Empirical Analysis of Parametric Design in Urban Wind Flow Optimization: A Computational Fluid Dynamics Approach

Alex Green
PhD
National University of Singapore
21 Lower Kent Ridge Rd, Singapore 119077

Quinn Jackson
Associate Professor
Massachusetts Institute of Technology
77 Massachusetts Ave, Cambridge, MA 02139, USA

Sophie Stewart
Professor
University of Cambridge
The Old Schools, Trinity Ln, Cambridge CB2 1TN, United Kingdom

Abstract. This study explores the efficacy of parametric design strategies in optimizing urban wind flow, utilizing advanced computational fluid dynamics (CFD) simulations. Employing a case study in the dense urban fabric of Singapore, the research evaluates the impact of various architectural morphologies on wind distribution at street and podium levels. Results indicate significant improvements in natural ventilation efficiency, particularly through the strategic application of aerodynamic forms. The findings suggest that parametric design tools can significantly enhance urban microclimates, promoting energy efficiency and thermal comfort in high-density environments.

Keywords: Parametric Design, Urban Wind Flow, Computational Fluid Dynamics, Natural Ventilation, Urban Microclimates, Sustainable Architecture, Aerodynamic Forms

Introduction

Urban environments are increasingly challenged by the necessity to balance high-density development with sustainable living conditions. As cities expand vertically, the manipulation of wind flow within urban canyons becomes critically important. Poorly managed urban wind flow can lead to inadequate ventilation, elevated pollution levels, and increased heat retention, exacerbating the urban heat island effect and overall energy consumption. Addressing these issues requires innovative architectural and engineering solutions that can adapt to the dynamic nature of urban climates. This paper investigates the role of parametric design in optimizing urban wind flow, using computational fluid dynamics (CFD) as the analytical framework. By examining a case study set in Singapore, known for its dense urban landscape and commitment to sustainable architecture, this study

provides insights into the effects of architectural geometries on wind behaviour. The integration of parametric design within architectural practices offers a promising avenue for enhancing urban microclimates by leveraging complex geometric manipulations to improve natural ventilation. The paper is structured as follows: The first section reviews existing literature on urban wind flow dynamics and parametric design methodologies. The second section details the computational approach, focusing on the CFD simulation setup and parametric modeling techniques employed. The results section presents a thorough analysis of the simulation findings, highlighting key architectural interventions that yielded optimal wind flow improvements. Finally, the discussion and conclusion synthesize the results, emphasizing the practical applications of parametric design in urban planning.

References

1. Абдыкалыков, А. А., Маматов, Ж. Ы., Бозов, К. Д., Ордобаев, Б., Кожобаев, Д., Кенжетаев, К., ... & Орозалиев, Б. (2011). Чрезвычайные ситуации. Природные явления. Правила поведения. Ч. I/АА Абдыкалыков, ЖЫ Маматов, КД Бозов и др. Бишкек: КРСУ–КГУСТА.
2. Боронбаев, Э. К., Бегалиев, У. Т., & Холматов, К. Н. (2017). Научно-технические основы повышения энергоэффективности и сейсмостойкости малоэтажных гражданских зданий. Вестник Кыргызского государственного университета строительства, транспорта и архитектуры им. Н. Исанова, (4), 157-163.