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Aesthetics and Construction of Bridges in Japan and in Great Britain

Esthétique et construction des ponts au Japon et au Royaume-Uni

Ästhetik und Konstruktion der Brücken in Japan und Grossbritannien

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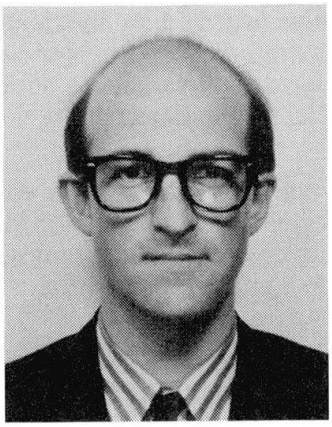

Alan Burden, born in 1960, studied civil engineering at Imperial College, London, where he also received his MSc degree. He worked for five years on the design of civil and building structures before starting his current comparative study of bridge design in Japan and the UK.

SUMMARY

The paper draws attention to the interaction between construction method and finished form in bridge design. The influence of constructive features on completed bridge appearance in Japan and the UK is compared against the background of recent aesthetic policy in the two countries.

RESUME

Cet article met l'accent sur l'interaction entre les méthodes de projet et l'apparence finale des ponts. L'influence des procédés de construction sur l'aspect final des ponts est présentée en tenant compte des récentes recommandations esthétiques au Japon et au Royaume-Uni.

ZUSAMMENFASSUNG

Dieser Artikel befasst sich mit der Wechselwirkung zwischen Konstruktionsmethode und Endgestaltungsform in der Brückenprojektierung. Der Einfluss von Konstruktionsmerkmalen auf die endgültige Erscheinungsform der Brücken in Japan und Grossbritannien wird den jüngsten ästhetischen Richtlinien beider Länder gegenübergestellt.

1. INTRODUCTION

Construction method can greatly affect the form of bridge structures. However, in the literature on design, the approach taken to the resolution of conflicts between requirements of constructability and those of visual form are discussed only rarely. The author has studied several recent bridges in Japan and the UK with the aim of discerning characteristic philosophies in the two countries for this aspect of design. Eight of these bridges are included as representative examples in the paper.

The bridge engineer needs to decide the degree of influence he will allow construction method to have on the finished form. In other words, how much should the structure be distorted from the desired final form in order to accommodate a particular construction method? Such questions arise in other types of civil engineering structures, and in building engineering too, but for bridges the construction method plays a crucial role in determining the viability of a design.

Looked at in a different way, we can ask to what extent the construction process can be considered a valid generator of form. If the construction stage has such importance, then perhaps it too should be readable in the completed bridge; the removal of all trace of construction may in this way be seen as another form of deception or decoration.

The differences in approach between the two countries have been influenced both by the particular circumstances of local civil engineering industry, and cultural trends in aesthetics.

2. ORGANIZATION OF DESIGN AND CONSTRUCTION IN JAPAN AND THE UK

For large projects in the UK a consulting engineer will normally be appointed to lead the design and prepare a detailed scheme for issue to contractors under tender. The option for the contractor to offer an alternative design will often be included, although the preparation of such alternative designs is at the contractor's expense. Attempts have been made to stimulate greater competition on recent bridge projects by tendering on a design-and-build basis. In these cases teams of contractors and consultants have been invited to submit priced proposals with freedom to select form within design restraints. Selection of the winning scheme has been based not only on price, but on factors such as aesthetics and buildability [1].

Japan has a long tradition of design being undertaken by the client in-house. This system has ancient roots, but emerged in its modern form following the introduction of industrial technology into Japan by foreign engineers during the late nineteenth century, and continues today in bridges commissioned by government and the road corporations. Most of the well known pre-WWII bridge engineers were attached to the civil engineering departments in Tokyo or Osaka city governments.

Although the first private bridge design office was established in the 1920's [2], widespread adoption of consulting engineers only began after the war. Today their role in the design process continues to be more limited than in the West, with overall design management remaining more completely with the client. The client will often employ several consulting engineers on a single project. Other specialists employed to advise on aspects of appearance will also be appointed directly to the client rather than to the engineer.

The further important feature in Japan is the degree to which contractors are able to offer design services. Whilst full design-and-construct projects are rare in bridge work, there are many examples where contractors tender or negotiate a contract on the basis of scheme design only, pricing to include detailed design in-house. However, under normal tendering procedures, contractors are not permitted to offer alternative designs.

3. CASE STUDIES ON BRIDGES IN JAPAN

3.1 Hamana Bridge 1976

Two features of the bridge had great bearing on the construction process. Firstly, the girders are made monolithic with the main piers. This allowed cantilevered construction from pier heads without the need for bents or temporary fixity. Secondly, piers are introduced at unusual positions in the side spans. The girder depth is still changing as it passes over these piers, giving a section depth which allowed construction of the adjoining portions by cantilevering from temporarily fixed heads.

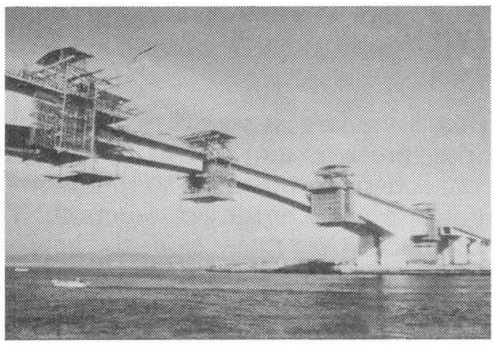

Fig. 1 Hamana Bridge

3.2 Ohshima Bridge 1988

Ohshima was the first suspension bridge in Japan to use a box-section girder. Constructionally, an interesting area of the design is the jointing methods used. Site connections of both towers and girder were made using simple friction-grip bolt connections with cover plates (excepting the girder upper flange which was site welded). Tower legs were erected in sections of just 6m length, giving ten horizontal joints above deck level in each leg. The joint positions are clearly visible, giving the observer an appreciation of the assembly process.

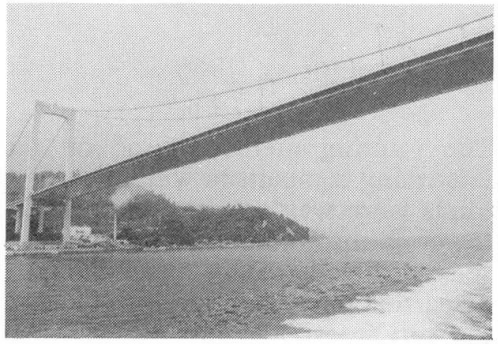

Fig. 2 Ohshima Bridge

3.3 Shorenjigawa Bridge 1989

The forms of many Japanese steel box-girder bridges show very flat soffit profiles, the girder often becoming of constant depth a short distance away from the piers. On Shorenjigawa the depth is constant for over half of the main span length. It is interesting also to compare this bridge with Foyle in the UK where moment prestressing was used during erection. River access for floating cranes allowed erection in large blocks for the main and north side spans, giving just two bolted joints. A large part of the south side span was erected in short sections off bents.

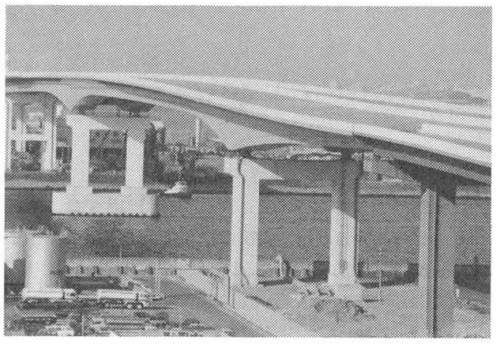

Fig. 3 Shorenjigawa Bridge

3.4 Hokawazu Bridge 1974

This bridge is a two-hinged RC arch of 170m span. It was the first in the world to be constructed using a full-cantilever method with cabling tied back over the abutment spandrel walls. In order to carry the high vertical reaction generated by the cables, these end walls were made of much heavier section than those adjacent. Visually there is a very clear difference in the scale of these walls. The influence of wind and seismic loads prior to closure on the abutment seats was minimized by flaring the ends of the arch rib.

Fig. 4 Hokawazu Bridge

4. CASE STUDIES ON BRIDGES IN THE UK

4.1 Orwell Bridge 1982

This is the largest prestressed concrete bridge in the UK. Like most examples of this type, the girder-pier connections are pinned, so that temporary propping was required for cantilever erection. The girder is fully continuous over main, side, and approach spans, giving a strong, smoothly transitioned camber line. The approach spans are gradated to progressively shorter length away from the centre of the bridge for visual reasons. Large chamfers are given to the tops of each pier in order to emphasize the role of the bearings. The cutwaters are pointed, but have rounded plane intersections.

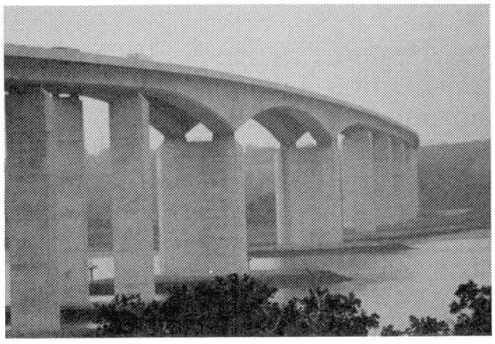

Fig. 5 Orwell Bridge

4.2 Severn Bridge 1966

The jointing methods used on this bridge make an interesting comparison with those on Ohshima. The girder joints were welded all-round on site. For the horizontal tower joints internal tension rods were used to stress sections together. This meant that all jointing work could be carried out within the towers, and that the joints were virtually invisible externally. This type of joint was first used on the Forth Road Bridge, and was used subsequently on both Bosporus Bridges. Ultimate efficiency in material use seems to have been a design aim; the bridge has one of the lowest unit steel weights for its type.

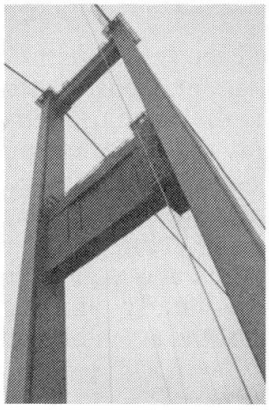

Fig. 6 Severn Bridge

4.3 Foyle Bridge 1984

The bridge was designed by a joint venture under a design-and-build contract, so that the contractor was involved in the design from the outset. A strongly cambered soffit line was chosen, and the section depth at mid-span was minimized by use of moment pre-stressing during erection. Minimum weight was a clear design aim; a steel weight of 0.45 tonne/m^2 was achieved comparing with 0.70 tonne/m^2 on Shorenjigawa.

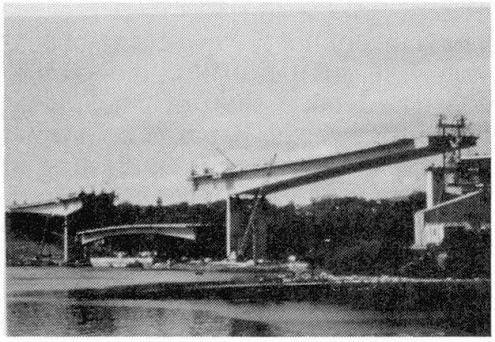

Fig. 7 Foyle Bridge

4.4 Kessock Bridge 1982

Like Foyle Bridge, this project was realized under a design-and-build tender system. Deep plate girders run continuously along each edge of the bridge, supporting an orthotropic deck on cross-beams. The approach piers are notable in that no cross-heads are provided. They are of sufficiently slender proportion that temporary bracing was required between the legs during erection cantilevering to carry wind loads. Temporary cables were also required to support the main spans near the pylons during erection.

Fig. 8 Kessock Bridge

5. AESTHETIC POLICY IN JAPAN AND THE UK

Following the bold and individual designs by the great bridge builders of the industrial revolution, early twentieth century work in Britain gradually discarded ornament and historical reference. Pioneers in the new materials of concrete and steel produced structurally expressive works with less and less recourse to factitious elements. Disguise was used only as a means of achieving pleasing lines. For example, gerber type bridges came to be given continuously curved soffits (Wandsworth Bridge, 1940). Completeness and boldness of individual elements was valued.

The first Japanese steel bridges to be designed without the assistance of foreign engineers date from around the turn of the century. Not surprisingly these showed a close resemblance to Western work of the time. Japanese engineers were often sent for training in American or European design offices, and many had been taught by Western engineers working in Japan. By the time of the re-building work after the Great Kanto Earthquake of 1923, well known bridge designers had emerged. Although there was some participation by architects at this stage, this practice gradually ceased as the separation between their work and that of the civil engineer became more and more defined by end product rather than discipline. The separation of roles in this way remains a major feature of Japanese construction today.

Amongst bridges built in Tokyo after the earthquake, many similarities can be found with contemporary European practice. Gerber forms appeared with suspended spans firstly of constant depth (Kototoi Bridge, 1928), and later with curved soffits (Ryokoku Bridge, 1932). Vertical stiffeners were attached externally. The early flat profile seen in gerber bridges has continued to be used in modern continuous types more frequently than in the UK, generally simplifying fabrication of the central span.

The war produced an abrupt break in Japanese engineers' writings on aesthetics. Hardly any discussion appears until the seventies, when the various road authorities began to consider appearance as part of their planning process [3]. In recent years bridge appearance has again come to attract considerable attention in the literature.

In recent UK designs there has been no desire for a return to the inclusion of decorative elements seen in historic work [4]. To the vision of a bold expression of efficiency which developed with the Modern Movement, has been added the desire to make works blend into the landscape through restrained styling. The concept of necessity in structure has been promoted [5]. Where architects have been involved, they have normally worked under the consulting engineer rather than the client. In this way they have generally not imposed an overall concept or vision of their own, but rather have worked to refine the details of a largely determined scheme.

There has been less concern for designing visually for a particular site. Bridges located in urban and rural districts may be handled in almost the same manner (compare Kessock and Dartford 1991, for example). In some forms definite preferences have emerged as standards. For prestressed concrete girders fixed pier heads have been considered fundamentally unacceptable visually, and the separation between beam and column has often been accentuated through detailing. Pinned connections have been used for this bridge type even in cases where piers are high (Dee Viaduct, 1990), or seismic loading has been present (Tsing Yi North, 1988).

In suspension bridge towers the invisibility of joints has been seen as an improvement in appearance. Ingenious design of these towers has allowed both vertical and horizontal connections to be concealed, giving the structures smooth faces, with interest provided through limited architectural detailing. This simple-is-best approach does not really admit the construction method as a visual influence. The aim is to achieve a clear, simple finished shape, and considerable effort may be expended on construction method in order to achieve this. The approach piers on Kessock are another example. The need for a clear demonstration of the structural form appears to have been a factor in the design of this bridge.

Trends in Japan have moved in a different direction. Starting from bare, functional work immediately after the war, there has been an increasing struggle to give back some form of identity to individual works, and to impart human scale and softness. Two streams appear to have broken away from the post-war functionalism. Firstly, some clients have encouraged the inclusion of direct symbolism in major structural elements. This has generally been based on local or national traditional architectural forms. Secondly, industrial designers have been commissioned to lead the aesthetic treatment of some works. Here the imagery has been closer to that found in product design, intended to appeal directly through ergonomic attraction.

A consideration of construction aspects seems only to have been consciously included in the visual program of the latter of these two groups. Jointing on some recent large suspension bridges such as Ohshima has been considered as a visual device in its own right for example [6]. On these bridges it was hoped that joints would help visual understanding of the make-up of the bridge. This work can be seen as giving a design honesty to the method of assembly as well as the structural material. In the case of arch bridges, the recurrent heavy end spandrel wall has been incorporated more positively on the recent Beppu Bridge, 1989. It is not in this case playing the role of a heavy end monument seen in some classical arches, but is simply an element set apart visually through its detailing, giving an indication of its special function.

On earlier Japanese bridges such as Hokawazu however, it appears that the construction-related elements were not seen as carrying potential visual meaning. They were included solely under the influence of construction economics, sometimes with rather crude and insensitive finish. Hokawazu was designed at the end of the post-war vacuum in Japanese aesthetic thought.

6. CONCLUSIONS AND SUGGESTIONS

The comparison included here is brief and far from exhaustive. It is suggested however, that the differences in approach demonstrated are aspects of national design style, so that something of the same character runs through most modern work in each country. In summary, it appears that the influence of the construction process is more visible in Japanese work, and that this influence has sometimes been used constructively as an aesthetic device. The aim of achieving a visually pure final form has prevailed in the UK, with construction method generally hidden at completion.

In consideration of the importance which construction method has in the economic design of bridge structures, it would seem that the retention of some trace of the process in the finished work is reasonable or even desirable. When the presence of such features is acknowledged in a positive way, they can then be incorporated as an interesting visual element.

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