Multi-Objective Optimization of a Concrete Shell

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Abstract

In this paper the design of a perforated free-form concrete shell structure is discussed, demonstrating the practical implementation of form-finding and optimization in a real-world design. This project (Figure 1) is designed as an architecturally expressive building with undulating, exposed material across several levels, housing interior and exterior living spaces. As one of the most significant features of the project, the upper surface of the building is envisioned perforated concrete shell, which is the focus of this paper. This surface is supported at the center of the shell, housing a swimming pool, and touches down at four locations at the perimeter of the shell.

A form-finding procedure, respecting the design intent of the shell is carried out, demonstrating the material-savings that can be achieved with minimal visual impact on the design. The topology of the shell perforations is controlled by a multi-objective optimization algorithm, minimizing mass and deflection to determine the size and distribution of the perforations on the shell surface. This iterative algorithm is constrained by maximum peak stresses for the envelope load combinations and architectural considerations. Options for visualizing the optimization problem are also presented.

Finally, investigation and comparison of numerous formwork options for the construction of the complex shell form, for the given design and location challenges, are presented.