SOD: A Tool Auto-Generates the Preliminary Structural Design of Steel-Composite Office Buildings

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At conceptual design phase of a building project design space exploration is often used to seek better design solutions. The number of design variants to be compared is limited by the analyzing time of each variant. Comparison of the engineering performance and the material consumption is usually based on preliminary structural designs or pure engineering experience, which we think can be improved. A practical assistant tool Sustainable Office Designer (SOD) is presented in this paper. It can fast auto-generate preliminary structural designs of steel-composite office buildings using an optimization approach.

Nomenclature

GA	=	Genetic Algorithm
SOD	=	Sustainable Office Designer
VAD	=	Volumetric Architectural Design
PSD	=	Preliminary Structural Design
PSM	=	Parametric Structural Model

I. Introduction

THE conceptual design phase is most crucial in the sense of achieving an optimal building design, because that the most significant decisions are made in this phase, such as the number of floors, the overall shape, the construction type (concrete, steel or wood), etc. These decisions restrict the possible improvement of the final design. Better decisions can be obtained by design space exploration, i.e. by comparing different design variants. Because engineering structural design is a complex task, at conceptual design phase the design models are usually limited to volumetric architectural design (VAD). The comparison of material consumption, which can be used to calculate the life-cycle assessment indicators and construction cost, are often based on preliminary structural designs (PSDs) or pure engineering experience. This limits the number of possible design variants and construction types to be considered in this early stage.

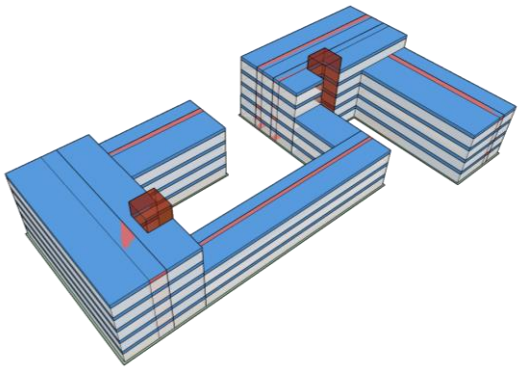

Figure 1: Volumetric Architectural Design

Therefore, shorten the creation of the PSD for each variant can enlarge the number of variants for comparison and lead to better decisions. Optimization approach is employed to seek optimal solution of engineering design problems for decades. Structural design is one of the complex engineering design problem. Former researches[1,2,3,4] shows great successes using genetic algorithms (GAs) to find optimized structural design solutions for concrete and steel constructions due to its robustness, flexibility and simplicity in implementation.

In this paper the principle and result of SOD is presented. It is an application to auto-generate PSD for low-rise steel-composite office buildings[5]. It employs a fast structural optimization approach. The presented study focuses on buildings having a floor-layout comprising one or more rectangular shapes, since rectangle is the most common shape in office buildings.

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II. Volumetric Architectural Design and Preliminary Structural Design

A. Volumetric Architectural Design

The volumetric model (see Fig. 1) is used in conceptual architectural design for visualization and to perform shading and building energy and other analyses.

Necessary information for generating PSD can be obtained from or defined in VAD, such as:

the shape of the floor layout,

the number of stories for each building part,

the story room height and the additional story height that allows the placement of structural elements (such as beams and slabs) and engineering components (such as ventilation and celling),

the façade width that restrict the column spacing and location of intermediate columns.

Figure 2: Preliminary Structural Design

B. Auto-generated Preliminary Structural Design

From the VAD we create the Parametric Structural Model (PSM) and then use a GA to find the optimized structural solution (see Fig. 2). To perform the optimization, we need to calculate the objective value and the penalty value. The objective value is calculated as weighted summation of the material consumption, which is easily calculated from the structural model. The penalty value is used to verify the structural design and eliminate the infeasible structural solutions. A simplified structural analysis routine is implemented to verify the structural components including continuous composite primary beams, composite secondary beams and steel columns w.r.t. “Eurocode 3” and “Eurocode 4”. Composite slabs are verified against pre-calculated design tables.

SOD only performs pre-structural analysis in order to gain computation speed. Therefore, in the calculations only vertical loads are taken into account. Horizontal loads are not considered. Due to the large number of possible vertical bracing options and the fact that additional masses for bracing and additional supporting elements are often independent of the structural design choices, the calculation of vertical bracing is neglected.

III. Result

For a building with floor height comprising six rectangular parts: 12m × 8m × 3 stories, 36m × 18m × 5 stories, 24m × 12m × 4 stories, 36m × 17m × 5 stories, 48m × 8m × 3 stories and 30m × 15m × 4 stories using the composite slab Holorib 120mm/140mm/160mm/180mm, Cofraplus 120mm/140mm/160mm/180mm or the TOPFloor system, SOD can generate an optimized preliminary structural design within several minutes on a normal laptop powered by Intel CPU i7 4900MQ and 16GB memory.

IV. Conclusions

SOD, an application of a fast optimization approach, has been implemented in this work to auto-generate preliminary structural design of steel-composite office buildings in early conceptual design phase. It uses a generic algorithm to generate optimized structural design based on the rectangular PSM. Simplified structural analysis is performed to verify the structural components. It has been shown that the PSD can be automatically generated in very short time to enlarge the number of deign variants for comparison. The further work is to extend the approach for more complex shapes besides rectangles and to take into account building cores.

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