Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 82 (1999)

Artikel: Bridges with spatial cable systems: theoretical and experimental studies
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DOI: https://doi.org/10.5169/seals-62120

Bridges with Spatial Cable Systems - Theoretical and Experimental Studies

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Abstract

In cable-stayed bridges with small width-to-span ratios the girder becomes inefficient in transferring lateral loads in bending. Furthermore, the critical load for lateral buckling decreases. A solution could be to apply a so-called spatial cable system that provides both vertical and lateral support for the girder.

1. Introduction

The present trend within design of cable supported bridges moves towards decreasing width-to-span ratios. This lateral slenderness is either the result of a very long span with a standard deck width or it may be due to an extremely narrow girder used in connection with a moderate span.

In an earth-anchored system, the lateral wind load is transferred partly by the girder in transverse bending and partly by the cable system due to the deflection of the cable planes. In a traditional self-anchored system with vertical cable planes, the wind load has to be transferred entirely by the girder in transverse bending as there will be no pendulum effect. Furthermore, in a self-anchored cable system the girder is subjected to a considerable compressive normal force induced by vertical loads.

As the girder becomes more narrow the transfer of lateral loads in bending looses in efficiency. A possible solution to problems associated with lateral wind load on cable supported bridges with small width-to-span ratios is to apply a so-called spatial cable system that provides both vertical and lateral support for the girder.

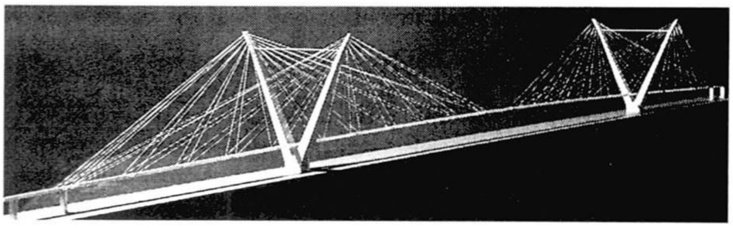

Figure 1.1 Architectural model of a cable-stayed bridge having a spatial cable system.

A full three-dimensional support of the girder will require at least three mutually inclined cable planes forming a spatial network of cables. However, to achieve symmetry four cable planes will generally be preferable, see Figure 1.1.

Until present pseudo-spatial cable systems have been applied for pedestrian and pipeline suspension bridges some of these spanning more than 300 m. This paper presents the results of studies on a prototype cable-stayed bridge with a spatial cable system having an 800 m main span and a girder width of 8 m. This gives a width-to-span ratio of 1:100 which is close to a factor of 2.5 compared to the width-to-span ratios found in cable-stayed bridges built until present.

2. Analytical Investigations and Parametric Studies

In order to determine the range of inclination of cable planes that is realistic to consider for spatial cable systems, parametric studies on the prototype bridge are carried out. These show that optimum height of a pylon supporting a spatial cable system does not differ from what is found for a pylon supporting a traditional cable system with vertical cable planes. An evaluation of material cost and of deflections due to wind load indicates that lateral inclination of cable planes should be between 1:4 and 1:2.

3. FE-analyses

Four different layouts of the spatial cable system are presented and compared by means of numerical analyses. The behaviour for wind load is studied in detail, in particular with respect to deflections. Emphasis in the FE-analyses is on the buckling stability of the girder. The results show that the modelled bridge type having an extremely narrow girder supported by a spatial cable system is not likely to exhibit any stability problems in its completed stage. However, as a distinctive feature related to a bridge having a narrow girder, the critical loads for lateral and vertical buckling are practically identical. This is in contrast to existing cable-stayed bridges where the critical load for lateral buckling is significantly higher than for vertical buckling.

4. Model Test

A comparative experimental study on both lateral and vertical girder instability phenomena is carried out on a model of the bridge in the erection stage. The parameter to be varied is the lateral inclination of cable planes. Based on the test results it seems that the spatial cable system can provide the requisite elastic support for a girder with a small width-to-span ratio to prevent lateral buckling of being more critical than vertical buckling when lateral inclination of cable planes is around 1:4. Thus the requisite inclination of cable planes to reduce the lateral deflections to an acceptable level also stabilises the narrow girder with respect to lateral buckling that would otherwise have a lower critical load than for vertical buckling.

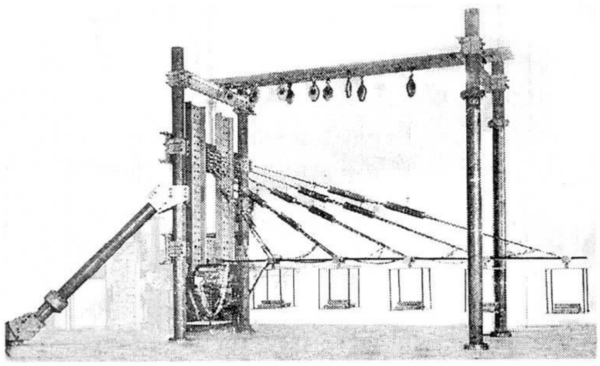

Figure 4.1 Test setup used in comparative experimental study on bridges with plane and spatial cable systems. The model girder is 5 m long.

5. Conclusions

Based on the investigations carried out in the present work it can be concluded, that arranging a spatial cable system is a promising way of solving problems related to applying a girder with a small width-to-span ratio.