Optimization in a realistic structural engineering context: redesign of the Market Hall in Ghent

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Abstract

Numerical optimization has a large potential in the context of structural design, but practical applications remain scarce. Even metaheuristic algorithms, which are easy to use, are rarely adopted in practice. Possible explanations are the fact that for problems with many design variables, metaheuristic algorithms converge slowly, and that structural optimization often leads to very complex structures, resulting in a high construction cost. The aim of this paper is to illustrate the potential of numerical optimization in a realistic design context. The focus is on the steel structure of the Ghent Market Hall, which is redesigned using a genetic algorithm. The structural member groups from the original design are maintained, such that the number of design variables is sufficiently low, and that the complexity of the design remains limited. Using this approach, a design is obtained that consumes 15 % less material than the original design.

Keywords: structural optimization; size optimization; genetic algorithm; metaheuristic; Eurocode design; steel design; material minimization.

1 Introduction

In current building practice, structural members are often not used to their full potential. This under-utilization is the result of design rationalization: structural designers trade in material efficiency for spare capacity in order to reduce engineering efforts as well as fabrication and construction costs. Whereas a spare capacity of 5 % to 20 % is considered acceptable among structural engineers [1–3], a recent study by Moynihan and Allwood [3] on more than 10,000 steel beams found that the average spare capacity was more than 50 % in reality. This discrepancy suggests that the trade-off between material efficiency and design rationalization is out of balance in current engineering practice, leaving room for considerable material savings.

Structural optimization can be used as a tool to improve the balance between efficiency and rationalization. The introduction of optimization methods in structural design practice is self-evident on paper, but turns out to be difficult in reality. There is a gap in the complexity of design problems considered in the academic literature on structural optimization and structural engineering practice [4–6]. The academic literature puts much more emphasis on the development of new optimization algorithms than on examples of their

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