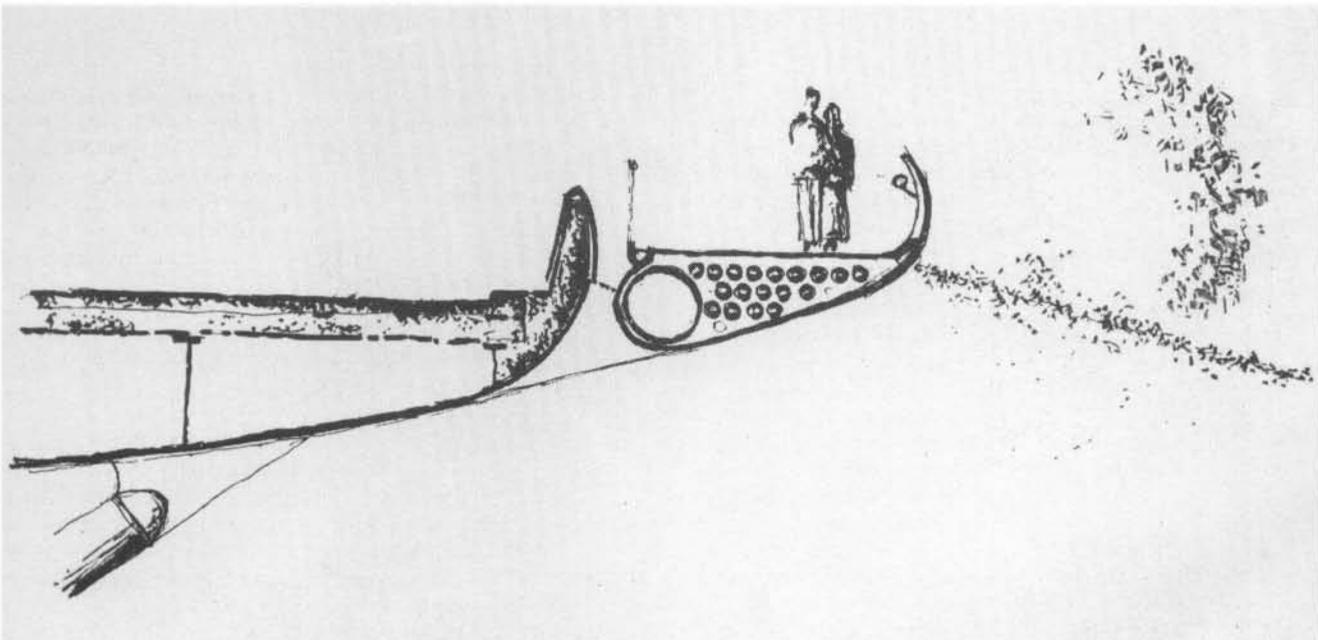
Finally, a point of relative detail about the design of the abutments seen in relation to the form of the 'underbelly' of the bridge deck structures. To contrast with the silver painted steel of the bridge deck, we proposed that the abutments should be clad in stone; a contextual, if not a formal reference to the stone dressings on the Lutyens bridge. In relation to this the oblique angular cut of the monocoque deck at each end is intended as a formal gesture of recognition and refinement. It addresses the conjunction between the elevated 'feel' of the steel structure and the earth-based character of the stone-clad abutments. It is here that with its feet on the ground the bridge may be seen to be both rooted and free-flying.

A Footnote

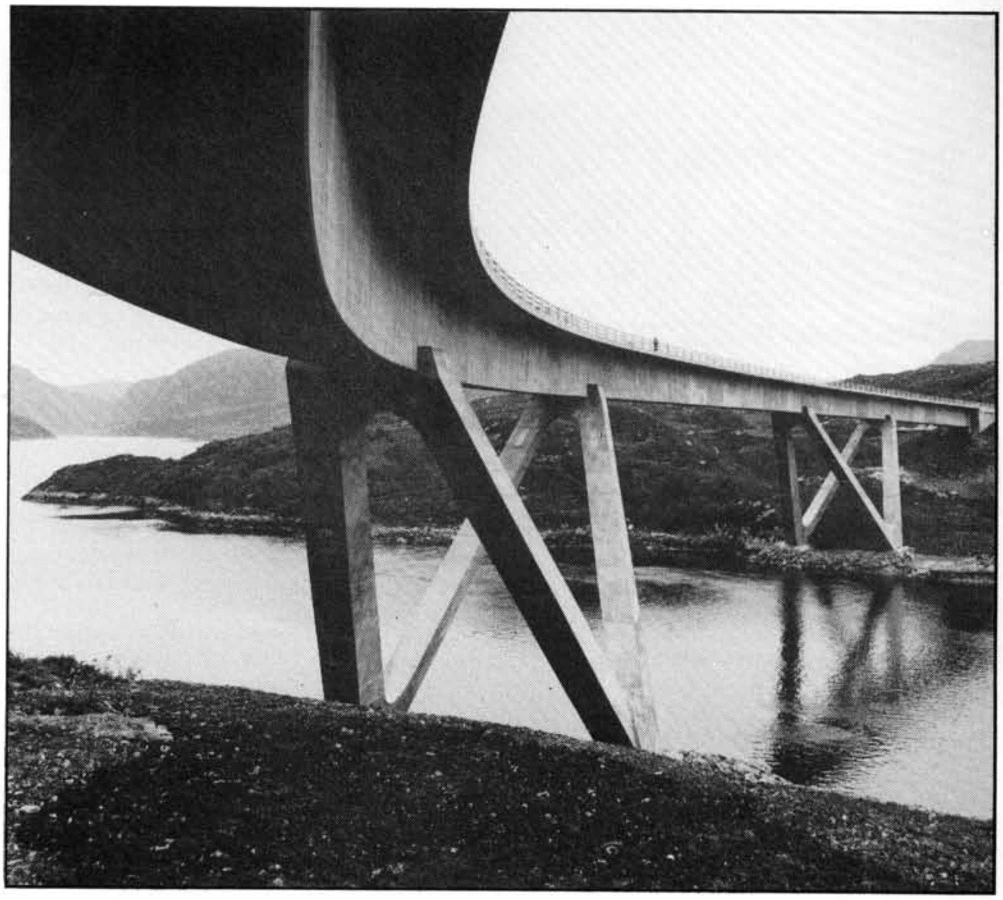
The outline design proposals for this bridge have been put to the RFAC and have been accepted. The scheme as a whole has still to go through the statutory procedures and, of course, the engineering detailed design has still to be completed; changes could follow. This paper has been prepared with the approval of the Director of the South East Construction Programme Divison of the Highways Agency.

Peter Ahrends
August 1994

Howard Humphreys, Consulting Engineers
Ahrends Burton & Koralek Architects



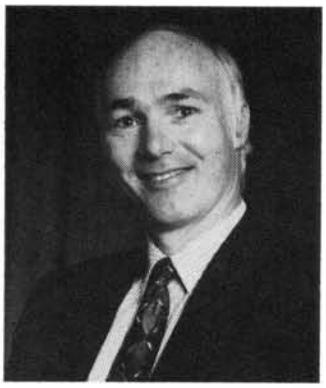
7 The walkway housing main services



"Kylesku Bridge is without doubt my favourite bridge. I happily admit that my involvement in the construction of the bridge does prejudice me greatly, but involvement in a project does not always lead on to satisfaction with the result! Kylesku Bridge has given, and continues to give me, immense satisfaction."

Kylesku Bridge - A masterpiece of todays era.

a value for QUALITY



Michael Martin BSc C.Eng MICE is a Director of Scottish based Morrison Construction Group, whom he joined in 1980 from Ove Arup and Partners. He moved to Scotland in 1978 to work for the Ove Arup team on the Kessock Bridge and since then has had an involvement in most of Scotland's major bridge projects.

The last fifty years have seen tremendous advances in bridge building and it is a great credit to the Engineering profession in the UK that we have played a major part in inspiring that progress. And yet, at the same time, I think that our whole industry is suffering from a malaise with dissatisfaction corroding it from the inside and vocal criticism tarnishing it from the outside. The criticisms are legion - low quality, low production, adversarial methods of working and, now, accusation of "visual bankruptcy".

Not all such allegations stand up to close examination but some do have more than an element of truth. Criticism of the visual design of some of our recent bridges is, I believe, one such example. On the surface, this may seem to be a problem that could be solved by the simple expedient of giving a "bigger" role to the visual designer. I believe that this approach will not work. It is far too simple a solution to what is a very complex problem. This "problem" with the visual design embraces a large interwoven set of issues, but linked to all of them are two questions:-

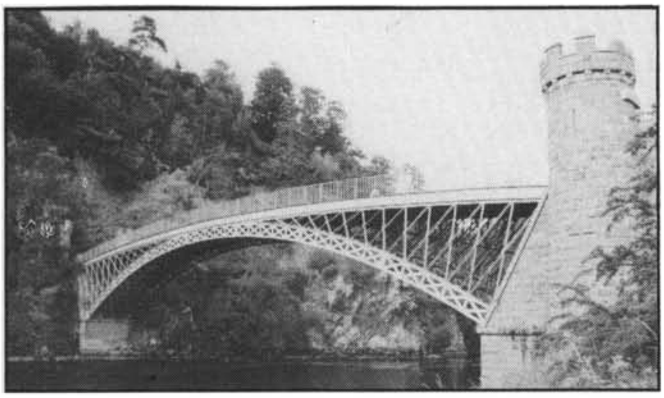
- *How do we view cost and value for money?*
- *Are we commited to Quality in the industry?*

To solve the "problem" we must recognise that lowest cost and value for money are not the same. We must also strive to ensure that our industry is committed to Quality. I believe we have started to recognise these fundamental issues and I can see evidence throughout the industry of a move away from a low cost, low quality adversarial approach to a commitment to provide value for money, with multi-disciplined teams of highly skilled professionals working in partnership with their clients to provide a quality service. This is where the real debate lies.

I want to return to these fundamental points, but before doing so I think it is worth trying to understand why this "problem" with bridge procurement has arisen.

UNRAVELLING THE PROCUREMENT WEAVE

Why do we build bridges, and what affects the process of bridge commissioning? I think that recent years have seen great changes in all of the factors that play a part in the process of commissioning a bridge. These changes have, in general, tended to isolate the visual design from the other issues that influence the process and I would like to look at what I believe to be the three



Telford's Craigellichie Bridge – A masterpiece from a previous era

key issues:-

- *The driving "need"*
- *Cost value assessment and competition*
- *Technological expertise and innovation*

The Driving Need

Almost without exception we build bridges today for the primary purpose of economic gain. This hasn't always been the case and it is worth reflecting on this when we compare recent bridges to some of the splendid structures that history has given us. For the larger part of history the strategic importance played by bridges in defence and empire building represented the major "need" that drove the commissioning process. From warrior and empire builder we moved on to become tradesmen - and the profit motive which now dominates most of our decision making processes started to wield its influences. This primary motive of economic gain is the need that drives bridge procurement and we must not forget it.

Cost Value Assessment and Competition

Although the profit motive has been with us for a good many years, it is only in more recent years that our ability to analytically compare cost to value has developed. A whole industry of advice dedicated to the science of present and future value assessment is now available to the prospective bridge procurer. Concepts, such as Generated Traffic, Non User Benefits, Revenue Elasticity, Return or Capital are all relatively new in the history of bridge commissioning, but have now achieved a sometimes seemingly vital significance. This significance is even more vital when, in a fiercely competitive market, the comparative assessment of cost and value is the mechanism used to judge the commissioning process. And, indeed, our market is more fiercely competitive than ever before - leaving no room whatsoever for the provision of anything not valued in the assessment process.

Looking at some of the great bridge masterpieces, it is interesting to speculate on what would have been built if today's criteria had to be addressed. "I leave a bridge forever to the generations of the world" is the epitaph of Caius Julius Lacer, the engineer of the Prente De Alcintara. This stone arch masterpiece is a testimony to the power and influence of the Roman Empire, but what value does this criteria attract in today's competitive tender competition?

Technological Expertise and Innovation

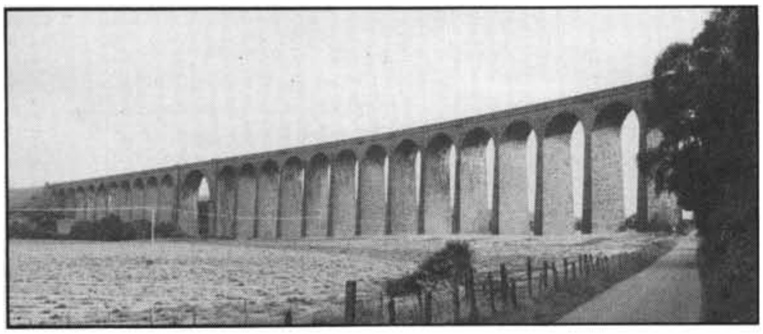
Undoubtedly our state of technological development plays a very large part in the procurement process. For a long period through the history of bridge building the design solutions and materials available were limited to those that nature itself provided. Over the last two hundred years, and in recent years at a greatly accelerating pace, man, the great innovator, has moved in leaps and bounds. Innovation has influenced every aspect of bridge building. From stone to concrete to reinforced concrete to prestressed concrete. From wrought iron to steel, to high tensile steel and on to carbon fibre and plastic. From rule of thumb to simple static's, to indeterminacy, and on to the main frame computer and finite element analysis. Innovation will never stop.

INDETERMINATE VALUE

We cannot escape from the fact that, as the profit motive is the main driving force behind the commissioning of bridges, we must compete on the basis of cost. What we must guard against, however, is not properly recognising and rewarding value, and it is here that we hit the problem. How do you put a value against the visual design? You cannot put a monetary benefit against it. You cannot specify it as you can with the structural design. Often as not we can't even agree on it! But the fact is - it does matter. As a nation we undoubtedly value the visual design of our bridges.

To somehow promote this indeterminate visual value into the cost driven procurement process is obviously no easy task. It may seem that we were able to achieve this in the past, but I believe that this was more often the result of circumstance rather than design. The use of the arch and of natural materials seems to be inherently pleasing and when they are the only solutions available the visual outcome is rarely disappointing. Today's greater range of structural concepts and materials, together with the often visually unsympathetic requirements for bridge deck furniture, make the visual outcome more problematic.

Today we have a very complex equation to solve. We cannot solve it by simply running away and turning a cost based competition into a beauty parade. The solution may allow some cost compromise, but it will be much more based on attitude of mind, a commitment to achieve an all round quality design and a team of professionals with a balance of skills. The question of who leads this team, I think, trivialises this complex issue. Gone are the days when it was possible for all of the scientific and visual skills to be present in



The natural stone arches of Culloden Viaduct fit well into the beautiful Nairn Valley.

one mind. Today, a team with complimentary skills is required and for a major bridge project that team includes experts from the scientific disciplines - structural, geotechnical, hydrological, aerodynamic, as well as from the visual and environmental disciplines. The question is not who should lead this team - the team will always be lead by the issues that dictate success. We must ensure that success is not simply the lowest price, but is a balanced recognition of all that is of value within the project and that must include the visual design.

BALANCING THE BENEFITS EQUATION

The fact that we can solve this complex benefits equation is evidenced in the many excellent bridges that we have produced over the years. Yes, we have had our failures, but let us not be too pessimistic. After all, failure in visual design is not unique to bridges!

I would now like to look at how this benefits equation has been approached on a few bridges that have particular significance to me.

Most of my bridge building experience has been linked to Scotland, and I have been fortunate to be involved in most of Scotland's major bridge schemes over the last twenty years. Each of these schemes called for a different balance between the purely cost driven benefits and the indeterminate visual benefit.

Looking back, I can already see how the cost driven benefits are starting to loose significance as the visual benefit, or the lack of it, comes to the fore. Looking back still further, I have found it particularly interesting to compare the designs of today with the designs of a previous era.

I think this highlights the complexity of todays procurement process but it also gives us an insight into how the next era of designers will judge our ability to properly balance this benefits equation.

Minor Masterpieces

Kylesku Bridge and Craigellachie Bridge are in my view two masterpieces of bridge design. Craigellachie Bridge built in 1814 was designed by Telford and Kylesku Bridge built in 1984 was designed by Ove Arup & Partners.

Craigellachie, now 180 years old, has achieved the fame it deserves. Kylesku, only 10 years old, is well on its way to achieving similar glory. I really don't know whether or not Telford's design was the cheapest, but one cannot help coming to the conclusion that it would have been hard to better. Ove Arup's design was almost certainly not the cheapest, but I believe it is tremendous value for money and clearly shows that we are more than capable of providing visually outstanding designs when given the opportunity to do so.

My own lasting recollection of building this bridge will be of teamwork. This was not a design and construct contract, but the design and construct team worked together with tremendous co-operation. The bridge cost substantially more than had been originally estimated and, although this initially was a disappointment to the client, he did recognise the value of his purchase. Ten years later I think the whole world recognises that value.

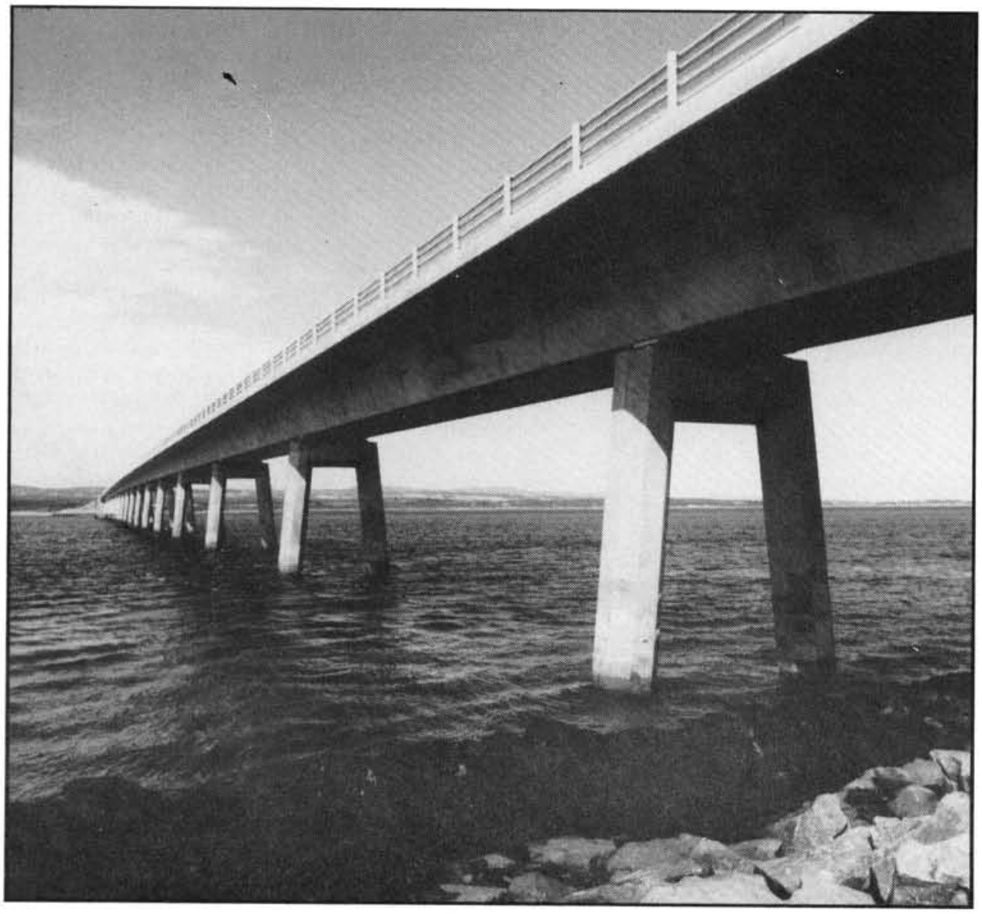
Functional Simplicity

Neither Culloden Viaduct or Dornoch Firth Bridge needs to be visually outstanding, but the very fine natural beauty at both locations calls for a sympathetic design. Culloden Viaduct was built in 1898 and designed by Murdoch Paterson. Dornoch Firth Bridge, was built in 1993 following a Design and Construct competition won by the Christiani-Morrison Joint Venture, along with the Joint Venture design team of Tony Gee & Partners and Sir Alexander Gibb & Partners. Neither of these bridges will ever receive the acclaim of Craigellachie or Kylesku, but I think that visually each works very well. The use of the stone arch automatically leads to the visual success of Culloden. Dornoch's success with the materials and design concepts of today did, however, have to be worked at.

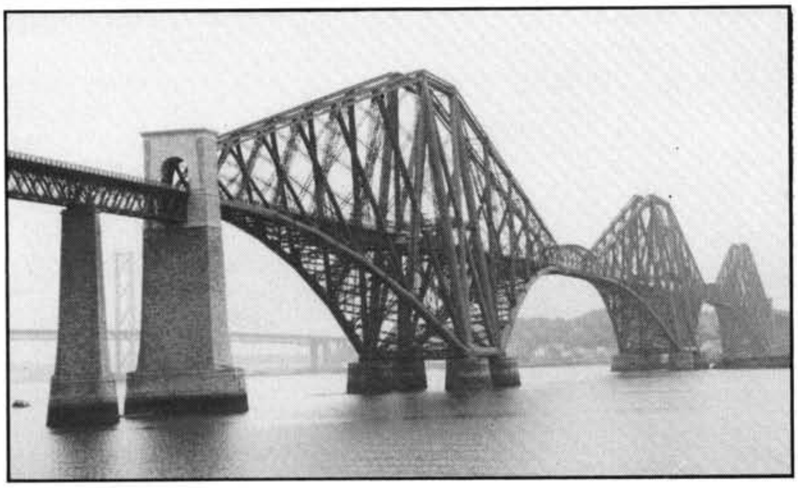
The design and construct competition took place in three stages, with the second stage seeing the elimination of any visually unacceptable proposal well before costs had been tabled. The design team took the greatest care in detailing the pier legs and the pier cross head to bridge deck junction. The sloping octagonal legs were certainly not the cheapest solution, but this was a small cost compared to the value of the visual benefit - and this attention to detail contributed significantly to the success of the design during the second stage of the competition. The bridge proved to be a clear winner on cost alone at the final stage.

Landmark Structures

Scotland has its fair share of "landmark" structures and these have been added to over recent years, with Kessock and

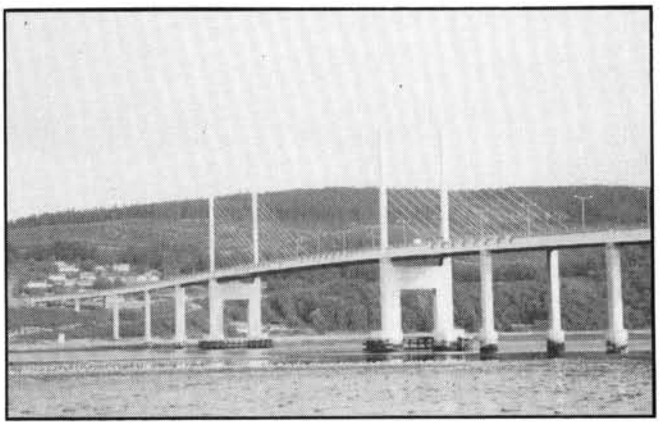


The functional simplicity of the Dornoch Firth Bridge.



The indestructible but elegant Forth rail bridge.

Kessock Bridge - Too much compromise to cost?



Skye bridges - and may be added to again with a second Forth road bridge.

Of all Scotland's landmark structures the Forth rail bridge is perhaps the best known. The bridge was built in 1890 using the then innovative Baker and Fowler cantilever design. The bridge was built not long after the notorious collapse of the Tay rail bridge, and the designers recognised the public's need to see a bridge that looked indestructible. The almost brutish robustness of the resulting design has proved to be indestructible, but somehow the bridge also has a splendid elegance. I can only attribute this to the visual balance - it is a marvellously well proportioned bridge.

Inverness, the "Gateway to the Highlands" provided the location for the Kessock Bridge and gave Scotland an opportunity to create another landmark structure. The original design for the bridge was an asymmetric cable stayed steel structure designed by Crouch & Hogg. This was a very fine looking bridge, but the price tag put on it at tender time was considered too high and it was not built. The bridge was re-tendered as a design and construct competition and a contract was subsequently awarded to the Cleveland RDC Kessock Consortium and their respective designers Dr-Ing Helmut Homberg and Trafalgar House Engineering Services. I worked on the bridge from 1978 to 1980 and subsequently chose to keep my family home in Inverness. I have studied the bridge from almost every angle and have taken countless family and friends to see it. It always impresses, but will never rank alongside Forth. It is simply a big bridge. The heavy concrete substructure and light steel superstructure take away the balances and elegance that the location really demanded. Did we compromise too much to cost? I fear we did.

The next opportunity to add to Scotland's bridge heritage came at Skye. I thought I would always regret that Morrison Construction's bid for Skye Bridge was unsuccessful, but the furore over the design since award of the concession, has made me think again. This Design, Build, Finance and Operation concession competition threw together all of the complex interwoven issues that I have referred to here. The final outcome has yet to be seen and let us hope that it is a success. The commissioning authority and the contractor have put such an enormous amount of work into this project, that they do deserve success. But more than that - the location surely demands it.

Finally, to the second Forth road bridge and for me an opportunity to benefit from lessons learned. Well just what have I learned?

- Price dictates the procurement process.

- To put a monetary value on visual design is practically impossible. Unacceptable visual designs must be rejected by the commissioning authority before they are priced.

- The design team must be a "team". Individual bridge elements can be structurally designed in isolation, but not the visual design. A dedicated visual designer - be he architect trained or engineer trained - has a role to play here, but only as part of the team.

- The procurement of today's major bridges - especially by the D.B.F.O. route - is a very complex process. To succeed in all respects a team of the very highest calibre is required.

The Forth Link Group, of which Morrison Construction is a part, has, I believe, brought together such a team. The design team contains some of the best bridge designers in the world and contains an outstanding bridge architect who, more than anyone, appears to appreciate the importance of creating a homogeneous team working to produce one well balanced visually homogeneous, but economic design.

SUCCESS IS NOT THE LOWEST PRICE

I have taken a rather circuitous route - but it is at this point that I return to my opening questions. How do we view cost and value for money and what is our commitment to quality?

If those responsible for devising the procurement process do not include a means by which that almost indefinable visual value can be acknowledged, we will not get value for money. Furthermore, if we, on the other side of the fence, do not commit ourselves to striving for quality in every aspect of our work, we will not be able to deliver value for money.

Steel Bridges: Structures & Aesthetic

Dr Graham W Owens
MSc(Eng), PhD, DIC, CEng, MICE, MWeldI

Two of the most important inputs that architects have to contribute to the visual quality of bridges are their concern for detail and for the perceptual qualities of form.

Detail

Concern over detail implies a level of concern over the entire design. Meticulous attention to detail strikes a gratifying chord of empathy with the public, even when they do not fully understand the function of what they see.

The most stimulating architects with whom I have worked have devoted the same attention to the proportion and position of a stiffener and a bolt group that they have to the overall structural form.

Engineers are inclined to devote attention primarily to the overall structure; design of details is frequently separated from design of the main structure; this separation of design activity usually implies a lower priority to details which are frequently designed by junior technical staff to simple structural criteria with little consideration for form and appearance.

Identity

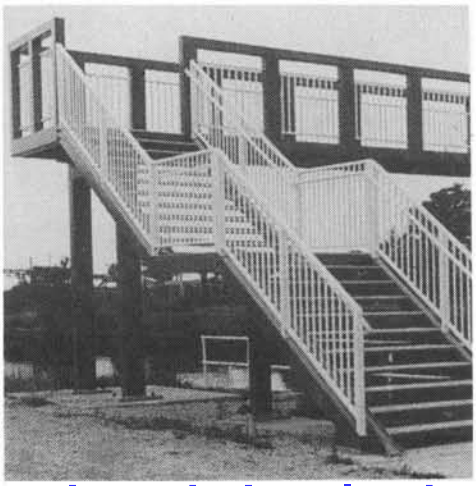
A bridge should have a natural and permanent association with its setting, having its own individuality and identity, although there will of course be recurring situations which justify the repetition of a really good design. The permanent relationship to setting calls for special attention to scale, form and choice of materials.

The designer should analyse the context very thoroughly to arrive at a suitable solution. He should consider, for example, whether the bridge forms a gateway, how it will be approached (on a curve, at a crest, in a hollow) and whether it can it be seen from a distance, from an oblique angle or at right angles.

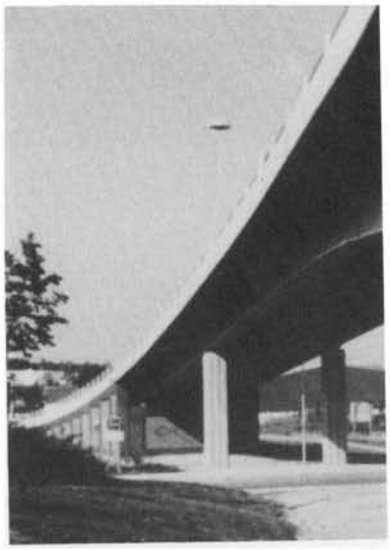
On the other hand, the physical requirements as well as speed and economy of construction may demand a high degree of standardisation; it is then particularly important that the design of the selected bridge type should be good enough to stand up to frequent repetition.

Form

Steel bridges have developed various generic or unique forms to meet particular combinations of the competing criteria of economy of material, ease of manufacture, strength and stiffness, construction value, and aesthetic expression.



Horam Footbridge



Festival Flyover

Modern high strength steels allow tension members to be attractively slender, with analogues to the tracery of a spider's web. Compression members and beams are in comparison relatively broad and this leads to a natural sculptural vocabulary where the size of members directly relates to the forces within them.

The modern cable-stayed and suspension bridge forms provide understandable and elegant monuments for major crossings. The slender tension elements are complemented by the robust stiffening girder acting in bending and compression. The visual qualities of

Hallen Bridge, near Bristol

each structure have been greatly enhanced by modern developments such as aerofoil section decks which improve stability against flutter in wind and reduce the depth of the deck edge and therefore the apparent mass of the stiffening girder.

Equally, modern equivalents of traditional truss construction can produce striking aesthetics whilst continuous highly elegant unified beam bridges provide imaginative solutions.

Function

All artefacts made from carbon steel require effective protection against corrosion. The appearance of paint systems has improved and the period between maintenance extended, such that it can now be well in excess of fifteen years. Today, the attractiveness and freshness of modern bridge paints have substantially improved the aesthetic appeal of steel bridges and additionally present the option of significantly changing a bridge's appearance at intervals during its life.

In appropriate circumstances, weathering steel can be used. This forms a corrosion resistant layer and gains a pleasing purplish brown patina as it ages.

One of the advantages of steel is that corrosion is readily detectable and can be controlled using known technology with quantifiable costs. Reliable coating systems are available and new systems, such as high-build elastomeric polyurethane, are expected to last at least 20 years between coatings. During the life of the coatings there is no significant change in surface appearance, except possibly where damage has occurred.

Forth Bridge

Performance

Motorway bridges are generally designed to be visually passive and structurally pragmatic. However, pragmatism should not negate the need for aesthetic quality, nor the relative simplicity of their design lessen the necessity to integrate architecture and engineering.

Plans to widen many hundreds of miles of the motorway network over the next decade mean that many new bridges will be constructed. Unlike the original bridges, these will be built under or over 'live' carriageways and the use of temporary supports will therefore be restricted. The need to minimise lane or motorway closure is paramount and therefore speed of construction is vital. The versatility of steel is crucially important.

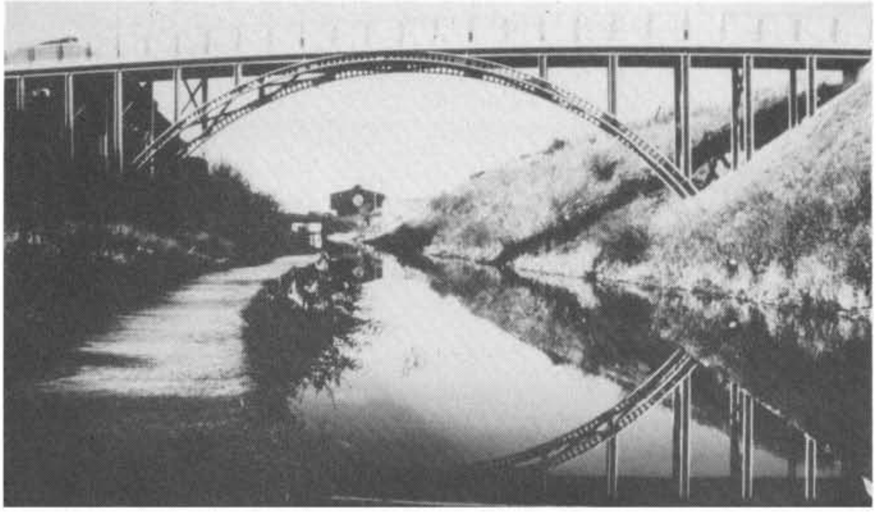
During the 1970's advances in the use of steel in offshore structures improved cleanliness, toughness and reliability of structural steels and these advances have been of considerable benefit to bridge designers. This is true not only in technical spheres such as plate behaviour, but also in appearance and maintenance.

The use of tubular piles and installation techniques also developed for the offshore sector will complement the adoption of integral (jointless) bridges. These bridges have no bearings and so naturally gain uninterrupted, clean, sweeping lines.

Foyle Bridge, Londonderry

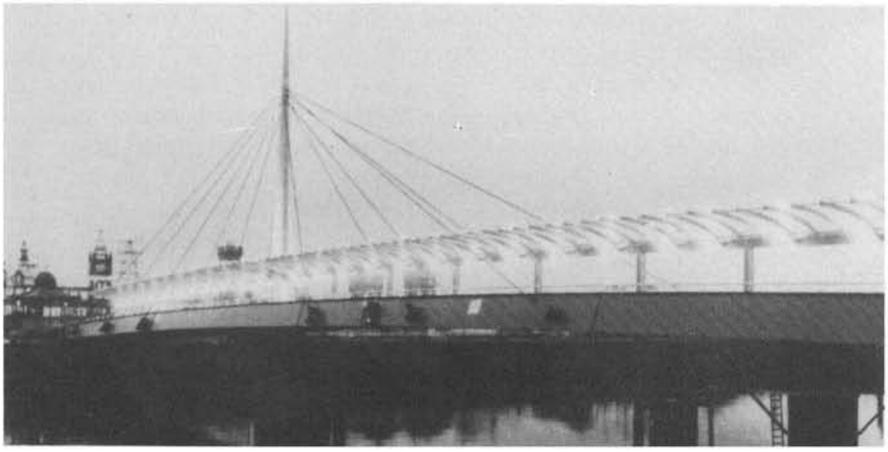
Nowhere is it more important for a bridge to fit naturally into its setting than over water. Bridges over water can give as much to their environment as they receive from it.

The substantial landmark of the Forth Bridge stands firm against the elements in an exposed situation and is a lasting monument to Victorian engineering. In contrast, the Foyle Bridge sweeps languidly over both the river and its flood plain, as many river bridges must. It follows the contours of the land and gently arches and curves to complement the hills beyond.



Chippenham Street Bridge

Often, the public judge the success of a bridge more on its appearance than on its technical merits. A particularly gratifying example of the blending of both occurs in the Chippenham Street Bridge. The curved and castellated beams are reminiscent of a bygone era, yet are fabricated by modern, sophisticated technology. The symmetry of the bridge is reflected in the water enhancing the poetry of its environment.



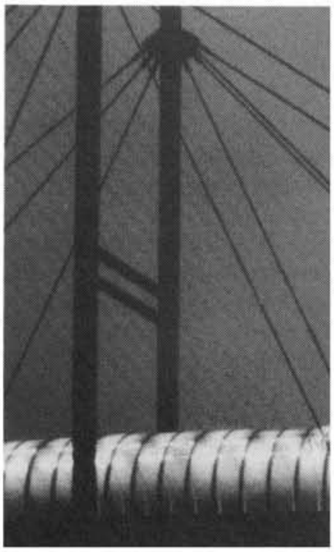
Bells Bridge, Glasgow

Whereas road and rail bridges are often viewed from afar or crossed at speed, footbridges are, by their nature, much more intimately observed by their users. This, in addition to the lower overall cost of the bridge, is the reason why there is much scope for imaginative design and elegant detailing.

The loads carried by footbridges are quite modest, permitting lighter structures, yet often their long, clear spans demand stiffness. Steel's versatility means that it can offer a number of alternatives, including tubular trusses, Vierendeel girders, steel beams, box girders, composite or even cable stayed bridges.

Coda

Bridges do not exist in microcosm, they are architectural statements in their own right. Steel provides versatility of overall form, and the possibility of dramatic visual expression. Advancing technology seems set to ensure that steel remains a natural choice for bridge construction for the foreseeable future.

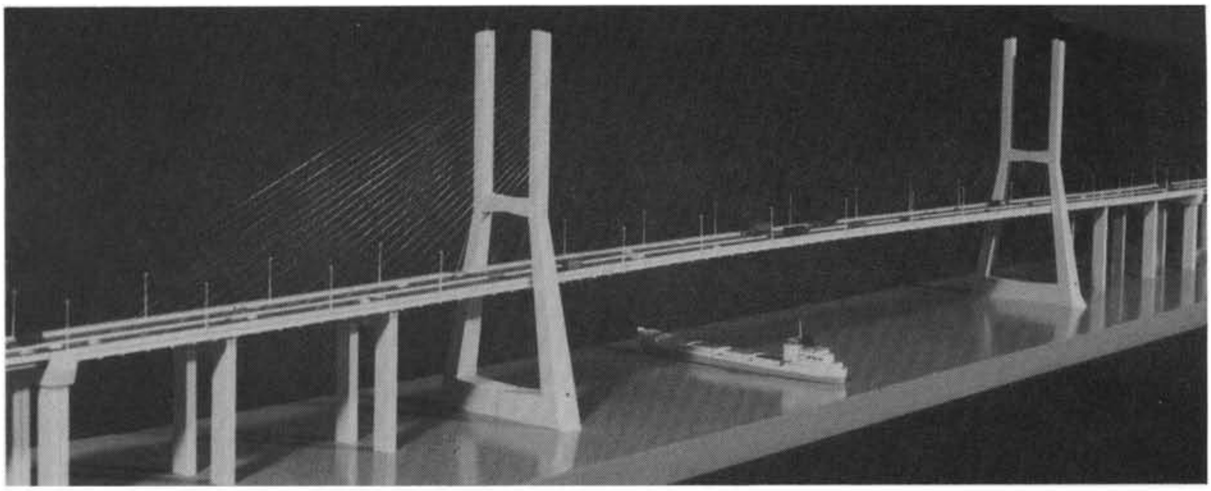


Poplar Footbridge, London Docklands

The Second Tagus Crossing

The Essentials of Good Bridge Design & Construction

by Peter M Deason BSc(Hons) CEng MICE MIHT



Cable Stayed Bridge: North Channel

The Dartford and East London River Crossing schemes generated a debate on bridge aesthetics. The debate has questioned the construction industry's ability to reconcile the importance of good design within a successful tender bid. There are concerns that if you leave it to the contractor, aesthetic considerations will be ignored. I believe that low cost and quality are not mutually exclusive - they can go hand in hand.

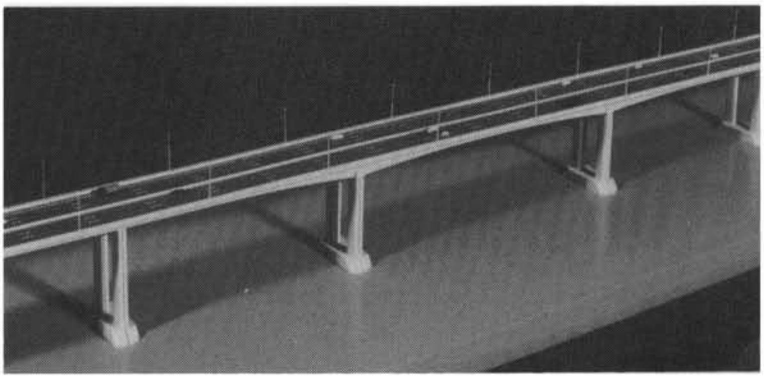
A successful bridge requires the blending of skills from many sources. The D&C route brings all the necessary disciplines together, within a single team, in a creative, non-confrontational environment: -

* The Concession company is interested in efficient operation, durability, and low maintenance.
* The financiers are seeking safe solutions.
* Low cost comes from the development of design solutions conceived around and tailored to efficient construction, maximum standardisation and simplicity of details. It is here that the contractors role is pivotal. The contractor also provides pricing information to enable the designers to achieve maximum economy within the framework of good design.
* The engineer and architect are able to bring their design skills and creativity to the design and specification.

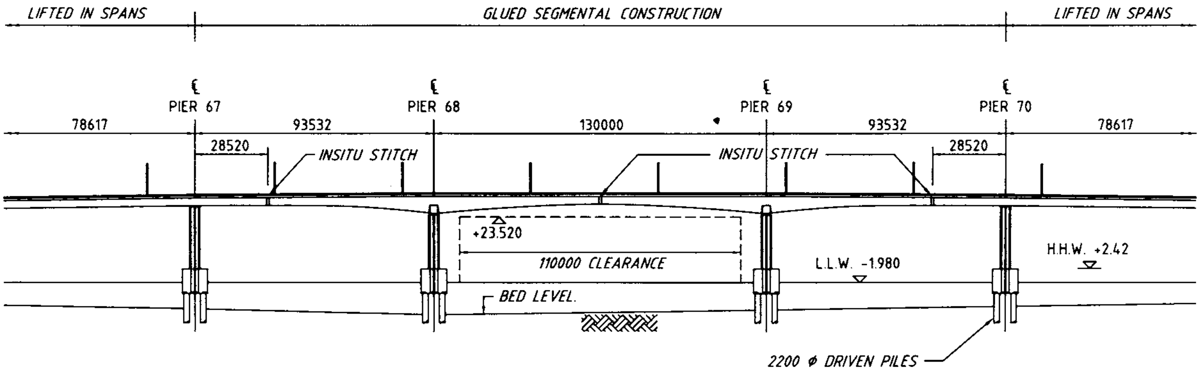
This is a powerful team, and with a well thought out brief and creative attitude it is possible to achieve low cost solutions of the highest quality within the tight time and cost constraints of a D&C tender.

In planning a project the client will have set his priorities and objectives. It is essential that these are conveyed clearly in the tender. The selection criteria, to target the clients aspirations, must be fully explained from the outset. At the end of the day the client will have at least three options from which to choose, one or all of which will achieve his aesthetic objectives within the target cost.

Independent judgement on design submissions is a valuable yardstick. The RFA, in this respect, has an important role to play as the guardians of good design in the



Navigation Span: Samora Channel



ELEVATION

Navigation Span: Samora Channel

UK. However they have a lesson to learn from the 1994 world cup. The referees must be as professional and informed as the players.

In summary the essentials of a quality project are:

- * Select the best players.
- * Set a clear brief and objectives.
- * Adopt a non-confrontational contractual framework which encourages partnership.
- * Ensure the objectives are met *before* signing the contract.

Engineering the Crossing

The new crossing lies approximately 13 km north of the existing 25th of April suspension bridge. The overall length of the concession is 20 km, of which the river crossing itself measures 10 km from shore to shore.

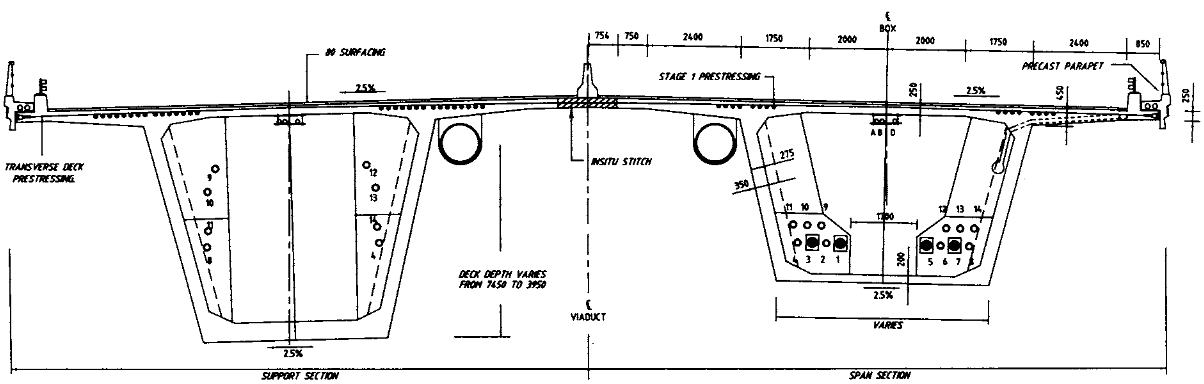
At its northern end the crossing connects with the Metropolitan Lisbon Area northern region highway scheme and the future EN10. On the south shore it joins the southern highway at Setubal, giving access to the Setubal peninsular, the Algarve and Spain. The crossing will also access the site of the proposed new airport.

The key feature of the crossing is the cable stayed bridge which spans the North channel close to the north river bank. The channel will be used by ships of up to 35000dwt, and the criteria call for a clear channel of 400m with an air height of 40m.

The main pylons are of reinforced concrete, constructed in short lifts using climbing forms. As soon as the first few sets of cable anchorages are ready the deck construction will commence, using the balanced cantilever method. The remaining pylon sections will continue concurrently with deck erection.

The entire in-situ deck is constructed using travelling forms. The construction bay length matches the cable module, allowing a new cable to be attached as each pour is completed. The pylon foundations are piled, with large cutwaters shaped and designed to resist ship impact.

The river crossing from the south end of the cable stayed structure to the Alcochet &



DECK CROSS SECTION

Navigation Span: Samora Channel

Samouco salt marshes, a length of approximately 6.5 km, is low level viaduct, punctuated only by two 120m span bridges across the Barcas and Samora channels.

After reviewing alternatives, 80m spans were chosen - the maximum effective span for floating in without heavy craneage. The deck is a twin trapezoidal box lifted separately and stitched together by the transverse deck prestress. Longitudinal prestress is with external tendons and continuity is achieved across the 200mm in-situ stitch at each pier with continuity prestress.

The R C pierlegs and pile caps are supported on 1.7m or 2.2m diameter piles founded at depth below the alluvium.

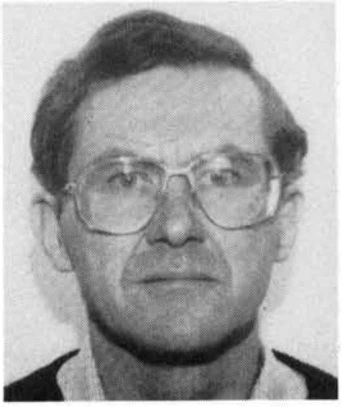
The secondary navigation spans are variable depth box girders constructed using the balanced cantilever, glued segmental method.

A Winning Solution

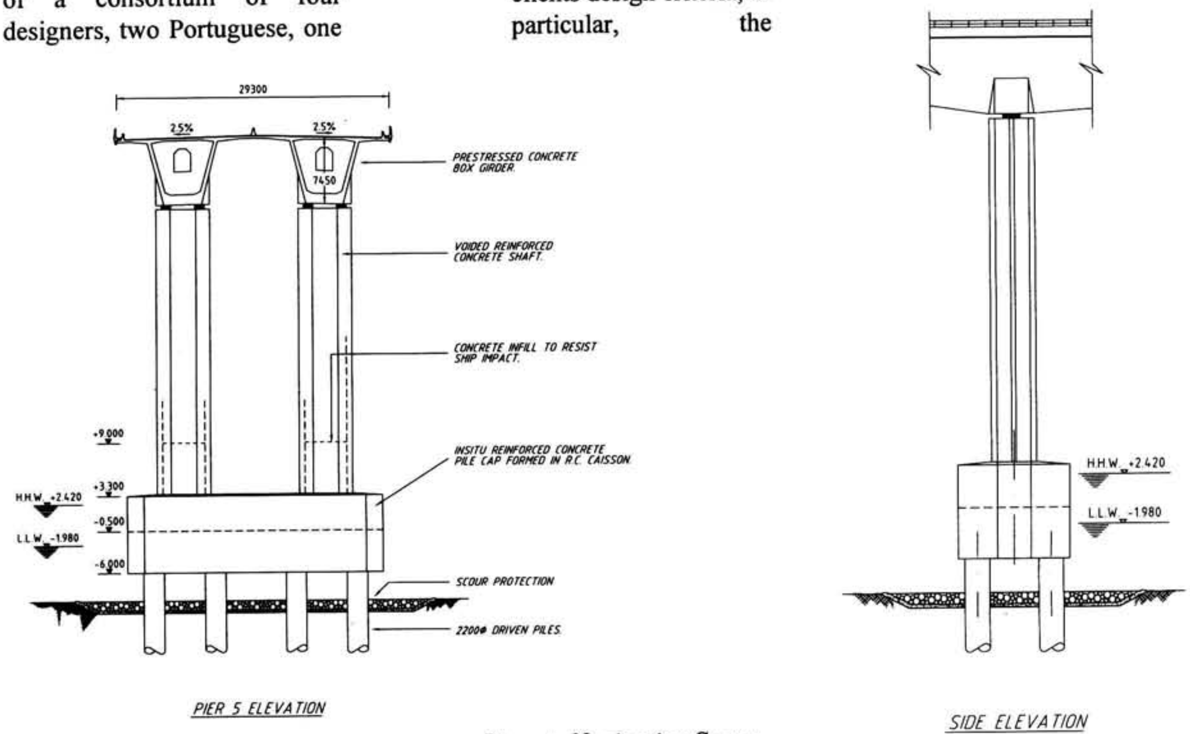
The design is the responsibility of a consortium of four designers, two Portuguese, one French and one British. Each member is responsible for a clearly defined element of the crossing, but under the control of a central co-ordinating team in Lisbon. Additionally the contractors have appointed a designer with overriding responsibility for aesthetics and seismic design, to ensure these key issues are given the right emphasis throughout the design process.

The tender design was developed in two phases, a three month optioneering phase to select the right concepts, followed by a development phase to work up the chosen solutions into the submission scheme with bills of quantity for pricing purposes. Regular development and review meetings were held throughout the tender period to ensure the solutions met the following objectives: -

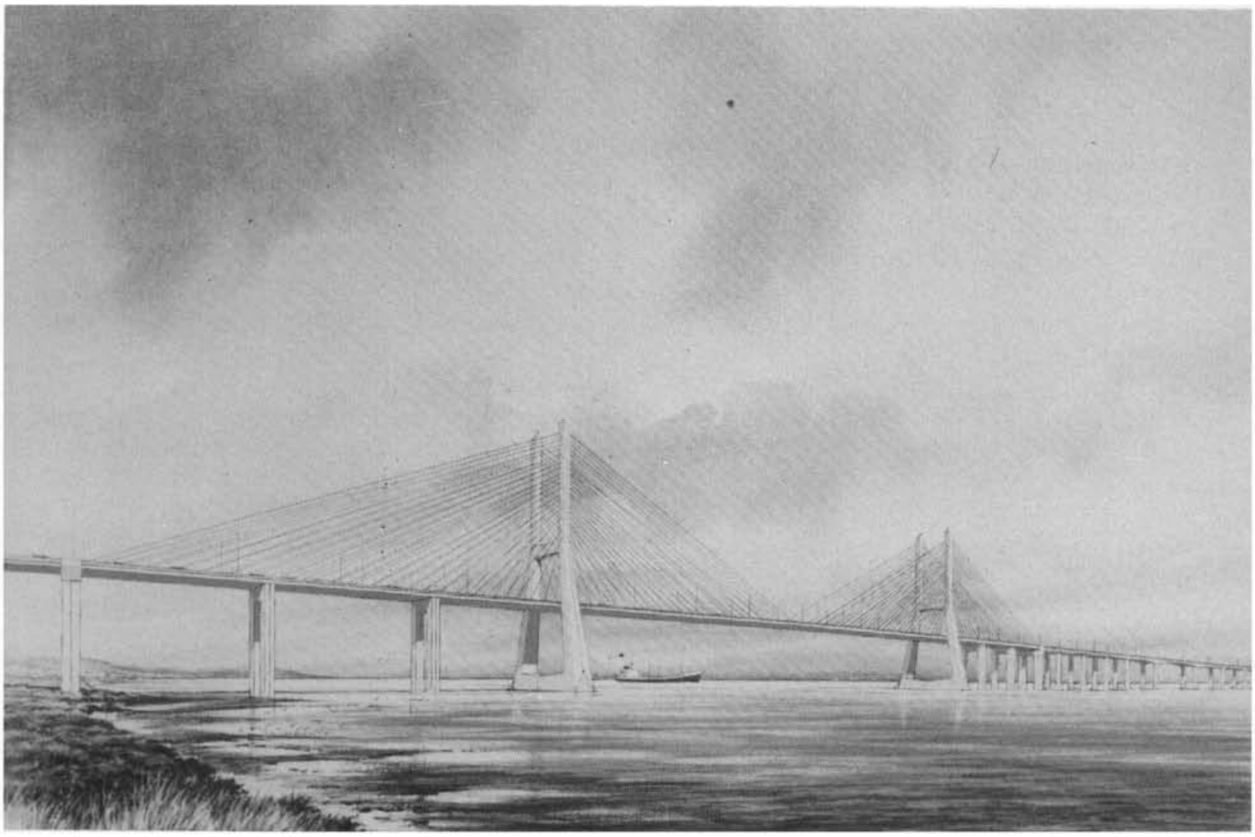
* High visual and technical quality.
* Buildability - essential to achieving the 3.5 year contract period.
* Compliance with the clients design criteria, in particular, the governing seismic and ship impact criteria.
* Ease of operation and maintenance.
* Durability.
* A winning price.



Mr Deason is the Managing Director of THT and Project Director for the Tagus and Birmingham Northern Relief Road projects. He specialises in major transport infrastructure projects, and in particular those procured by the D&C and BOOT routes.



Piers to Navigation Spans



Is Design-and-Build an Aesthetic Wilderness?

by Ronald Yee BA(hons) Dipl Arch RIBA

Bridge Contractors today find it difficult and commercially unsound to include aesthetics in the design development costs, when there is no premium or criteria for good design specifically set down in the tender document.

If bridge Commissioners do not shortlist contractors with a track record for constructing visually pleasing structures, nor set down pre-selection criteria for good design, then design-and-build will remain in an aesthetic wilderness.

Like it or not, competitive design and build (D & B) tendering, as a means of major bridge procurement, is here to stay. Chosen by clients for the advantages it offers of an assured contract period and a fixed contract sum, D & B has been widely criticised for its poor aesthetic results. No contractor nor his team of consultants deliberately want to design or construct a bad looking bridge, neither does a client want to commission one. So why are some D & B bridge designs, so aesthetically poor?

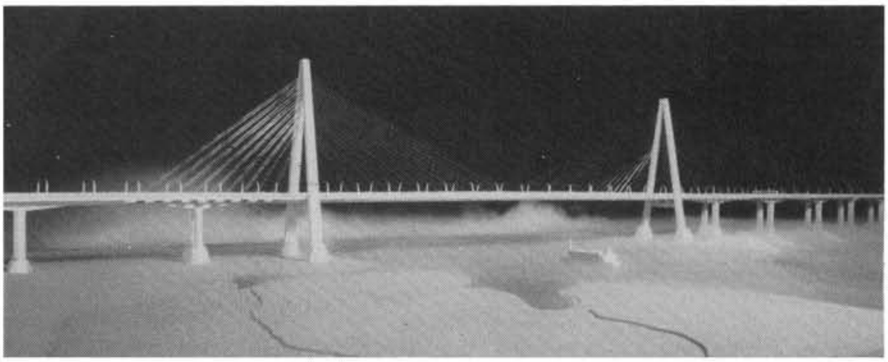
I believe the fault lies in the criteria for D & B tender selection which takes no account of aesthetics, nor for including aesthetically orientated D & B consortia on the tender list.

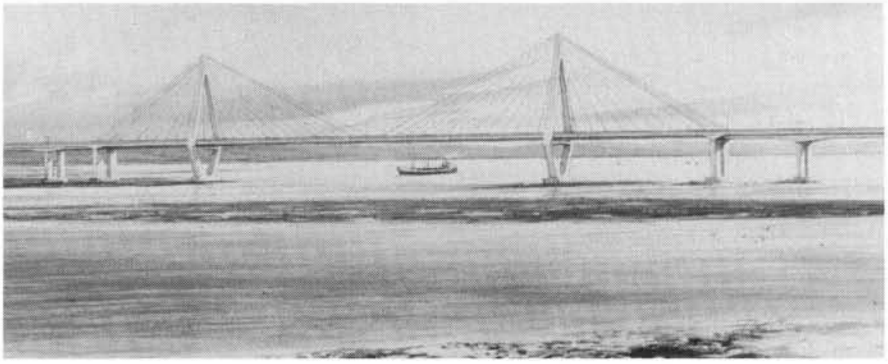
What follows is an account of the selection procedures for two major crossings where aesthetics was introduced into the tender process. The first is British and the second Portuguese, both of them are two-stage, design-build-and-operate tenders. The lessons learnt here suggest there is a better way to ensure that bridge aesthetics is given proper consideration in future.

The Second Severn Road Crossing is intended to relieve traffic congestion over the existing Severn Bridge. The tender was administered by the Department of Transport in consultation with the Royal Fine Arts Commission. It featured an intermediate submission to the RFAC during the tender period, allowing the Commission to comment on the initial designs. A second submission was later made after which two, of the original four designs, were eliminated on aesthetic grounds, following advice from the Commission. The two remaining schemes were then developed further before the final selection was made, based on price and detailed conditions of contract. Although this process has been claimed to be an aesthetic triumph by the RFAC, it is clear that it does not necessarily select the best aesthetic design but merely ensures for an aesthetically acceptable one.

D & B places the responsibility for both the design and erection on the contractor. However, most contractors

opposite Architects Impression of the Second Tagus Road Crossing, Portugal. Viewed from the 1998 World Expo site.
this page Unsuccessful tender designs for the Second Severn Crossing,
above Trafalgar House/Ove Arup,
below Mott MacDonald/ Leonhardt & Andra/ Yee Associates.





find it difficult to perceive or value the aesthetic component of a design and focus instead on construction. Motivated by financial penalties for overrunning the contract period, and bonus for finishing early, they are reluctant to innovate and prefer the assurance of conventional forms and traditional designs. Furthermore, the bridge engineer, being numerical in nature, is generally not attune to the aesthetic implications of his decisions. Without an aesthetic adviser, the engineer can see design only as a mathematical process which meets a functional brief and codified standards.

Obra de Arte
In contrast the tender for the Second Tagus Road Crossing, was largely determined on design merit and not solely financial considerations. Selection, administration and promotion of the tender has been conducted by G.A.T.T.E.L. (Gabinte da Travessia do Tejo em Lisboa) a specially formed quango composed of an international panel of experts with long span bridge experience. It is interesting to note, that the Portuguese title for highway bridge works is "Obra de Arte" *-works of art -* which is an indication of the cultural importance they place on bridges and bridge design.

Originally six consortia pre-qualified from which only three submitted tender designs. Two were shortlisted, mainly on price. A negotiation phase then followed when detailed aesthetic discussions were conducted, design methodology checked and contract details clarified with the shortlisted teams. Upon conclusion of the negotiation period G.A.T.T.E.L. reassessed the amended designs and made its recommendation to the Ministry of Public Works. Selection was based on a points system which favoured design merit, over cost criteria. The decision was duly ratified by the Portuguese Minister of Transport and Communication in April 94.

A description of Lusoponte's, a consortium comprising, Trafalgar House, Campenon Bernard etal; winning design follows.

The Architecture of the Second Tagus Road Crossing.
Due to its vast scale and proximity to the 1998 World Expo site, the new Tagus crossing will become a national landmark and a show case for contemporary bridge design and technical expertise. Therefore for reasons of national pride and impact on the estuary landscape, the aesthetic appearance was considered to be of great importance.

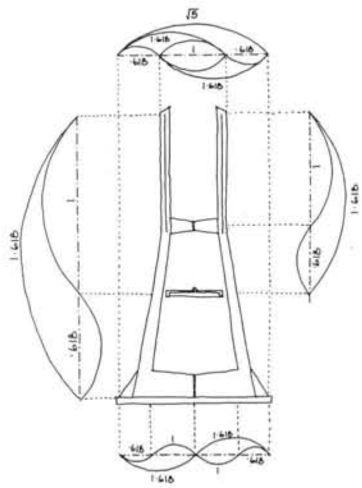
The Lusoponte consortium included architects Yee Associates, who were responsible for the aesthetic appearance of the project and co-ordinating the overall design.

The final design was the culmination of a considerable period of aesthetic design and appraisal, to determine the optimum form for the bridge, the main and approach viaducts, and the Northern and Southern interchanges and toll plaza.

The horizontal and vertical alignment of the bridge has been determined by the planned locations of the traffic interchanges, foundations and navigation requirements. A slight curve in alignment at the Cala das Barcas provides a perspective view of the crossing's southern elevation, whilst on the southern approach the alignments sweeping curve provides a grand overview northwards.

Proportion and the Golden Mean
Several spanning options were investigated for the Cala do Norte and for technical, constructional and navigational reasons a cable stayed arrangement was selected.

Since the pylons are the most prominent feature of the crossing, it was necessary for them to have a clear aesthetic identity and yet be in harmony with the other elements of the construction. Each pylon is conceived

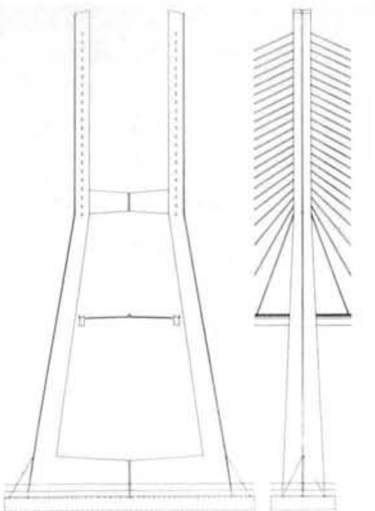


above Pylon shaping and proportion according to the Golden Mean as a pure sculpted form as if carved from a single piece with all surfaces flowing smoothly and continuously, one into the other. Proportioned according to the Golden Mean, the pylon's simple lines gives them an abstract quality that will emphasis the drama of their height. The legs are cranked to allow a vertical cable plane and still provide sufficient clearance for the deck. Acknowledgement of the great forces being transferred through the pylon is expressed by a subtle flaring of the legs, below the change in angle. A mid tie-beam, required for seismic and constructional reasons, is placed according to the golden proportion. Its "bow tie" form integrates it with the pylon structure and lightens its appearance. Omission of a tie beam below the deck, made possible by the shaping of the base, clearly articulates the fact that the deck is actually suspended. A recessed feature is incorporated into the pylons outer edges to break up their mass and safeguard against any adverse weathering.

Back span piers are rectangular in cross section and bear the same vertical feature as the pylons. The difference between the main bridge and approach viaducts is masked by a shaped transition pier with flank walls elevated to parapet level, and topped by a handrail.

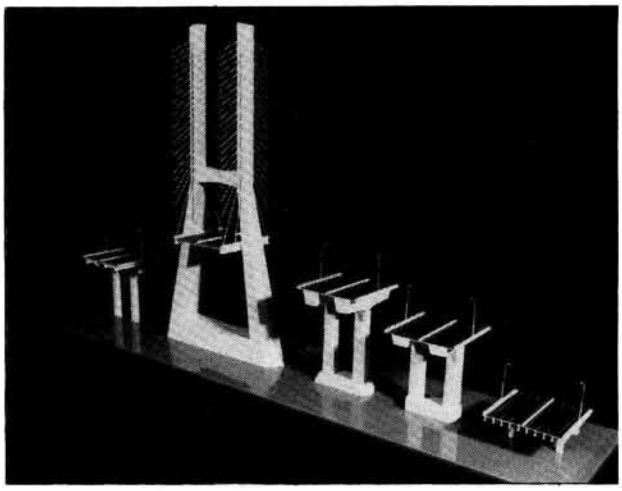
Viaducts

For ease of construction, two types of structural systems are employed for the viaducts. A twin box sectioned deck is used at high level on the northern approach to the cable stay bridge and the crossing over the estuary. The box sections are constant in depth for the majority of the viaduct, but increases to achieve the longer spans over the Barcas and Samora navigation channels. For the low level northern approach and the low level section over the Alcochet & Samouco salt marshes, a launched double tee section deck is employed.



above General arrangement : cable stay pylons

Model sections through main structural elements.



The main spans are 80m, decreasing to 45m at the northern abutment and the low level section over the salt marshes. Maintaining a reasonable span to height ratio and a regular pier rhythm was very important.

Interchanges

Interchange layouts and alignments are mainly predetermined by traffic flow criteria. However retaining walls, underpasses and flyovers are integrated with the design of the main crossing by using similar parapet and concrete detailing, road side furniture, lighting and signage. They are planned to minimise land take and utilise the existing context to maximum.

Toll Plaza

Located south of the crossing, the toll plaza comprises a concession building, administration block, maintenance workshop and garages, toll collection facilities and a police station. The buildings, visible from the road, are designed in a contemporary style using local materials.

Toll booths and collection machines are set under a protective canopy that is profiled to express the individual lanes and incorporate the statutory traffic signage. To aid supervision they are placed obliquely across the plaza.

A central control room is located on the upper floor of the administration building and an all-round observation window provides good visual coverage of the plaza and distant views of the crossing.

Landscape

Strategic use of hard and soft landscape decreases the impact of the new road and integrates it with the existing townscape. Interlocking earth retaining systems are used in areas of cutting or embankment, to permit plant cover. Zones requiring noise separation are densely planted with shrubs and trees, to visually conceal the sound fencing and to diffuse traffic noise with a more acceptable back ground sound, e.g. rustling leaves, etc.

Areas of landscaping and construction are placed to form focal points along the route of the crossing and interchanges. Creating a rich coherent experience that has continuity and rhythm.

Good design must strive to be thorough in intellectual logic, elegance of line and proportion, harmony of components and finish detailing. Collaboration between the architect, engineer and contractor throughout the project period, and not just at the concept stage, is essential if D & B results are to improve aesthetically. The generally accepted measure of quality are the details therefore it is here that the architect can make his greatest contribution.

Ronald Yee is an architect and a partner of Yee Associates. He began bridging as a commissioned officer in the Royal Engineers (V) and is the third generation of his family to be involved with bridges.

Yee Associates specialises in giving architectural advice to the civil engineering profession and are also the architects for the 1400m Tsing Ma Suspension Bridge currently under construction in Hong Kong.

APPEARANCE AND PERFORMANCE OF CONCRETE BRIDGES

George Somerville, PhD, FICE

Photo of GS

"The image of concrete bridges has become somewhat tarnished, partly due to a perceived lack of performance (e.g. corrosion) and partly due to its unimaginative use in some applications, especially motorway bridges. There is now no reason why this should continue. Good and bad concrete bridges are both made with the same basic materials; provided some basic principles are followed, we now know enough to produce bridges which both look good and also meet the more stringent technical performance required for the 1990s and beyond."

"Beauty is in the eye of the beholder". The old maxim certainly applies to bridges. There will always be a subjective element to aesthetics, [1,2] but appearance also depends on location, on the viewpoint (literally) and on whether the bridge is new or well through its service life - some designs mature better than others.

Nevertheless, there are some basic principles, which, if applied, would make more bridges more attractive to more people more of the time. I will look at these briefly. However, aesthetics cannot be treated in splendid isolation. Bridges are there for a purpose and also represent a life-time financial commitment to the owner. In both regards, we are in a period of change. On function, the cost of traffic delays during construction and maintenance, has become a major issue. There is growing recognition that many bridges can become obsolete relatively quickly (e.g. the current motorway widening programme) and we are grappling with this simultaneously with a perceived lack of technical performance (e.g. corrosion due to deicing salts - an unknown 'loading', at the time of design). This has sharply increased our interest in life-cycle costing, [3] on the financial front.

Some hard lessons have been learnt on these issues, and there is a growing belief that we can quantify them, even in cost terms. Engineers are comfortable with a quantitative approach. While some performance aspects do affect aesthetics - and can be quantified (e.g. durability) - appearance in general is qualitative, and harder to put a price tag on. Against that background let us look at some basic principles, and at how they have worked (or not) in the past.

Some Basic Principles

Past experience tells us that appearance, linked to technical performance in durability terms, depends on significant design input at each of three different levels. These levels are:-

Design concept - *How to balance often conflicting needs, in arriving at the 'right' structural type and form, built to a good standard with the right materials to meet clearly-defined performance requirements on the actual location, for a prescribed period of time, with agreed levels of maintenance.*

Architectural and Engineering Detailing *- Edge treatments. Bearings and articulation. The handling of water, in all its forms. Sub-structure type, and its detailing, with respect to the superstructure. Parapets. Merging the structure into the location. etc, etc.*

Surface Treatments *- Decorative, colourful or protective. This may often be the icing on the cake, but can enhance even a mundane design, especially in weathering terms. Long-standing guidance still holds good [4], but there are new opportunities* *here, with new 1990s materials, for more imaginative approaches.*

Design concept and detailing are the fundamental issues. In developing good design instincts on these, we must also be aware of the buildability factor. The criteria for that may have changed in the 1990s, but there has to be a compatible marriage between design concept, construction method and choice of materials. This was recognised in the last century, became 'lost' in this one, but is now being re-introduced with a shift in methods of procurement.

Concrete Options

All concrete bridges fall into one of three categories:-

- arches
- suspension/ cable-stayed
- beams

Figure 1 briefly itemises current construction methods, with respect to span. It may be seen that there is a strong emphasis on building beam-type bridges by different means. Beams far outnumber the other two types, and it is here that most mistakes have been made in the past, both in terms of appearance and performance.

Arches

Arches are compression structures. Arches and concrete therefore go together, where location and function permit. It is an attractive structural form, comparatively invulnerable to vagaries in design and detailing, although care is necessary in proportioning, and in avoiding fussy details. The art was perfected by Robert Maillart some 60 years ago, and there are some magnificent examples of concrete arches throughout the world, for spans between 10 and 350m. Arches do need the right setting, can be more expensive or impose functional limits (headroom). Nevertheless, they are inherently idiot proof, and are not considered often enough.

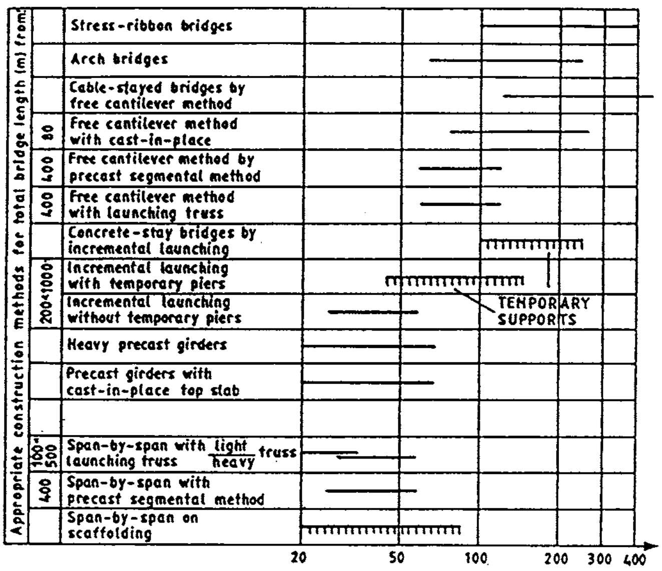


Figure 1: Limits of modern bridge construction methods for 20 to 400m spans

Cable-stayed bridges

Until relatively recently, there was no major track record for concrete. This has now changed.[5] The reducing cost of cables, coupled with concrete's cost advantage for the deck, is now offsetting concrete's major disadvantage: weight. Spans well over 400m are becoming common, but cable-stays are also being used at the lower end of the span range; down to 35m in France, where it is a practical option for motorway widening.

As with conventional suspension bridges, aesthetics are very much a question of scale, proportioning and detail. There are few examples in the U.K.; one well known landmark on the M25 suffers from deficiencies in proportioning and in details. There is nothing wrong with the concept; aided by modern prestressing technology, this is another structural form, whose use should increase right across the span range.

Beam-bridges

These can look very good, both in urban and rural environments; two personal favourites are - London Bridge and Kylesku Bridge in

Figure 2: example of motorway overbridges built in the early 1960s

Figure 3: Examples of the influence of poor detailing and appearance of concrete bridges

the north of Scotland.

However, they can go badly wrong, also. Nowhere is this more obvious than with motorway over-bridges. Figure 2 shows four examples of the breed, photographs taken when the bridges were relatively new. On a scale of 1 to 10, I rate these between 2 and 8, considering aesthetics, weathering and durability together. While location and cost can set limits on what might be achieved, good detailing can improve performance significantly. Figure 3 shows two examples, where this has not been achieved. This type of deficiency can lead to major repair bills, and, in extreme cases, to major re-construction, or even demolition, because of the vulnerability to corrosion and other debilitating mechanisms.

The Concrete Bridge Development Group (CBDG)

This embryo group - now 2 years old, and a mix of 96 owners, consultants, contractors, material producers and academics - is currently concerned with improving technical performance standards to meet the perceived changes in need, briefly outlined in the Introduction. This is reflected in a simple listing of active Task Groups, within the CBDG:

* *Durable post-tensioned grouted construction*
* *Life-cycle costing*
* *Detailing for buildability, durability and adaptability*
* *Concrete options for motorway widening*
* *Bridge assessment - maintenance, management and upgrading.*

The emphasis on the maintenance of function is clear, as is that on durability. Durability, at least, can be directly related to appearance, and hence directly to the theme of this Conference. However, the real points being made here are that performance requirements for bridges are currently undergoing significant change, and that we need to re-examine the balance that we want to strike between - function and technical performance with time;

aesthetics; environmental issues (in the broadest sense) - and, of course, cost (what we are prepared to pay, both in the short and long-term).

What can be done?

There is no single answer. A better balance between choice of bridge types will help, as indicated earlier. So will the activities of the CBDG, in providing information on what does and does not work, at the detailing level.

However, we need to take a fundamental look at what we are trying to provide, in terms of function and appearance - at a price. This is timely, since performance requirements are changing, as are productivity and procurement methods to meet these changes.

Above all, we need a change in culture. In developing better design instincts, there has to be recognition that numeracy is not king. This is an educational problem, in that much that is important cannot be taught conventionally. The bridge pioneers of the 19th century understood this intuitively, in merging design and construction with a full understanding of materials, to produce bridges which both looked good and lasted. We now have enough experience and know-how, to do the self-same thing with the major material of the 20th century - concrete.

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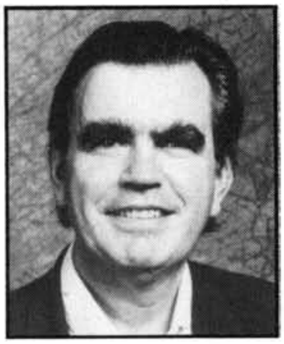


TERRY FARRELL
OBE, MRTPI, FSCD, RIBA

Terry Farrell grew up in Newcastle on Tyne and attended the University of Newcastle School of Architecture from 1956 to 1961.

He founded his practice in 1965 as a partnership with Nick Grimshaw, and has continued it in his own name since 1980. Over the past thirty years he has had considerable and diversified experience in architecture, urban design, planning and conservation, in all types of built projects and studies.

He was awarded the Order of the British Empire for services to architecture in 1978.

In London the River Thames has acted as a physical barrier to development of a railway network that links the north and south of the country.

Thameslink 2000, for which Terry Farrell & Company were appointed Masterplanners, will provide a route of much greater capacity linking the north and south of the country, without the need for inconvenient interchanges.

The design proposals and recommendation are in two stages. Stage One deals with improvements at Farringdon, Blackfriars and London Bridge; with new grade separations at Bermondsey and New Cross Gate. Stage Two involves the creation of a new rail link from Kings Cross to the East Coast line.

The design development of Blackfriars Bridge Station and the New Cross Gate flyover are described.

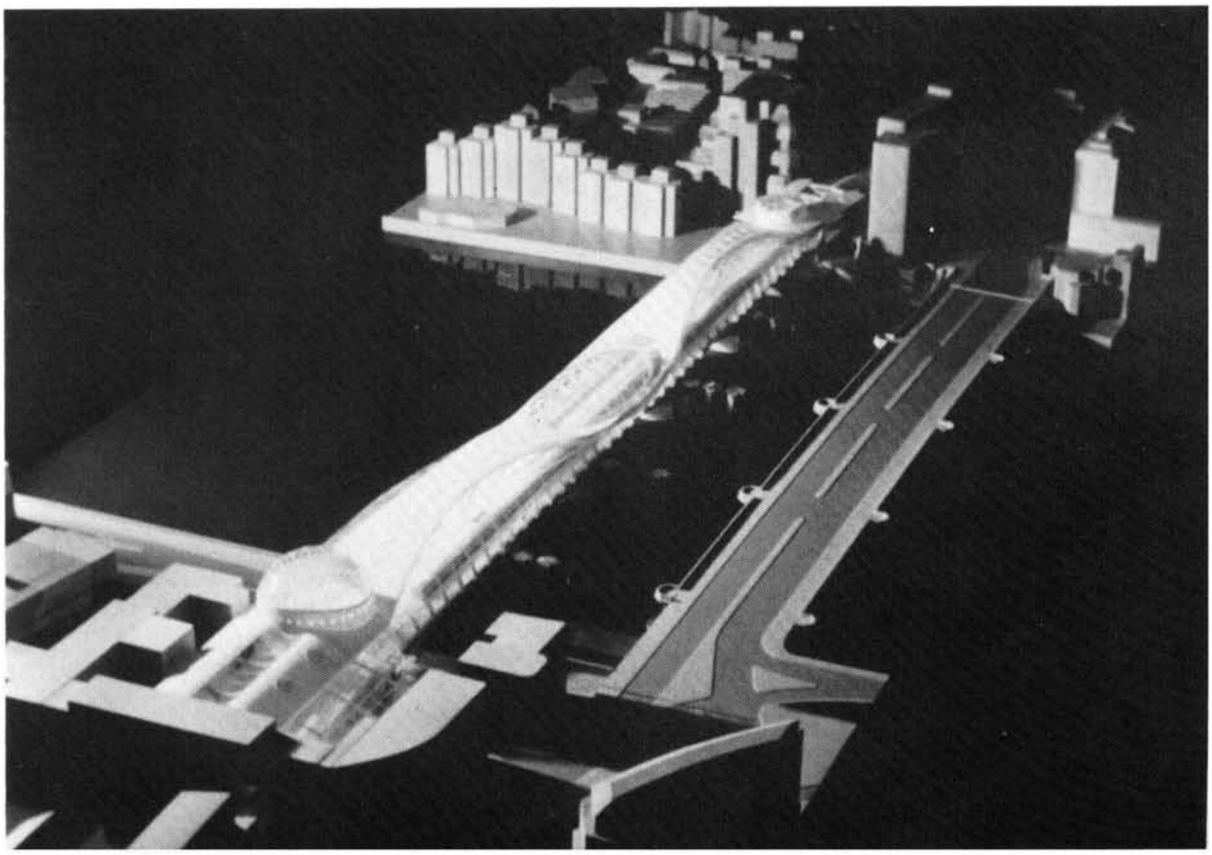
BLACKFRIARS BRIDGE STATION

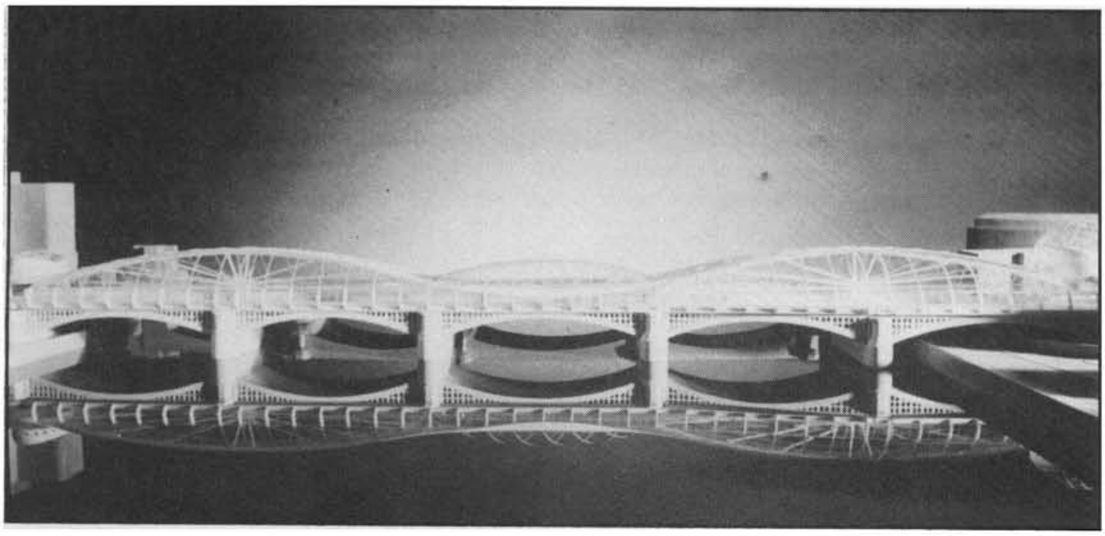
Blackfriars is the centrepiece of the Thameslink Project, providing a station spanning the River Thames and thereby giving visible expression to the name 'Thameslink'. It presents one of the most challenging design opportunities of today for a railway network of the future.

As an architect I have always been fascinated by railway lines and stations and the way in which these were superimposed on an existing urban order in the 19th Century, to create the present day pattern.

The compelling business case for increasing the Thameslink capacity and train frequency needs to be matched by a station which captures public imagination, whilst also meeting many technical criteria to ensure an efficient, sensible and easily buildable design.

Blackfriars Bridge Station - The New Station Enclosure





Photograph of Model Station

CONSTRAINTS AND OPPORTUNITIES

Blackfriars Station demands a design solution which will ensure that it becomes the flagship of the whole Thameslink Project; an instantly recognisable and well-known landmark. The building must provide an enjoyable, welcoming and comfortable environment for all the travelling public, with easy access, practical design and a readily understood layout.

The project presents a number of practical difficulties which must be overcome. These include: constructing an appropriately modern structure on a Victorian bridge; providing a design which takes account of the sensitivity of the setting of Blackfriars Bridge, in particular St Paul's Heights views, the adjacent listed road bridge and the conservation area. Uuderstanding the practical issues relating to maintaining the Thameslink service during the period of construction; being aware of the structural implications inherent in re-using an existing bridge structure. Creating design and technical solution which facilitate buildability and maintainability on a structure which spans a major waterway. Understanding the complexity and significance of the approvals process necessary to achieve this unique project. Providing public presentation and advocacy for the project throughout its passage through the approvals process, which will include major national bodies and heritage organisations.

EARLY DESIGN IDEAS

The station design has been analysed into its three components: Blackfriars North, Blackfriars South and the bridge superstructure. These have been synthesised into a sculpted form which will both excite and arrest public imagination whilst respecting its noble surroundings.

The new superstructure has been designed to relate to the Victorian bridge structure whilst maintaining its own structural and design integrity. It takes its shape from the rhythm of the historic bridge, but does so in counter point, creating light and activity across the water both by day and by night, responding to changes in light patterns from the surrounding environment.

The southern end of the bridge at Southwark has been designed to maximise accessibility to platform levels from the street below, whilst protecting the operation of neighbouring Express Newspapers and Lloyds Computer Centre. It meets the requirement for disabled access and links to the riverside walks. Again, a light and generous hall at the southern end marks the southern station arrival point on the platform above the river bank.

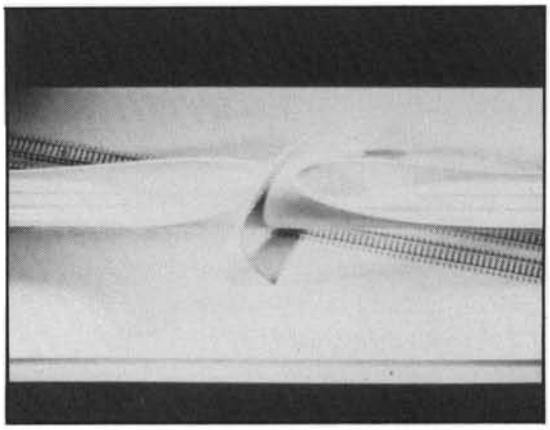
Views of the new station from up and downstream have been carefully considered to ensure that the scheme is in no way creating a `wall across the Thames'.

Night-view of Proposed Station

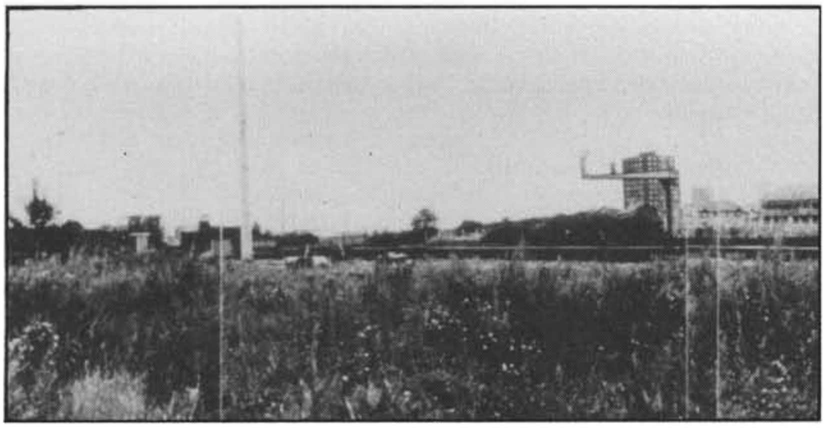
NEW CROSS GATE FLYOVER

As at South Bermondsey, it is intended to rationalise the existing infrastructure through the elimination of flat junctions. In order to transfer the Thameslink services from one side of the main tracks to the other, it is necessary for a new track to be carried over the main tracks. This cannot be achieved effectively by points which would cause intermittent disruption to through services.

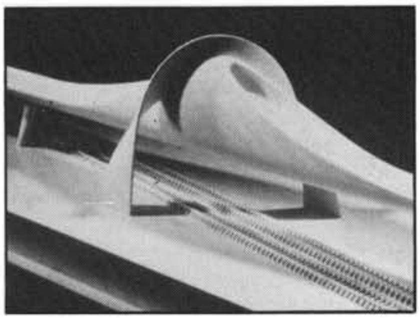
Whitby & Bird concept of overhead view



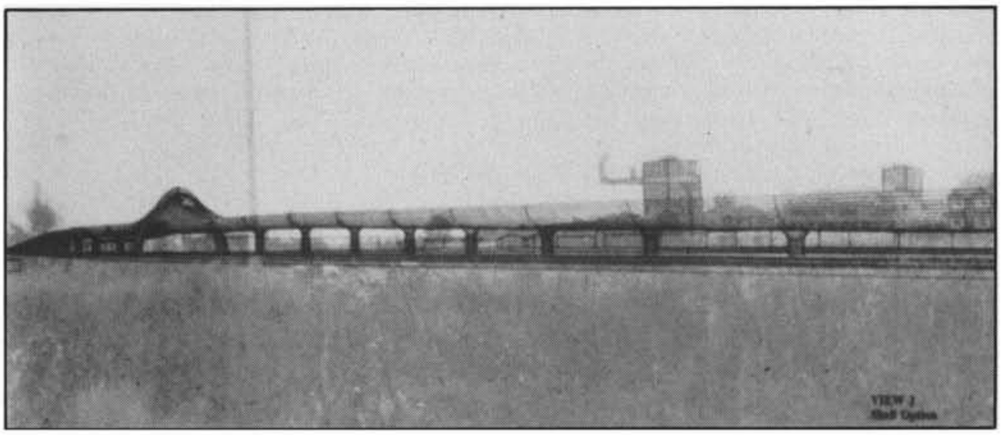
New Cross Gate Existing



Whitby & Bird concept of oblique view



New Cross Gate the Shell Viaduct Option



THE SHELL OPTION

Designed by structural engineers Whitby & Bird, the "Shell Option" for the flyover at New Cross Gate has been derived from a concept of spanning the existing track by the shortest distance - at almost right angles. The centre of the main span is supported by a twisted arch, which also serves to give lateral and torsional stiffness to the bridge.

This somewhat unorthodox design provides an economic, aesthetically pleasing and technically practicable solution for the flyover at New Cross Gate.

"A DAY IN THE LIFE"

Andrew Carruthers BSc MICE

He is Divisional Director of DHV (UK) responsible for the Civil Engineering Division. Since joining Freeman Fox in 1983 he has worked on a number of Bridge Projects, most notably the Second Bosporus Bridge Crossing.

He was project director for DHV on the £350m Thameslink Project, which introduced him to Terry Farrell and bridge aesthetics.

"Is the design of good looking bridges the domain of master bridge engineers only or do "typical" bridge engineers have something to offer? It is "typical" bridge engineers that are responsible for the design of the vast bulk of bridges and have, potentially, the most to offer. They must place aesthetics, architecture and the environment alongside shear lag and bending moments, as part of the design issues".

I am a fairly typical bridge engineer in the United Kingdom with a fairly typical career history.

After graduating with a civil engineer degree, I worked on a wide range of projects including power stations, sewage treatment works, hospitals and the most enjoyable, a brewery bottling plant. In 1983, I joined Freeman Fox, in those days, the master bridge engineers. I was involved in the design of bridges ranging from suspension bridges, such as the Second Bosporus Highway Bridge, to small culverts. I continued this work through the 80's until today.

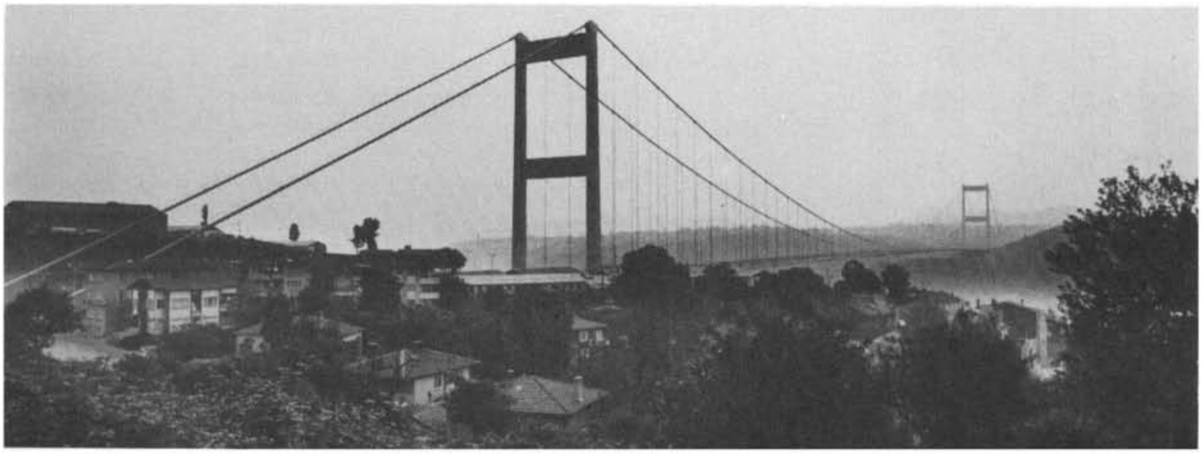
It is "typical" bridge engineers that are responsible for the design of the vast bulk of bridges. The majority of bridges are motorway overbridges, railway underline bridges, pedestrian bridges and so on. Not many are major river crossings. The environment of the United Kingdom is dominated by the more humble bridge.

Although I maybe a "typical" bridge engineer, I can distinguish between good and bad designs and what looks pleasing to the eye and what is awful. The majority of humdrum bridges in the United Kingdom look miserable, tawdry and ugly.

There are those saying that we must improve the quality of the environment, the quality of bridges. Nobody is going to argue against those principles.

Now is the time to re-examine engineering thinking and re-assess the bridge design process.

Fig 1: The Second Bosporus Highway Crossing - an example of good design.



The question is "how do we make it happen?". What can a "typical" bridge engineer do when he next sits down to design a typical humdrum bridge. His training is probably like mine. He knows more about bending moments, shear lag, torsional and distortional warping and prestress forces than form, balance and visual symmetry.

THE GOOD AND THE UGLY

We can make a start by critically reviewing past work, both the good and the ugly, to increase awareness of design skills and shortcomings.

In my experience for the "good" read the Second Bosporus Highway Crossing (Figure 1). The towers at 106 metres high are relatively short for a suspension bridge. The design team was concerned that this would create towers of stocky appearance. The aesthetic appeal of suspension bridges is in the sleekness of the deck and the slenderness of the towers. Extensive design efforts were made to keep the towers as slender as possible. In the end the towers measured 4 metres by 5 metres at the base tapering to 4 metres by 3 metres at the top. Quite an achievement and an example of good design.

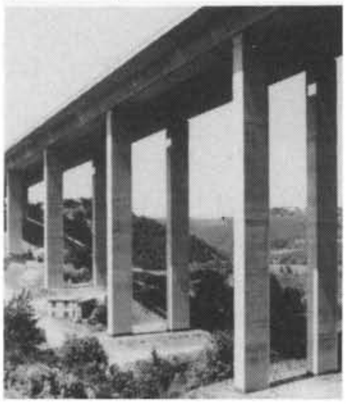


Fig 2: The Elmali Viaduct - does the structural form look right?

For the "ugly" read the Elmali Viaduct, part of the approach road to the Second Bosporus Highway Crossing (Figure 2). On this multispan bridge, the design team were conscious not to create a solid wall of piers. Maintaining the openness of the area and of the spans internally was thought to be important. Does the structural form look right, when seen from ground level? On a structure of this form, the

appraising bridge structures as routine. I have been helped by working alongside architects. When a "typical" bridge engineer sits down to design a typical bridge, he needs to embrace aesthetics, architecture and the environment as part of the design issues. The debate is not about engineer versus architect, what it is about is good design and all that it incorporates.

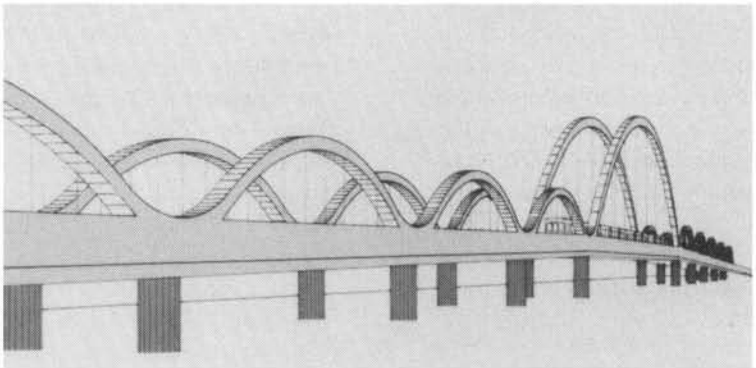


Fig 3: Initial concept for bow-string option for New Cross Gate Flyover - affectionately known as Nessie. The twin cylindrical piers gave the substructure an awkward look.

proportions between height, width and spacing of the piers dictates the aesthetic quality. Although economically designed the proportions tend to make the structure look squat. Perhaps tapered piers would have been better seen from ground level, accentuating the height and sleekness of the spans.

Many say "immediate change is not possible because it's got to be integrated into the education and training of bridge engineers of the future". I say a "typical" bridge engineer has much to offer and much he can learn from his own experience and curiosity.

In my experience, bridge designers can acquire an aesthetic eye by looking and

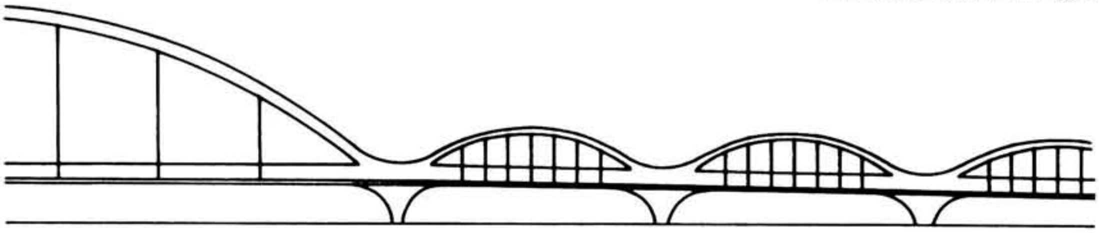
ENGINEER AND ARCHITECT SYNERGY

For me, the most rewarding experience was working alongside architects on Thameslink 2000.

British Rail planned to upgrade its existing cross - London Thameslink route, which links passenger services from north and south London via Blackfriars Bridge. At present, no trains can run during peak hours over parts of the Thameslink route. There is either no spare capacity on the track or at some of the junctions. Our study showed that additional railway infrastructure was needed at five locations in central and south-east London.

The engineering team in DHV had been working on the scheme for many months. The key section being between Southwark Street and London

Fig 4: Later sketch of "Nessie", the twin cylindrical piers replaced by single conical piers to mirror the superstructure appearance. The vertical cables were brought in front of the concrete noise barrier to create a more slender and unusual appearance.



Bridge Station, a distance of some 700 metres. Our proposal was to construct a new railway viaduct, carrying two tracks, alongside the existing viaduct. The new viaduct would be constructed on the southern side of the existing and would be a mix of structural types, including steel trusses and reinforced concrete decks.

The engineering solution was sound, but what about the importance of historic structures such as the Borough Market, the Hop Exchange and Southwark Cathedral. A new viaduct would have a significant impact on the community. At £350 million,

Thameslink 2000 is a major engineering project and will impact on the environment of London. We were aware that the works would affect the character and appearance of the area. We were aware of archaeological remains. Management of the social engineering and environmental understanding of the urban

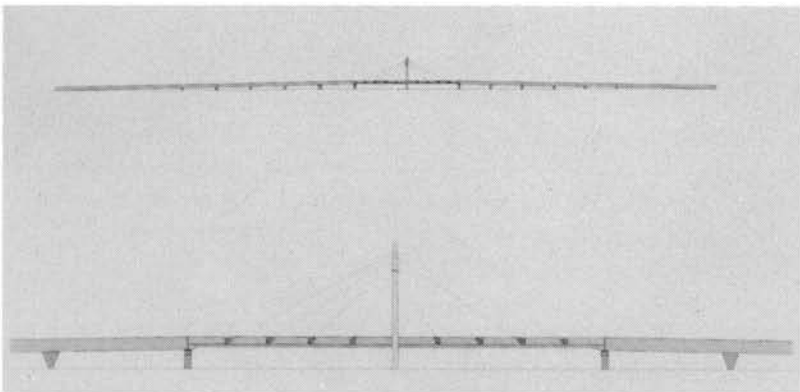


Fig 5: Concept ideas for cable-stayed options for New Cross Gate flyover. The aim was to produce a landmark structure with the lower visible from some distance away. The chimneys to the nearby South East London Combined Heat and Power Station, approximately 100 metres high, the shorter towers to the cable-stayed flyover would hardly be the desired landmark.

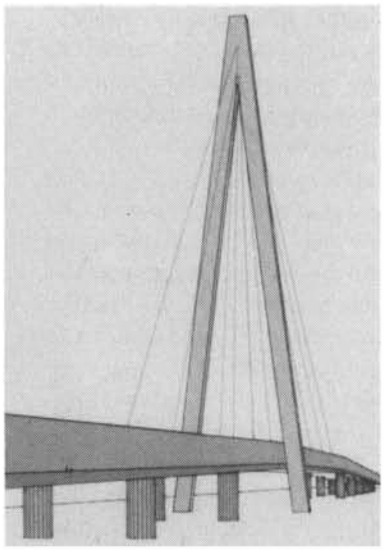


Fig 6: The isomeric view highlights the problem of dull, repetitive approaches.

landscape was vital. We were not sure how to tackle these problems.

The engineers on Thameslink pressed for architects to be appointed. There was no pretence, that as engineers, we would be able to deal with the full breadth and depth of environmental issues. Working with the right architect was essential.

The impact on team spirit and design innovation was dramatic.

In came the historical perspective and the relationship between the existing railway and this part of Southwark. When the viaduct was built in 1862 it created an urban barrier. To this day the area north of the viaduct is "up-market" and that to the south is "down-market".

I learnt about "permeability" through studying aerial photographs. Although maps of the area give the impression of a densely developed urban block, the opposite is true. The footprint of the viaducts at ground level is quite minimal and if the stalls were removed, the Borough Market area could be a vast open space to the foot of Southwark Cathedral.

A series of masterplan studies looked at environmental mitigation and environmental enhancement. The studies looked at opportunities to exploit positively the proposed works and to remove urban barriers, to regenerate this part of Southwark. The masterplans illustrated that bridge architecture is not just about the structure and its appearance. It is about the whole environment.

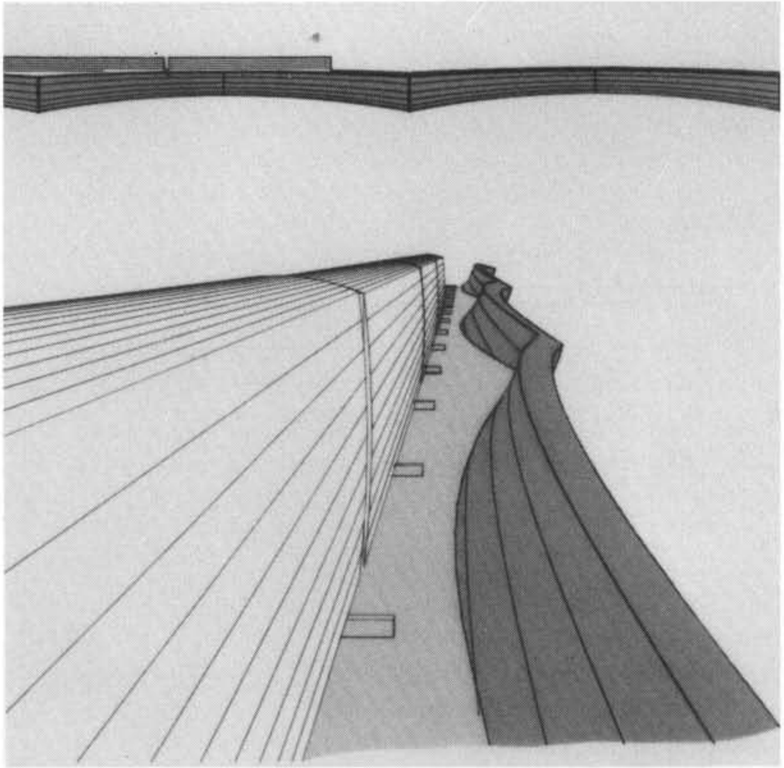


Fig 7: The "Hyperboloid" - simple yet varying. Cost effective construction using re-usable formwork systems. The noise barriers become an integral part of the structural form. Further interest could be created by the use of blue pigmented concrete.

Architecture began to become part of the engineering language. I began to look at structures, such as New Cross Gate Flyover quite differently.

NEW CROSS GATE FLYOVER

At New Cross Gate, a viaduct carrying a single track was required. The viaduct would be long, potentially up to 750 metres, with a main span of 140 metres. Particular attention had to be paid to the relationship between the main span and the approach structures. Creating a feature of the main span and ignoring the approaches is a common mistake. Yet it is the approaches that so often dominate.

The area is fairly flat with mainly residential and industrial land use. From nearby streets and houses only glimpses of the viaduct would be seen. Even train passengers would only see short stretches from their windows.

It was important that the structure had interest along its full length. Shrugging aside the engineers fear of playing with ideas, a number of alternatives were developed (Figures 3 to 8). The "typical" bridge engineer was able to stimulate discussion and debate. Some of the ideas were adopted, those that were not, could always be used for other schemes in the future!

The structure was not viewed as a series of elevations, plans and sections, but actual views from street corners, from windows on a train and from windows of houses. The views of the local residents were sought and an understanding developed.

NO EXCUSE FOR BANALITY

After Thameslink I recognised the true potential of the engineer and architect synergy. The major lesson I learnt was that bridges, no matter how small, can add to the environment and can open up the environment. Starting from a position of mitigation is defensive.

Now I tackle a bridge project quite differently. Understanding the site is key to the solution. An arbitrary style should not be imposed on the environment. This, in itself, will lead to tremendous variation from pure engineering and thinking.

Bridges are about people. It is important that we build bridges that people can relate to, not necessarily monuments and certainly not monstrosities.

I learnt that the efforts put into good bridge design are well rewarded. Local residents, councillors and the travelling public could see that we were putting forward a product that addressed social and environmental engineering, as well as structural engineering.

Good bridge engineers need to show off their new found skills to remain adaptive and receptive to change. Hiding behind codes and specifications is an excuse for mundane banal design, not a reason.

Good bridge design may cost a little extra money, but the rewards are larger. Bettering people's environment and quality of life is a worthwhile goal. "A day in the life" of a bridge engineer will forever become days to remember.

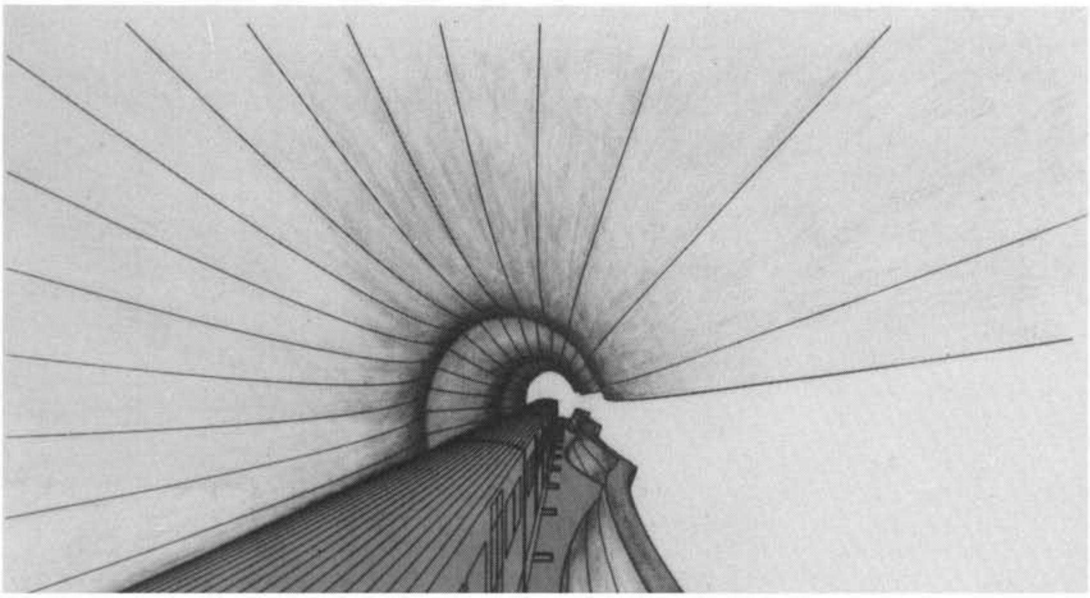


Fig 8: With railway noise such an issue at New Cross, an obvious extension of the "Hyperboloid" concept.

THE BRIDGE

The linking of places via bridges symbolises co-operation, communication and interdependence.

For this reason the bridge is one of the most important structures that is built. Because it is often a pure expression of structure, it has come to be assumed that the bridge is the province of the engineer. Historically architects have designed many bridges, although often on a small scale, which emphasise an elegance, and sometimes a human dimension, beyond what we experience in today's designs.

The design of bridges has removed itself from the architect as spans and loads have increased. In other words there is a perception that this is beyond the capabilities of the architect.

NOT SO.

The other major enemy of the architects involvement in Bridge Design is very often the method of procurement. This is most in evidence on motorway bridges. Often feasibility studies precede construction by years and when eventually the work proceed it is tendered to contractors who are allowed to propose variations on designs, that have not been fully designed. It is no wonder that the client is reluctant to pay for carefully considered design work for something that might not be realised for 10 _ 15 years and then be totally replaced.

As a result of this not even the engineers, let alone the architects, are used properly. As a result, we, the public, have to endure ugly bridges. This is not good enough.

William Alsop

THE ARCHITECTURE OF BRIDGE DESIGN

26 October 1994

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Bee	Simon	Benroy Limited
Bennett	D C	Devon County Council
Bennett	David	David Bennett Associates
Beuvink	John	Atkins Lister Drew Ltd
Black	Jim	Highways Agency
Boothman	John	Sir Alexander Gibb & Ptnrs
Borland	Kirsteen	Royal Fine Art Comm Scotland
Bourne	Simon	Robert Benaim & Associates
Bowden	Geoff	L G Mouchel & Partners Ltd
Bradley	John	BRETS
Brandon	Clive	Railtrack - Major Projects Div
Bridge	Mike	WS Atkins Consultants Ltd
Brown	David	British Waterways Board
Buckby	Roger	Sir Williams Halcrow & Partner
Burns	Andy	L G Mouchel & Partners Ltd
Busby	Peter	WS Atkins
Cadell	Bill	Royal Fine Art Comm Scotland
Carr	David	Leeds City Council (Dept.Highways)
Casey	Joseph	Highways Agency
Champion	Martin	Mott MacDonald Group
Chauhan	Ashwin	Avon County Council
Cho	Bom-Sik	Daewoo UK Ltd
Church	Robin	Essex County Council
Clark	Michael	Rust Consulting Ltd
Clark	Gordon	Gifford & Partners Ltd
Clash	Peter	Peter Clash Associates
Clutton	Eric	Churchill House
Collard	Mike	Sir Robert McAlpine
Collings	David	Robert Benaim & Associates
Collins	John	Highways Directorate
Collinson	Andrew	Sir Alexander Gibb & Ptnrs
Conisbee	Alan	Alan Conisbee & Associates
Cooke	Richard	Ove Arup Partnership
Coxon	Steve	Surrey County Council
Craig	Richard	WS Atkins Consultants Ltd

Name	Forename	Company
Darrall	Les	DHV
Davies	Nick	Trafalgar House Construction
Davies	Stephen	Ove Arup & Partners
Day	Adrian	Ove Arup & Partners
Dobrovolsky	Leszek	Sir Alexander Gibb & Partners
Duckett	Antony	A.D.A.D.
Dugmore	Katharine	British Waterways (WES)
Dyke	Alan	Union Railways
Dyke	Sally	Highways Agency
Dyson	Steve	Ove Arup & Partners
Eyre	Jim	Studio 2
Firth	Ian	Flint & Neill Partnership
Foster	Matthew	DHV
Fraenkel	Peter	Peter Fraenkel & Partners
Freeman	Anthony	RAF & Associates
Gaitt	Clive	Ove Arup & Partners
Gerrelli	Les	DHV
Gill	Jolyon	Acer Consultants
Gingell	Robert	Kent County Council
Gordon	Ron	Balfour Beatty
Grant	Cynthia	London Dockland Dev Corp
Hammond	Colin	Nottinghamshire County Council
Hampshire	Peter	DHV
Hardie	Philip	Harris & Sutherland
Hartley	Peter	DHV
Head	Peter	Maunsell Limited
Healy	Paul	Parkman
Hewson	Nigel	Acer Group Ltd
Hollands	Paul	Balfour Beatty
Hollett	Graham	Derbyshire Consulting Engin.
Horwell	Nigel	Cornwall County Council
Hughes	W R	Osborne Ltd
Hunt	Tony	Anthony Hunt Associates
Iles	David	Steel Construction Industry
Jeffers	Edwin	L G Mouchel & Partners Ltd
Jensen	Poul Ove	Dissing & Weitling Architects
Johnstone	Raymund	Scottish Office Industry Dep.
Jones	David	BCA
Jongejan	Maarten	Hollandia BV
Kerkovius	Andreas	Stewart Scott Inc
Kirkdale	Alan	Highways Agency
Kirkland	David	Nicholas Grimshaw & Partners
Kirkman	Keith	WSP Kenchington Ford

Name	Forename	Company
Kirkpatrick	James	DOE
Kreps	Alison	BBC Television
Kuiper	Hans	Ingenieursbureau NS
Lang	Alastair	Bridon International
Lamont	John	DHV
Leeming	Mike	L G Mouchel & Partners Ltd
Lendford	David	Architecte FAS-SIA
London	Gary	Brown and Root
Low	Angus	Ove Arup Partnership
Luscher	Rodolphe	Architecte FAS-SIA
Lynch	Martin	Highways Agency
MacIntyre	Duncan	Ove Arup & Partners
Macfarlane	Tim	Dewhurst Macfarlane
Maisey	Simon	
Major	Alan	Acer Group Ltd
Marshall	Graeme	Rendel Palmer & Tritton
Martin	Peter	DHV
Massam	Brendan	Ove Arup & Partners
Matthews	Stephen	Frank Graham Cons Engs
Mayne	Keith	Highway + Transport. Services
McKittrick	Bob	Scott Wilson Kirkpatrick
Melhuish	Clare	Building Design
Moller	Pouli	Dissing & Weitling Architects
Moore	Greg	DHV
Murray	Morris	Babtie Shaw & Morton
Naylor	Andrew	Bridon International
Newman-Sanders	Edward	Ove Arup & Partners
Nicholson	Tim	Sir Alexander Gibb & Ptnrs
Nielsen	Lars	Ove Arup & Partners
Norfolk	Tony	Kent County Council
Nourbakhsh	Farhad	Robert Benaim & Associates
O'Sullivan	Kevin	O'Sullivan & Graham Ltd
Otlet	Mike	WS Atkins - Oxford
Palmer	John	AMEC Civil Ent Ltd
Parker	John	W S P Kenchington Ford
Parkes	Matthew	
Parody	Derek	Parkman
Payne	Lucy	BBC Television
Peakin	Maurice	London Docklands Dev Corp
Perry	Paul	Sir Alexander Gibbs & Partners
Peters	John	Nottingham County Council

Name	Forename	Company
Potts	Martin	Kent County Council
Prendereast	Sophie	Amey Construction
Price	David	Sir Alexander Gibb & Ptnrs
Prosser	Charles	Royal Fine Art Comm Scotland
Puaar	Jaswir	Highways Agency
Quick	Tim	Sir Norman Foster Partnership
Raiss	Mark	Robert Benaim & Associates
Ramsay	David	DHV
Rawson	John	SCI
Redelinghuys	Johan	WS Atkins Consultants Ltd
Ridley	Tom	Royal Fine Art Comm Scotland
Rowley	Frank	Tony Gee & Partners
Ryall	Michael	University of Surrey
Saunders	Jeff	Travers Morgan Limited
Schreuder	Max	DHV Environment & Infrastruct.
Scott	Trevor	Dewhurst Macfarlane
Sewell	Steve	Hertfordshire County Council
Shanmugam	Shan	The Highways Agency
Slavid	Ruth	Architects Journal
Slocombe	Nick	Rust Consulting Limited
Smit	Jo	New Civil Engineer
Smith	Steve	Highways Agency
Smith	Michael	British Waterways (North East)
Southcott	Martin	Reinforced Concrete Council
Spackman	Bob	Tony Gee and Partners
Stanley	Pat	Mott MacDonald Group
Stafford	Nev	DHV
Stearman	Martin	Atkins Lister Drew Ltd
Steedman	Bob	Royal Fine Art Commission
Steven	Tim	Railtrack MPD
Sutherland	James	Harris & Sutherland
Tame	Roger	Guildford Borough
Tasker	David	Travers Morgan
Taylor	Malcolm	L G Mouchel & Partners Ltd
Thomas	M	Acer Wallace Evans
Thompson	Sheila	LDDC
Thompson	Vincent	Vincent Thompson Architects
Tivey	Graham	Ove Arup & Partners
Troughton	Jamie	Troughton McAslan
Valentine	Carl	WCC Dept Planning & Highways

Name	Forename	Company
Van Doorn	Bart	Bouwdienst Rijkswaterstaat
Van der Ree	Paul	Ingenieursbureau NS
Wall	Mick	Hertfordshire County Council
Wallace	Alasdair	Crouch Hogg Waterman
Wedgwood	Roland	Royal Fine Art Commission
Weeks	Ronald	Percy Thomas Partnership
Weertman	D	Bouwdienst Rijkswaterstaat
Weller	Mile	Highways Agency
Wernick	Jane	Ove Arup & Partners
Whalley	Andrew	Nicholas Grimshaw & Ptns
Wheatley	Rob	DHV
Whitby	Mark	Whitby and Bird
Wilkinson	Duncan	Ove Arup & Partners
Wilson	Ian	Ove Arup & Partners
Wilson	David	Royal Fine Art Commission
Withycombe	Stuart	Sir Williams Halcron & Ptnrs.
Wood	Humphrey	
Woodward	Richard	Transport Research Laboratory
Van der Weijde	Henk	Bouwdienst Rijkswaterstaat

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