Structural Optimization for a Sustainable Architecture

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Abstract

Several practical tools for the characterization of the optimal layout of material in a structure have been developed in recent years based on both numerical and analytical approaches. Such tools enable engineers and architects to identify forms and geometries that, by being optimal, are also more sustainable. The focus of this paper is to describe some of these methodologies and illustrate with examples their application to a variety of structures.

Keywords: sustainable design, conceptual design, structural optimization, topology optimization, graphic statics.

1 Introduction

Achieving a design that combines structural efficiency, aesthetics and sustainability is one of the major challenges of the modern building industry. An answer to this challenge is the application of structural optimization techniques in design.

Structural optimization has been attracting increasing interest in the building industry, especially in the design of high-rise structures. By selectively distributing the material in a building, the resulting design is structurally efficient, often aesthetically pleasant and minimizes the embedded carbon.

Several optimization tools for the conceptual development of innovative structural/architectural topologies are available to the engineers and their utilization 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.

The design is usually optimized to achieve the maximum stiffness of the building, which is typically measured by the compliance of the lateral system or by the tip displacement of the building itself. Therefore, the resulting design is the stiffest structure that can be obtained for the volume fraction of material considered and satisfies the performance requirements under gravity and lateral loads (wind and seismic).

The optimal geometry is usually derived under the assumption of elastic material behaviour, which is accurate for wind loads and earthquakes with a relatively low return period. However, when earthquakes with a longer return period are considered, the structure will exceed the elastic

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