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Performance-based Design of Tall Building Envelopes using Competing Wind Load and Wind Flow Criteria

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Abstract

This paper investigates performance-based tall building design and the development of a combined architectural-urban design method focusing on the effects of wind loads on- and wind flows around tall buildings. The paper provides an overview of related buildings codes and city development design guidelines that define requirements for structural façade wind loading and urban ventilation. A review of performance-based design methods for the generation, analysis and optimization of buildings is also presented. Within this frame, an approach to performance-based tall building envelope design is proposed. The approach is aimed at addressing wind loading and wind impact requirements based on generative parametric modelling and performance analysis that integrates physical parameters at the architectural and urban scales and performance criteria can support filtering and optimization relative to prevailing wind conditions.

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Keywords: Performance-Based Design; Optimizing Wind Flow Profile

1. Introduction

Tall building design strategies have been given increasing attention over the last two decades. Conventional tall building design methods typically focus on single-objective design optimisation techniques and/or produce a small number of design alternatives that explore wind loading and wind flows. An integrated method that addresses performance-based design simulation and optimization of wind loads *on*- and wind flows *around*- the envelope of

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tall buildings is therefore lacking. Building codes and city development design guidelines for tall buildings specify requirements for structural wind loads acting on tall buildings (building codes) and wind flow impacts arising from tall buildings (design guidelines), e.g., at the pedestrian level. As separate compliance processes, building codes and design guidelines each define distinct criteria, calculation methods and testing procedures for assessing wind loads and flows for design compliance. Building codes and guidelines generally define the required performance via the specification of minimum structural performance requirements under wind load and maximum (and in some cases minimum) 'acceptable levels' of velocity and turbulence around tall buildings relative to the impact of the building envelope on wind flow at the pedestrian level. However, in meeting these requirements separately the interdependencies between architectural and urban scales are ignored. It also, neglects the importance of addressing design criteria surrounding wind flow in the early conceptual stages of design. Understanding the nature of aerodynamic behaviour at both architectural and urban scales is an important aspect of tall building design [1]. However, the evaluation of the design relative to building wind loads and urban wind flows is separate from each other. Further, assessing how design requirements are fulfilled relies on the insight of the designer who can focus only on a limited range of performance criteria. Traditional tall building design methods are increasingly facing the difficulties of meeting the requirements of multiple disciplines that can be addressed using performance-based design methods. The application of these methods are especially complex when considered in the context of the competing wind load and wind flow criteria occurring at the architectural and urban scales.

This paper explores the notion of performance-based simulation and optimization of tall building envelope design for competing wind profiles, namely structural wind load and urban wind flow. The overall aim of the research is to develop a method for optimizing tall building envelope alternatives during the early conceptual design stages according to competing design criteria defined at both architectural and urban scales. Optimization is therefore achieved using realistic and reliable information of the probable performance of tall building envelops relative to structural wind loads and urban wind flows. In its purest form, performance-based design entails the development of a preliminary design, mathematical modelling of the design, and simulation of the design's response to various wind flow conditions and comparison of the predicted performance of these events with the performance objectives adopted as the design criteria. If the performance predicted in the simulations is found to meet the stated objectives the design is acceptable, if not the design must be revised and the simulations repeated until acceptable performance is predicted. This approach aims to provide a method of designing tall building envelops for specific intended wind load and flow performance that can be used in the early design stages, thereby mitigating the risk of costly design changes in the detailed design stages when compliance against building codes and design guidelines is typically sought. In the context of this research problem the intended performance of a tall building envelope design may be initially found to be superior or inferior to the required design behavior defined within building codes and design guidelines. Further, it also provides a method to benchmark existing buildings relative to the requirements of building codes and design guidelines so as to assess the actual performance achieved.

This research project sits within a growing field of research that is attempting to advance the current paradigm of performance-optimized building design by developing techniques that account for both the architectural and the urban level; moving from building information modelling to city information modelling. Computational fluid dynamics and generative performance-based design simulation and optimization techniques provide two foundational computational design methods of this research. The paper proceeds by presenting the research objectives and method. The authors then present the results of the two literature studies. The first presents an analysis of relevant building codes and city development design guidelines related to the design of tall buildings focusing on structural wind loads and urban wind flows. The second review surveys recent work on performance-based building design and urban planning methods focusing on techniques developed for performance-based simulation of environmental criteria, with some examples of designing for aerodynamic behaviors. The paper identifies gaps in current approaches and presents a framework that identifies the design criteria for a tall building envelope design method such that solutions can be generated, analyzed and optimized to achieve performance objectives related to satisfying competing wind flow profiles. The authors then discuss performance-based simulation and optimization for combined wind load and wind flow analysis for tall building envelope design relative to design iteration and exploration in the early conceptual design stages. The paper closes with conclusions and future work.