Structural Optimization of Prestressed Concrete Shells with Ruled Surface Geometry

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Abstract

Doubly curved concrete shells can exhibit an exceptionally efficient load carrying behavior due to their ability to redistribute spatial loads almost entirely through membrane forces. This minimization of large bending moments throughout the structure allows for the realization of a minimal shell thickness to span width ratio. The resulting structures, while elegant in form, are often uneconomical due to the expensive formworks required to achieve such complicated geometry. Ruled surfaces are particularly suited to address this issue as they can take on complex geometries by sweeping straight lines through space [1]. This allows for the construction of ruled surface shells using formworks of exclusively linear elements, greatly reducing their cost.

The linear nature of a ruled surface can also be exploited for the design of prestressed elements, in that straight tendons can be constructed along a given generatrix. This allows for the construction of prestressed precast structural elements, which are highly cost effective compared to the curved tendon geometries in post-tensioned shells. However, for this to be feasible the membrane forces in the shell under a given load must flow along the generatrix in such a way that warrants prestressing. Unfortunately, the load carrying behavior of a ruled surface does not necessarily correspond to the generatrixes used to generate its geometry, making it difficult to successfully capitalize on the ease with which prestressed elements could potentially be used [2]. This paper aims to investigate the possibility of optimizing the geometry of ruled surface concrete shells for the implementation of prestressed tendons along the generatrixes. To achieve this goal, a new objective function was developed and implemented together with structural optimization methods in an attempt to find ruled surface forms with the desired force flow suited for prestressing with linear tendons.

Finally, an example is investigated using the methodology described above in order to demonstrate the applicability of the concepts introduced in this paper. All of this research was funded with the help of the German Research Foundation (DFG) as part of the project SPP 1542 “Leicht Bauen mit Beton”.

References

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