# Concept and cable-tensioning optimization of post-tensioned shells made of structural glass

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**Abstract**

Shells made of structural glass are charming objects from both the aesthetics and the engineering point of view. However, they pose two significant challenges. The first one is to assure adequate safety and redundancy concerning possible global collapse. Being single-layered, in a shell made of structural glass the brittle cracking of a single pane can lead to a sudden propagation of failure, up to instability. The second one is to guarantee cheap replacing possibilities for potentially collapsed components.

To address both requirements, this research explores a novel concept where glass is both post-tensioned and reinforced. Following the Fail-Safe Design (FSD) principles, a steel reinforcement relieves glass deficiencies (i.e. brittleness and low tensile strength). Following the Damage Avoidance Design (DAD) principles, glass segmentation and post-tensioning avoid the propagation of cracks. Up to now, glass-steel systems were limited to mono-dimensional elements (such as beams and columns) or simple bi-dimensional elements (arches, domes, barrel vaults). On the other hand, grid shells, in which glass is used as cladding, are preferred alternatives for approximating larger and more complex shapes.

This research proposes piecewise triangulated glass shells to enable the creation of 3D free-form glass-steel systems, where glass is load-bearing material. Hence, laminated glass panels are mechanically coupled with a filigree steel truss, whose elements are placed at the panels edges and act as an unbonded reinforcement. In a performance-based perspective, these steel trusses can be sized to bear at least the weight of all panels in the occurrence of simultaneous cracks (worst-case scenario).

To prevent crack initiation, the panels are post-tensioned using a set of edge-aligned cables that add a beneficial compressive stress on the surface. The cable placement and accompanying pre-loads are derived with an optimization strategy that minimizes the tensile stress acting on the shell. This optimization procedure also involves the manufacturing constraints.

The investigated shells optimize the material usage by providing not only a transparent and fascinating building separation but also load-bearing capabilities. The shells show good static performances, high stiffness and redundancy rate with respect to the worst-case scenario. Visual and structural lightness are substantially improved with respect to grid shell competitors.