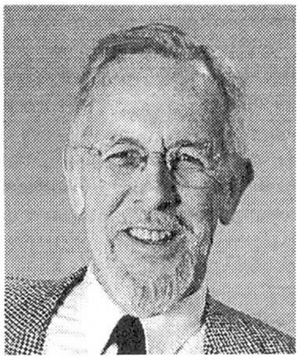
Bridge aesthetics and structural honesty

Bridge Aesthetics and Structural Honesty

Niels J GIMSING
Professor
BKM, DTU
Lyngby, Denmark



Niels J Gimsing, born 1935, is professor at the Technical University of Denmark since 1976. He has at several occasions acted as specialist consultant during the design of major bridges.

Abstract

In bridges the overall form must be chosen with due respect to the transmission of forces if efficient structures shall be created. The design must therefore be governed by experienced structural engineers - in some cases assisted by aesthetic advisers on specific issues.

In contrast to a structure forming a part of a building or a large roof where the structure is more or less covered by walls, floors, roofing and other non-structural elements, the structure of a bridge is generally visible in its entirety. So mistakes in composing the bridge structure will be clearly exhibited. However, with the development of modern high strength materials the designers can to a certain extent neglect structural efficiency without being warned by arriving at elements of ungainly dimensions.

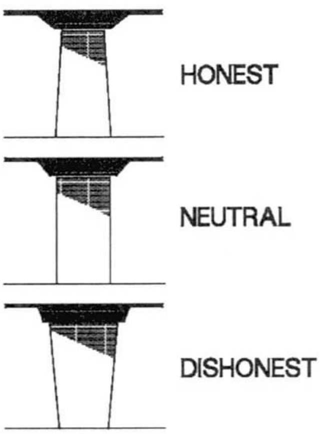


Fig.1 Pier shafts

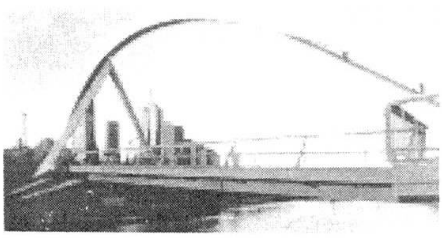
The term 'structural honesty' relates to structures designed so that the strength requirements are reflected in the form of the bridge as a whole and its individual elements. As an example Fig.1 shows three pier shaft configurations. They will all be subjected at the top to a large vertical force, a moderate eccentricity moment and a lateral force, e.g. from wind load. The latter will induce a bending moment that increases from top to bottom so it will be honest to vary the width of the pier shaft as shown at the top. With a constant width the form does neither emphasise nor contradict the structural function so it can be regarded as neutral. Finally, if the shaft is designed with the smallest width at the bottom where the highest strength is required then the form is obviously dishonest in relation to the structural function. Nevertheless, it is quite common to see the variation shown at the bottom in real structures.

For many centuries arches were the preferred structural form to be used in major bridges. This was, however, not a choice based on pure aesthetic considerations but much more because it is the most efficient form of a structure built of materials able to transmit only compressive forces. After the introduction of structural materials with large tensile strengths the arches were in many cases substituted by trusses, plate girders or box girders.

In recent times the arches have again become fashionable but in several cases they are chosen only for their aesthetic merits without considering the relation between form and structural efficiency. The result is that 'false' arches flourish in bridges designed without considering the structural function..

In reality the principles for choosing the shape of an arch are very simple:

- The arch shall be curved where it is subjected to a distributed load
- The arch shall have a sharp bend where it is subjected to a concentrated force
- The arch shall be straight where no load is applied.



An example on an arch bridge designed without considering the principles outlined above, is shown in Fig.2. Here the load from the bridge deck is transferred at one point so the correct form of the arch would have been two straight members leading directly to the supporting points. However, the designer apparently found a curved arch to look nicer so this form was chosen despite the consequences regarding material consumption.

This aspect is illustrated in Fig.3 showing a comparison between a correctly shaped arch (consisting of two inclined, straight members) and a parabolic arch - both made of steel. It is seen that the (unnecessary) bending induced in the curved arch results in a considerably larger cross section, with plate thickness of up to 60 mm, whereas the correctly shaped structure can be composed of more slender members with plate thickness of only 18 mm. As a result of this difference in dimensions the steel quantity will be tripled if the incorrect curved shape is chosen.

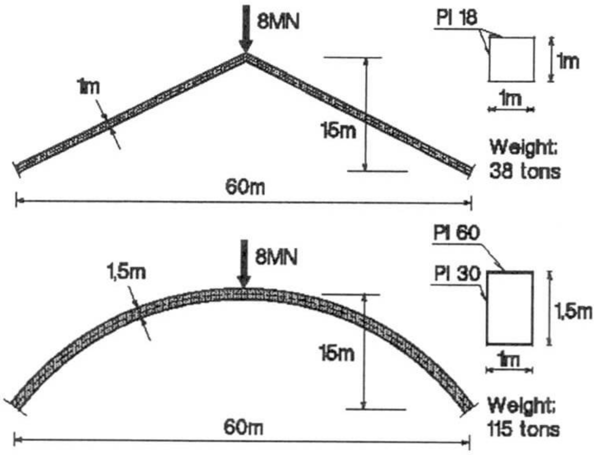


Fig.3 True and false arch with one concentrated force at midspan

Conclusion

Bridges should be designed in such a way that structural function and efficiency is expressed in the form. Modern high strength materials should be used to make the bridge light and graceful, not to shape it without considering the structural function.