Three-dimensional antifunicular geometries in spatial arch bridges

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Summary

The structural behaviour of spatial arch bridges extends from the essentially vertical in-plane behaviour of the "classic" arch bridges to a three-dimensional behaviour. When the arch is subjected to out-of-plane loads, its antifunicular geometry becomes a warped curve, i.e. not contained within a plane. This paper, which intends to be useful at the conceptual stage of bridge design, presents several alternative iterative methods for obtaining three-dimensional antifunicular arches. These geometries are also obtained for some representative arch-deck configurations, and the influence on them of some relevant geometrical and mechanical parameters is discussed. This paper also shows the need to consider additional criteria for selecting the most efficient form, and the high aesthetic potential of this type of structures.

Keywords: spatial arch, antifunicular geometry, form-finding, curved deck, graphical statics, force density method.

1. Introduction

The structural behaviour of spatial arch bridges (a concept introduced in [1]) extends from the essentially vertical in-plane behaviour of the "classic" arch bridges to a three-dimensional behaviour [1-3]. This happens, among other reasons, because the arch is subjected to out-of-plane loads, for example, when the deck is curved in plan or when the arch is rotated about a vertical axis, two of the cases shown in this paper. In these and other configurations, and for a given load case (usually the permanent loads), the three-dimensional antifunicular geometry (which is the geometry free from bending stresses) becomes a warped curve, i.e. which is not contained whithin a plane, such as the well-known Ripshorst footbridge [4], designed by J. Schlaich (Figure 1).

Fig. 1: Riphorst footbridge. J. Schlaich.

This paper intends to be useful, at the conceptual stage of bridge design, when the spatial arch bridge typology must be considered, either because of functional requirements, structural efficiency or with aesthetical purposes. Firstly, in section 2, several alternative methods for obtaining three-dimensional antifunicular geometries arches are presented. These geometries are, in section 3, obtained for some representative arch-deck configurations, and the influence on them of relevant geometrical and mechanical parameters is discussed. Particularly, section 3 shows the influence of the number of hangers and the self-weight of the arch; the so-called "diagonal-arch", in which the arch spans diagonally across the deck; and the influence of the arch-deck relative position, both vertical and transversal.

https://doi.org/10.2749/222137814814067987
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