I-150 CONSTRUCTION PROCESS AND STRUCTURAL FORM IN BRIDGE DESIGN

University of Tokyo Student Member A R Burden

Introduction Construction method can greatly affect bridge form. In the literature on design, questions concerning the relation between the need for an efficient and economic construction procedure, and aesthetic requirements in the completed structure, have not been widely discussed. The author has looked at several recent bridges in Japan and the UK with the aim of discerning characteristic philosophies in the two countries for this aspect of design.

Basic Ideas Recent studies in bridge aesthetics have suggested that a major design aim in bridge engineering should be to produce forms in which function may be clearly read by the observer (1,2). Thus good designs are felt to spring from the use of direct and undecorated systems, with materials distributed to make optimum use of their physical properties. However the design process is complex, and the engineer needs to consider many factors apart from the load-bearing function in arriving at his final design. One such factor is a consideration of construction method.

The designer needs to form a philosophy governing the amount of influence he will allow construction to have on the final form. In other words, how much should the structure be distorted from the desired final form in order to accommodate an appropriate construction method? Such questions arise in other types of civil engineering structures, and in building also, but for bridges the construction process plays a crucial role in determining the viability of a design.

Looked at in a different way, we might 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 itself be considered a form of deception or decoration.

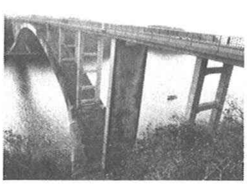
Although engineers have not generally written about their ideas on this matter, each must have decided on a balance with which he will resolve any dilemmas which may arise between final form and construction. By looking at completed works it is shown how the design approaches in this area have characteristics specific to their country.

Background to Design and Construction in Japan and the UK The organization of the design and construction process in the two countries differs distinctly in the role which consulting engineers play.

In the UK a consultant will usually be appointed to lead the design and prepare a completed scheme for issue to contractors by tender. The designer and contractor will have no contact during the design period. It is open to the contractor to suggest amendments to the proposed construction method if he can offer a price reduction with these. He may also be allowed to propose a completely new design. However, due to the limited period for tender, and the need for independent checking of designs, these have been offered only rarely. Recently several large bridges have been constructed under design and construct competition procedures in an attempt to increase the involvement of the contractors expertise at the design stage.

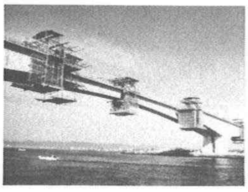
Japan has a long tradition of design being undertaken either by the promoting public body, or by contractors. The separation of design activity from construction has not proceeded as far as in the West, and even today contractors will offer the design of small bridges as "service" and not bill this as a separate fee. Consulting engineers have only emerged over the past 25 years, and their role in the design process remains more limited than their UK counterparts.

Case Studies on Japanese Bridges

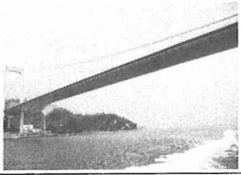


Hokawazu Bridge 1974 This bridge is a standard form two-hinged RC arch of 170m span. It was the first in the world to be constructed by the full-cantilever method using cables as temporary diagonal members between spandrel walls. In order to carry the high vertical loads generated by the end bay cables, the abutment spandrel wall has been made of much heavier form than those adjacent to it. There is such an obvious difference in the structure of these walls, that the observer may be puzzled until he deduces their prior role.

Wind loads on the cantilevers prior to closure produced large lateral moments at the abutments. These were dealt with by flaring the ends of the arch ring outside the width of the remainder of the structure. This aspect again leaves the viewer initially puzzled.



Hamana Bridge 1976 Two features of the bridge had great bearing on the construction process. Firstly, the deck girders are made monolithic with the main piers. This allowed cantilevering from the pier heads without the need for bents. Monolithic form has been a feature of almost all Japanese bridges of this type. Secondly there are piers introduced at unusual positions in the side spans. They support the girder at positions where the section depth is still changing, and were used to cantilever the girder from temporary fixed heads. Their positioning seems odd when the structure is appreciated only in its completed form.



Ohshima Bridge 1988 This was the first box-section suspension bridge to be built in Japan. Constructionally, an important area of this structure is the jointing methods used. Sections of both the towers and deck are connected using simple friction grip bolt connections. The joint positions are clearly visible, and indeed it was a stated design policy that the method of assembly of sections be made apparent in the finished work.

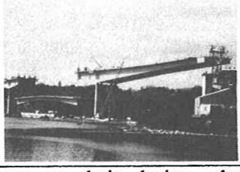
Shorenjigawa Bridge 1989 The forms of many Japanese steel box-girder bridges show very flat soffit profiles, the girder often becoming of constant section a short distance away from the piers. Shorenjigawa is a good example of this type. The use of constant depth cross-section over a large section of the span would seem to simplify the fabrication process. It is interesting also to compare this bridge with the Foyle Bridge of similar scale in the UK, where the shallow depth of the girder at midspan necessitated the use of moment prestressing during erection.

Case Studies on UK Bridges

Kessock Bridge 1982 The bridge was designed by a joint venture in which the contractor was involved from the outset. The approach piers are notable in that no cross-heads are present. This meant that temporary bracing was required between the pier legs during erection cantilevering to carry wind loads. Careful thought was given to the economical erection of the steelwork. For example, cable anchorages for the permanent cable were also used for temporary cantilevering of side spans. However, temporary cables were required for support of the main spans during erection.

Orwell Bridge 1982 This is the most recent prestressed concrete cantilever bridge built in the UK, however the tendering was conducted under traditional procedures. Like most UK bridges of this type, the girder-pier connections are pinned, so that temporary propping was required for cantilever erection. UK engineers have considered the monolithic connection of piers to girders aesthetically unsatisfactory.

Severn Bridge 1966 The jointing methods used on this bridge make an interesting comparison with those of the Ohshima Bridge. Firstly the girder joints were welded together on site. Perhaps more important though was the type of joint used for the towers. By using tension rods to stress the sections together, all jointing work could be carried out within the tower. This method was first used on the Forth Road Bridge, and eliminated the need for external staging during erection. The joints are almost invisible to the observer of the completed towers.



Foyle Bridge 1984 Like the Kessock Bridge, a design-and-construct tender system was used for this project. The retention of a strongly cambered soffit line typical of UK designs lead to the need for end-jacking to introduce hogging moments at mid-span. The use of this technique during construction is not clear to an observer unless he has a detailed knowledge of the structure.

Conclusions Both the completed structures themselves and engineer's writings on their design, show a different approach in each country to the handling of the influence of construction process on completed form. In the UK, bridges do not reveal as much information on the process as those in Japan. UK designers think carefully about possible construction methods which will leave the structure in a condition which appears pure from the viewpoint of completed mechanical state.

Japanese bridges show more structural features which are connected with the process of making. The concepts of design and construction appear less definitely separated. An aesthetic is held which allows more of the construction process to be manifest in the final form. Parallels may be drawn with other areas of Japanese culture such as craft and architecture, where the reduction of dualism between manufacture and the finished product is also visible.

In both countries much is written about the influence of economics on the choice of construction method. However, the effects of this choice on final form are seldom mentioned, although engineers clearly consider this aspect during design. It is to be hoped that discussion of this aspect will develop in the future.

Acknowledgements The author is grateful to Professor M Ito, Associate Professor Y Fujino, and Miss Y Yamashita for their helpful advice in the preparation of this paper.

References 1. SUGIYAMA, K., Structure and beauty of bridges, Kyoryo to Kiso, 1982, 16, Nov. ,18-23, Dec.,33-39; 2. ALLEN, B.J., Some notes on significance of form in bridge engineering, Proc. Instn. Civ. Engrs, Pt. 1, 1976, 60, Feb., 79-94.