Tendon layout optimization in prestressed concrete slabs

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Abstract

It is several decades now that prestressed concrete slabs are widely used in residential, commercial and office buildings. For the most part, manual tendon layout design is performed by structural engineers based on their prior knowledge, experience and good practice rules. In recent years, however, several studies have used structural optimization in purpose to automate the design process. Nearly all research so far was based on predefined tendon patterns with very few free parameters determined by optimization, hence the flexibility in tendon design is not fully utilized. Consequently, the resultant tendon layouts resemble traditional designs obtained by common engineering practice. Recently, a conceptually different approach was proposed based on stiffness optimization of the slab. The results show unconventional tendon layouts that lead to significant savings in tendon cost [1]. The main drawback of this method is the considerable manual post processing that is required to complete the design. In our current research, we propose a direct formulation for tendon layout optimization that does not require any post processing.

In the proposed formulation, we aim to minimize the cost of the prestressed concrete slab using both topological and shape design variables. The slab is modeled by finite elements based on the first order plate shear theory. The internal forces applied by the tendons on the slab are determined according to the exact tendon geometry, including frictional and other force losses along the tendon. A potential net of tendons, called ground structure, is defined and each tendon is assigned with a topological variable that determines its existence in the optimized layout. In addition to these topological design variables, shape design variables are assigned to the spatial coordinates of the control points defining the tendon geometries. The resultant parametrization enables to freely optimize the tendon shapes, concurrently with finding the optimal number of tendons. We ensure the feasibility of the tendon layout by introducing constraints on the minimal spacing between tendons.

Results of numerical experiments on single-span slabs show reduction in tendon length and cost of up to 15% compared to traditional design, while maintaining equivalent structural performance. Moreover, the tendon trajectories are conceptually similar to those obtained by Sarkisian et al [1], and differ significantly from common practice patterns. The formulation is currently extended to optimize multiple spans and to include also serviceability constraints such as allowable deflection and stresses. Based on the results obtained so far, we believe that the proposed direct parametrization can facilitate the development of a practical, easy-to-use computational design tool that will lead to cost savings in prestressed concrete slabs construction.

References

[1] M. Sarkisian, E. long, A. Begihini, R. Garai, D. Shook, R. Henoch, A. Diaz, "optiml Tendon Layouts for Concrete Slabs in Buildings Derived Through Density-Based Topology Optimization Algorithms," in *WCSMO12*, 2017.