Design of multi-story timber building using multi-objective particle swarm optimization

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DESIGN OF MULTI-STORY TIMBER BUILDING USING MUTLI-OBJECTIVE PARTICLE SWARM OPTIMIZATION

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ABSTRACT: This paper presents a design method for multi-story timber building with consideration of regulatory constraints. The objective is to optimize in the same time thermal, structural and environmental objectives taking into account the industrial feasibility. To set up this method and the appropriate tool a study case is developed and will be implemented.

KEYWORDS: Multi-story timber building, Multi-objective optimization, Energy simulation, Structural analysis, Environmental impact, Multidisciplinary Design Optimization, Particle Swarm Optimization (PSO)

1 INTRODUCTION

Wood is a low environmental impacts material with a dry and rapid implementation, facilitated by prefabrication. However in France, timber buildings are still underdeveloped with a building incorporation rate of 10% against 15% in Germany and 35% in Scandinavia and North America [1]. Furthermore, a lack of knowledge in timber building, especially for multi-story slows its development [2]. To expand multi-story timber building there is a need to develop design methods with regulatory constraints consideration.

Building is a complex system, subject of multidisciplinary design studies generally considered by technological fields. Building envelopes design is guided by different disciplines including structural engineering, energetics, environment, lighting, and acoustics. In order to develop optimized building design considering thermal, structural and environmental objectives, it is necessary to increase design understanding tradeoffs involved. This makes it a challenging multi-objective optimization problem.

2 STATE OF ART

Usually, in multi-objective optimization building problems, one of the two strategies below is used as detailed on the review [3]: optimizing a weighted function including the different objectives or Pareto optimization. The first strategy leads to a single solution while the second one leads to a set of optimal compromise between objectives, maintaining a clear view on results significance which is its major benefit. Well adapted to this strategy, the use of metaheuristic techniques to optimize multi-objective building design problems is growing over the years [3]. As studied on [3,4] reviews, the aim is often to optimize building considering conflicting design objectives such as energy consumption, cost, comfort and environmental impact (Fig. 1).

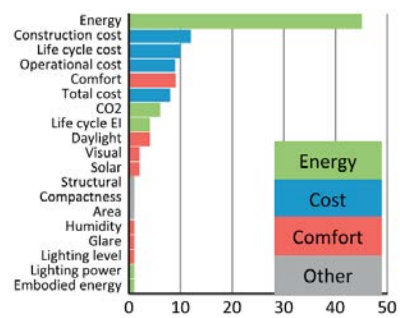

***Figure 1:** Choices of optimization objective function [3]*

Three reviews on optimization methods and tools applied to sustainable building design [3-5] underline and conclude on the necessity to develop tools that integrate both, building physic simulation and optimization process. However, optimization process can lead to a large computational burden especially when detailed simulation models are used. Such tools have to reduce computation time, to be accurate, and to support decision making.

3 METHODOLOGY

Developed by Kennedy and Eberhart [6], Particule Swarm Optimization (PSO), like other metaheuristic techniques,

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finds a set of optimal solutions to a difficult optimization problem. This technique, motivated by the simulation of social behavior, has proved to be very efficient in multi-objective optimization including continuous and discrete decision variables. Multi-objective PSO technique is especially and fully suitable for our problem where six objectives have to be optimized with continuous and discrete decision variables.

The six objectives to optimize in our problems are:

- to minimize energy needs of the building,
- to minimize thermal discomfort in the building,
- to minimize floor height,
- to maximize floor vibration comfort,
- to minimize CO2 emission of the building during its life cycle (Pre-Use, Use and End of Life),
- to minimize embodied energy of the building during its life cycle.

The PSO optimization process will be performed using the *Ted©* tool (Tool for Ecodesign) [7]; structural and environmental objectives will be modeled using analytic functions that can comprise continuous and discrete decision variables. EnergyPlus 7.2 (DOE, U.S Department of Energy) will be used for energy and comfort simulation; and corresponding metamodels will be generated and used as objective functions to be implemented in *Ted©* (Fig. 2).

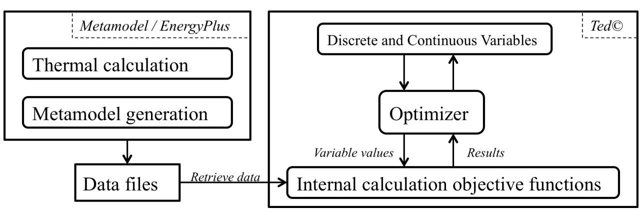

Figure 2: *Components and their relationships for simulation-based optimization*

4 STUDY CASE

The case study (Fig. 3) is a five-storey office building. Architectural geometry, location and use are fixed parameters. Timber structure is a discrete variable. Three options will be considered during the optimization process: beam to beam, cross laminated timber and timber frame structure. Others variables concern the building envelope such as insulation level, glazing, beam section etc.

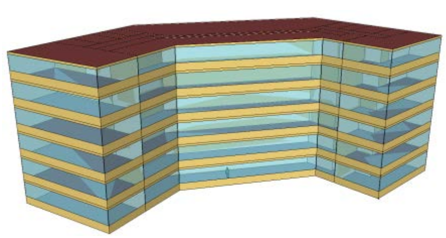

Figure 3: *Study case building*

Analysis of the resulting set of solutions can be difficult, particularly where there are a large number of objectives and decision variables to consider. In addition to the Pareto front, use of a parallel coordinate plot [8] (Fig. 4) will enable to selectively visualize impact of decision variables on the objectives and to support decision making.

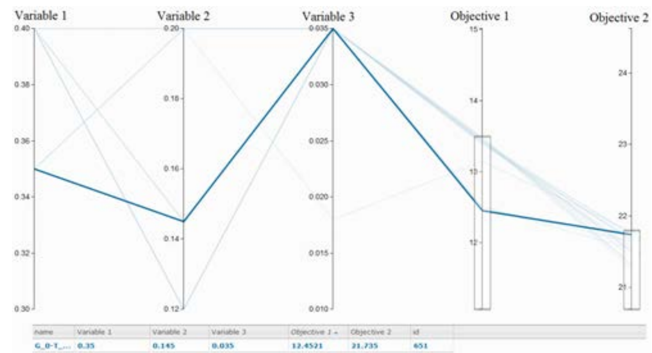

Figure 4: *Parallel coordinate plot*

5 CONCLUSIONS

To expand multi-story timber buildings with multidisciplinary design, a multi-objective optimization method and tools are proposed. The building design will include the optimization of structural, energy and environmental objectives though the minimizing of energy needs, thermal discomfort, floor height, CO_2-eq emission and embodied energy of the building and the maximizing of floor vibration comfort.

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