Design of a funicular concrete bridge with knitted formwork

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Abstract

This paper presents the design, engineering and digital fabrication strategies for a circular pedestrian bridge to be built as part of "De Groene Boog" development of the A16 highway north of Rotterdam, The Netherlands. The bridge is designed as a lightweight funicular unreinforced concrete gridshell with openings based on the principle of a three-hinged arch extrapolated to 3D geometry. In its realisation, it demonstrates a model of circular construction using recent material developments (such as recycled concrete) and an efficient flexible formwork system using knitted textiles. The presented design and fabrication process is developed collaboratively by the Block Research Group at ETH Zurich and De Groene Boog. The structure is commissioned by the Dutch Ministry of Infrastructure and Water Management (Rijkswaterstaat).

Keywords: funicular bridge; recycled concrete; knitted formwork; circular design; pedestrian bridge; graphic statics; Thrust Network Analysis; circular economy; sustainable design

1 Introduction

The need for design, engineering and fabrication strategies for sustainable concrete construction is recognised as a key challenge in the building industry. Using principles of structural geometry and material effectiveness in design makes it possible to significantly reduce the amount of material used in a structure and its embodied emissions [1].

Despite their highly efficient material use and elegance [2], shell typologies are rarely applied in bridge structures. Few noteworthy modern examples are the bridge over the Basento river by Musmeci (1976) [3], the twin concrete shell bridges in the Manzanares park in Madrid by Fhecor Ingenieros (2011) [4], and the stainless steel gridshell in Ditzingen by Schlaich Bergermann Partner (2018) [5]. A summary of modern shell-supported bridges is given by Fenu [6].

Identified difficulties are precise geometric control of the fabrication and construction of the gridshell, typically requiring uneconomic and wasteful formwork strategies; and clean load introduction between deck and gridshell, requiring constrained form finding methods. Both topics are addressed in the initial design phases of this circular pedestrian bridge.

A hybrid spline-supported 3D-knitted textile made of recycled and natural fibres, that is easy and fast to assemble, will be the formwork to cast the complex structural geometry, needing only minimal scaffolding. A computational pipeline developed in-house, based on the open-source COMPAS framework [7], enables the efficient form finding, engineering, collaborative exchange and streamlined fabrication of the bridge. Figures 1 and 2 show the conceptual design proposal for the funicular pedestrian bridge, with a span of 13,5m. The ambition of the design is to provide an icon in terms of efficient design and circularity.

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