Free-form Design of Funicular Arches Coupled by Straight Bars in Two and Three Dimensions

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Abstract

Funicularity is a central concept in the design of slender, lightweight structures. Slender funicular structures balance external loads through axial forces. For a given load distribution, only a limited set of shapes can bear loads in a funicular manner. This constraint poses a challenge for the widespread application of funicular structures and necessitates form-finding during the conceptual design phase.

In this work, we focus on the form-finding of *coupled pairs*-structures composed of two coplanar or spatial curvilinear arches, connected by a set of densely distributed elements (representing hangers or spandrel columns). Existing form-finding methods for coupled curves allow freedom in shaping one arch, while the shape of the second is dictated by the requirement of funicularity. We introduce new methods that enable designers to prescribe the shapes of both arches in the planar case by appropriately distributing the connecting elements between them. These methods are then extended to pairs of spatially curved arches, where the projected shapes of the curves in a plane can be prescribed by the designer, with the spatial form determined by equilibrium equations. This extension can be seen as a special case of form-finding using Thrust Network Analysis.

The results presented here are relevant to the conceptual design of spatial arch and suspension bridges, cable trusses, beams with external post-tensioning, and the retrofitting of existing beams or vaults.

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