Applications of Structural Optimization to Architectural Design

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Abstract

Structural optimization is a computational technique that has been attracting increasing interest in the building industry to identify optimal geometries of structural systems, especially in the design of high-rise buildings and long span structures. By selectively distributing the material in a structure or by optimizing the layout of members in a frame, the performance of the resulting design can be optimized. The resulting designs are not only efficient, lightweight and minimize the embedded carbon, but are also often aesthetically pleasant from an architectural point of view.

Optimization techniques have been already successfully applied to structures in a variety of industries like the aeronautical, automobile, and mechanical industries where natural force flows are modeled and a least energy response achieved. The applications of these techniques to architectural design has been subject of several studies. The type of optimization tools applied to the conceptual development of innovative structural/architectural topologies depends on the specific project or application considered. Commercial software employing gradient-based optimization, for example, has been successfully applied for topology and shape optimization of several structures. Educational codes are also provided by several universities to make the latest methodologies in topology optimization research available to the public. Other custom-written optimization tools have been developed by accessing the advanced programming interface (API) of commercial software and utilizing several of their built-in functions. Another methodology successfully employed involves parametric optimization utilizing genetic algorithms. Genetic algorithms mimic natural selection processes and when applied to the parametric environment can optimize multiple parameters for multiple concurrent objectives.

In addition, several studies have been conducted on optimal layouts of discrete truss systems, which are characterized by specific geometric and energetic properties. Such studies led the engineers to rediscover a variety of theorems, including Maxwell's theorem on load paths and Rankine’s theorem for funicular frames.

This presentation will highlight methodologies to identify optimal geometrical layouts and will include several applications to a number of high-rise buildings or bridges under design.

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