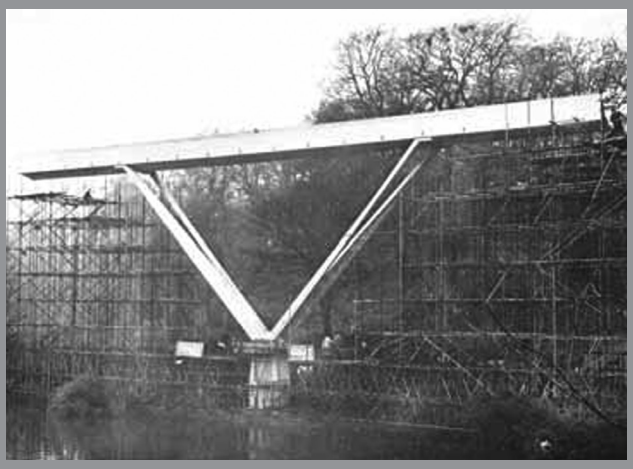
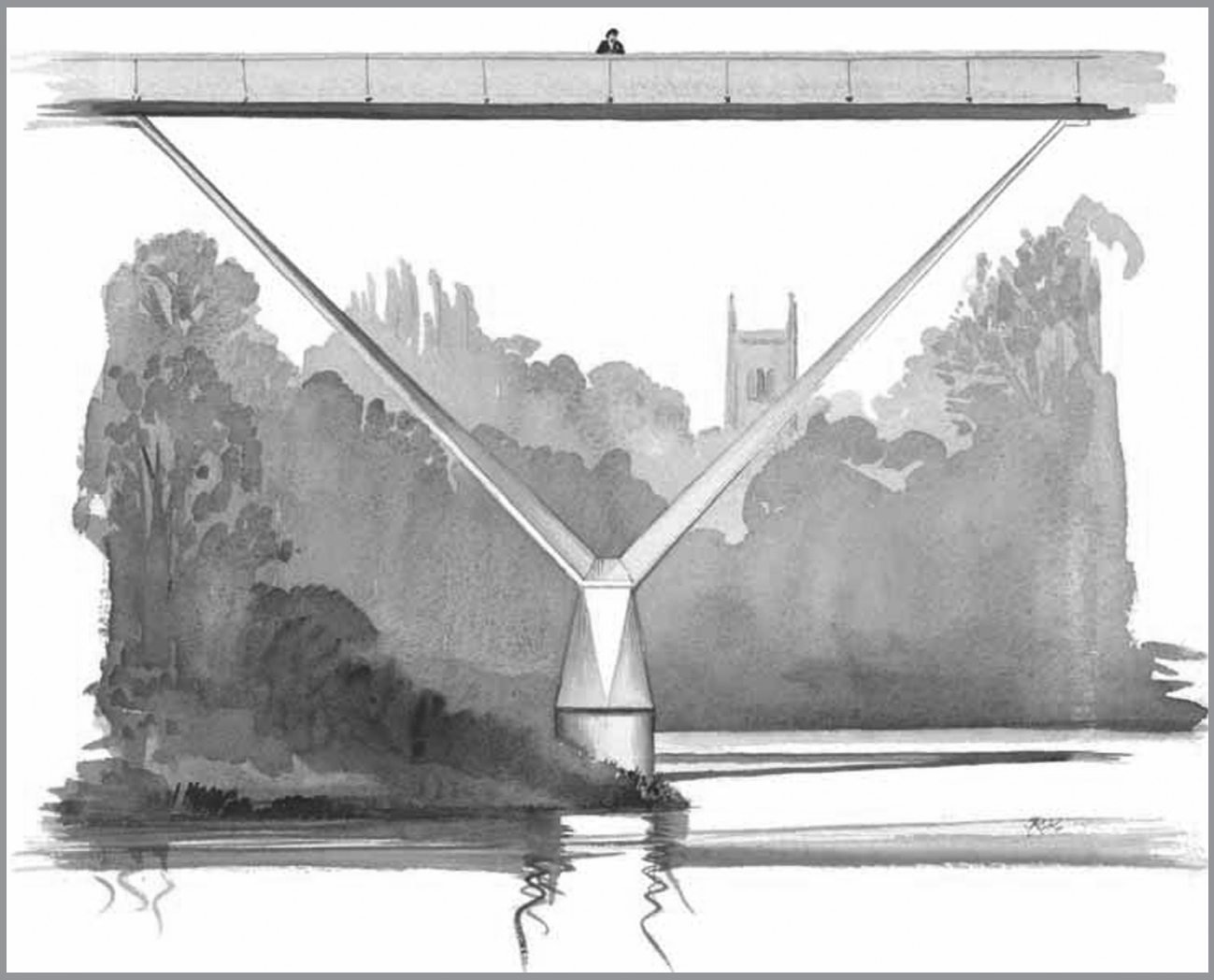
Sir Ove Arup: The Design of Bridges[1]





OVE ARUP (1895-1988) once said in a BBC interview that the two structures that had given him most satisfaction were the Highpoint flats in North London (1935) and the Kingsgate footbridge, Durham, Yorkshire (1963), as "both are rather perfect examples of the complete integration of architecture, structure and method of construction".

By Jørgen Nissen

BUT before Kingsgate Ove had designed other bridges. Although they were for real none was built, for reasons unconnected with their design. But he wrote about them in an article that appeared in the Arup *London Newsletter* 21 and 22, February and April 1964, written a few years earlier so that Kingsgate only comes in with a few final lines, almost as an after thought.

In 1961 Ove had shown sketches of some of his bridge designs to his CIBA friend the Italian architect Ernesto Rogers (1909–1969), who was then editor of the architecture magazine *Casabella*. The article "*Cinqueponti*" duly appeared in June 1961. Ove changed it lightly two years later, and a shortened version, "Trois projets de ponts", appeared in the October/November1963 issue of *L'Architecture d'Aujourd'hui*. *The London Newsletter* editor, Rosemary Devine, reverted to the longer English original for the Arup publication (but to a then very small internal audience).

It is a fascinating article, well worth studying even now almost 50 years later, and not only by bridge engineers. In it Ove lucidly describes what he meant by what he would later call "total architecture"—which, what ever we call it now, is very much what we are about. He wrote extensively about "total architecture" through out his career, but usually in the abstract, almost philosophically. Here, uniquely in his writings, he is addressing the subject in specific contexts, with real if unbuilt examples, revealing step–by–step how his thoughts progressed.

He says it all at the start, emphasising that he is writing about bridges: "... a more rewarding field for the study of unity between architecture and structure. A bridge is architecture with a clear and simply formulated function. All one has to worry about is the stability, durability, cost, and appearance." And as for appearance: "there will always remain a number of more or less arbitrary decisions, which have to be made on purely aesthetic or sculptural grounds. I suggest, however, that the best result is obtained if there are very few of such arbitrary decisions to be made, in other words, if decisions affecting proportion and form at the same time make structural and constructional sense".

In spite of writing for an audience of architects—or perhaps because of it—he did not offer any thoughts on how these decisions should be taken. He did not need to. He was writing about the engineering. In the earlier *Casabella* version he had included a small footbridge at Bowring Park, St Johns, Newfoundland, but he almost apologises for it at the end of the paper: "it does not really belong in this series because the method of construction is not in any way out of the ordinary and in fact, the whole object is small and insignificant and presents no structural and constructional difficulties. But the appearance was important—it always should be anyhow. This is therefore a case of satisfying function and structure in a pleasing and neat manner—construction is of lesser importance."

And when he refers to Kingsgate at the end he adds: "Although appearance was of major importance in this case, the form was largely influenced by structural and constructional considerations". He did work with the architect Yuzo Mikami on this bridge and it is a great pity that he could not include a full account here and so close the argument.

A few years later, in 1971, Ove was asked by the Institution of Civil Engineers to advise on "how to improve the appearance of engineering structures...if architects are not to muscle in on the Engineer's domain" (sic!)... and "please write a paper which will teach engineers how to design beautiful and efficient structures". True to character, he wrote a fairly long paper explaining why he could not write such a paper, concluding: "you cannot make rules or principles for what is beautiful, but you may be able to learn by examples of good design—by studying it in *statu nascendi*". He does just that in this article. All four bridges were to be built over water and therefore called for particular engineering expertise. Ove had that expertise; he had been chief designer for contractors specialising in marine structures for nearly 20 years: "We were designers and contractors in one, design and construction were naturally integrated. Now the bulk of designers are mostly unacquainted with the problems on site."

The construction methods he proposes are complex,

< Kingsgate Bridge in Durham by Ove Arup, under construction and watercolor. Completed in 1963.

but as ever Ove explains them in simple direct language. He is aware of the danger of writing expost but he writes about it as it is, not leaving out ideas that had to be aborted and only including the successful ones. The construction methods are all quite sophisticated and would have been innovative at the time but feasible. His partner Geoffrey Wood (1911–2007), who had a great deal of experience of working in Africa, did argue that the Ghana bridges required technology not then available in Africa. But Ove insisted that they had been "designed down to the last detail". So they had, but then maybe the local contractors did not yet have an Ove .

Would we do the same today? We might. But technology has moved on; we now have at our disposal stronger and more durable materials, more precise controls and better methods of analysis and forecasting, more sophisticated construction methods, etc. The limits of what we can now do have expanded. And society has greater expectations; environmental and social issues are significant and Ove's "more or less arbitrary decisions" now weigh heavier in the balance sheet.

He would have approved. His approach is as relevant now as it ever was, even if the input to the process and therefore the outcomes may be different. It is a pity that these four bridges were never built, but he did at least leave us the best: the delightful Kingsgate bridge and our approach to "holistic design".

After the article was written, the Ministry of Transport, then England's main client for bridges, announced its first–ever design competition, for the Calder Bridge in Yorkshire. 110 designs were submitted, five of them from Arup (*London Newsletters* 19–22, January–May 1964), a team from Povl Ahm's group including Yuzo Mikami as architect won a special prize. This led directly to the award in 1965 of our first bridge project by the Ministry, the Gateshead Viaduct, and the Highways and Bridge group in London was born. Ove took an interest—and sometimes more than an interest—in some of our subsequent bridges, particularly the Jesmond Dene Bridge in Newcastle, close to his birthplace. The design was almost ready for tender when the project was cancelled following public pressure not to demolish the existing wrought iron Armstrong Bridge built in 1878. This is in fact a striking bridge and is now listed.

Kylesku Bridge in the Scottish Highlands

The Kylesku Bridge has one of the most remote and dramatic and beautiful sites in the British Isles—a unique site worthy of a unique bridge:

> *Bridge design is an intimate mixture of design and construction resolving a 'chaos of facts and circumstances into a unique and beautiful unified whole'. Using the examples of bridges designed throughout the world, the authors make the case that while a bridge engineer will seek unity, consistency, scale and proportion, and an eye for detail, the overriding factor in bridge design is the importance of the site, its precise shape, and the views from it.*[2]

A Little Background

The west coast road between Ullapool and Scourie at the northwestern tip of Scotland is interrupted at Kylestrome by a deep sea loch. The bridge replaced a ferry that operated from dawn to dusk. After dark, which comes early during the winter, travellers had to make a 110 miles long detour if they wanted to cross the loch. The Highlands Regional Council therefore took the initiative to upgrade the road link under the Crofter Counties Scheme and included a bridge at Kylesku in the project.

A bridge would make travel available around the clock and so improve contact between the scattered local communities and help them to co–operate and explore the tourist potential of the area.

The Road

The topography in the area is exceptional. Rock faces rise steeply from deep sea lochs on the severely indented coastline in a dramatic landscape that poses an exciting challenge to road designers.

Great care was taken in fitting the road as closely as possible to the contours to preserve the character of the landscape, and by avoiding to make deep cuts in the granite the new works were made to act in sympathy with the land forms.

As a result, the road winds it way through the hills in a continuous series of curves. One of these is at the crossing of the sea loch at Kylesku.

The Bridge

The width of the loch at the crossing is at about 135 m and the bridge is 278 m long between abutments. It is a serious bridge, and to propose that it should be curved in plan was very unusual at the time. The received wisdom then was simply that road bridges are straight.

The clearance under the bridge was set to 24 m by the Department of Trade, apparently to allow the Royal Yacht Britannia to pass under the bridge when it were to be opened by the Queen! Nevertheless, the two beautiful inland sea lochs attract cruise vessels and yachtsmen who now have a very attractive entrance to the lochs.

The form of the bridge is intimately linked with the method of construction.

The sea loch is narrow and very deep at the bridge site, and tides through the narrows are very strong, ruling out any falsework over the water. But the generous height above the banks was used to create an understructure

Images of Kylesku Bridge when it was built in 1984 and today.

with inclined legs that reduced the spans of the deck, as at Ove Arup's Kingsgate Bridge at Durham. The deck is a relatively shallow and economical hollow box girder made from prestressed concrete.

Exposed to very high 100 mph winds, the structure is very stable and expresses that stability.

Building the road and the bridge was a major and challenging undertaking. The remote site and the climate with its severe winters and very high winds (measured in excess of 100mph) called for sophisticated construction techniques and made access and deliveries of materials difficult and expensive. In spite of this, the bridge was completed within the planned time frame.

The bridge was built in three stages. The two landward spans were built first from the abutments to the landward legs of the piers, and they were then completed between the landward and seaward legs of the piers. In both stages the *in situ* structure was supported on major temporary works founded on the rock. Finally, the 85m centre span was cast on a temporary jetty at shore, floated out, lifted into position and stressed back to complete the structure. The bridge is made from concrete to make it practically maintenance free in this remote area but easy access is still provided for inspection and maintenance.

Was it Worth it?

Queen Elizabeth II formally opened the bridge in August 1984. It has been a great success. It has not only received many awards for design and construction but it has also, and more importantly, dramatically changed the lives of the people living in the area. Community activities such as education are now shared across the region, small co-operative industries based on fishing and agriculture have been established and a lively tourist industry has developed.

Even the road and the bridge have become tourist targets in their own right as witnessed by the large number of photographs uploaded on Flickr.

The drive along the winding road is interesting and extremely pleasant and at the bridge the continuously changing views for drivers and hikers give them a closer rapport with the surrounding nature than they would have on a straight bridge.

This was Arup's first curved bridge and we have since made use of curves on bridges whenever it has been appropriate—as for example most famously and at a much larger scale at the Øresund Bridge between Denmark and Sweden.

On Total Design

Arup is about Total Design. This is an example of Total Design at its best—all important factors—the relation to the site, structure, construction, appearance, economy—were taken into account right from the start. And in this case the major factors turned out to be the site and construction.

Notes

1. From foreword from article in The Arup Journal 2/2009.
2. Introduction to "Total design of bridges" by Bill Smyth and Jørgen Nissen in *Arups on Engineering*, Ernst & Sohn, 1996.

Jørgen Nissen

Joined Arup in 1962, at first designing shell structures. He was one of the prize-winning Calder Bridge competition team and later in attendance at the birth of the Highways and Bridges group. He was made a director in 1977, a main board director in 1984 and a trustee in 1992. He retired from the board in 1999 and as a trustee in 2004. He is now a consultant to Arup.