Proceedings of the 3rd International Conference on Civil Engineering Fundamentals and Applications (ICCEFA'22)
~~Seoul, South Korea~~ Virtual Conference- October 24 - 26, 2022
Paper No. 115
DOI: 10.11159/iccefa22.115

A Machine Learning-Based Geometry Optimization for an Elevated Beachfront House under Typhoon Wind Conditions using Numerical Simulations

Jamie F. Townsend[1], Jinsheng Wang[1], Tom-Robin Teschner[2], Guoji Xu[1]
[1]School of Civil Engineering, Southwest Jiaotong University
Chengdu, China, 610031
j.townsend@swjtu.edu.cn; jinshengwangrjc@swjtu.edu.cn; guoji.xu@swjtu.edu.cn
[2]Centre for Computational Engineering Sciences, Cranfield University
Cranfield, MK43 0AL, UK
tom.teschner@cranfield.ac.uk

Abstract **-** Coastal residential houses and infrastructure in tropical cyclone-prone regions are vulnerable to damage due to high wind-speeds, as well as other natural hazards. This work considers a machine learning (ML) based geometry optimization for a model low-rise elevated beachfront coastal house typically found in U.S. Gulf States. Specifically, the optimization aims to reduce pressure forces on the roof surface under a hurricane/typhoon wind load. A 1:25 base model geometry consisting of a 5:12 (22.62°) gable roof with overhanging eave has been fully parametrized such that the roof thickness, overhang length, and roof slope can be easily adjusted. Experimental wind tunnel testing and computational fluid dynamics (CFD) analysis are studied for the base geometry subject to varying incident wind angles. Through aerodynamic analysis, quartering wind angles are shown to leave the roof ridge prone to intense suction regions which is hypothesized to be a function of the roof pitch. Furthermore, suction at the overhanging eave is found to increase due to quartering winds, which is hypothesized to be a function of the overhang length. Based on these findings, the fully parametrized house model is modified over parameter spaces considering 10–45° of roof pitch and 0.3–1.3m of overhanging eave length. Numerical simulations and geometry optimization are conducted over this parameter space during 0–90° wind angles with the objective of reducing the wind pressure distribution across the roof. Steady-state Reynolds-Averaged Navier–Stokes (RANS) simulations are used to compute the pressure forces during the optimization process. An efficient optimization framework is then proposed, specifically, the Kriging model is employed to establish a relationship between design variables and the target parameter of interest, upon which the optimization can be easily performed without running extensive numerical simulations. To avoid the drawbacks of the traditional "one-shot" design of experiments (DoE), the surrogate model is constructed adaptively during the optimization, whereby the DoE is enriched with some new judiciously selected samples. Overall, the proposed ML-based geometry optimization framework is highly efficient without mitigating the accuracy of the optimization result.

Keywords**:** Wind Tunnel, Computational Fluid dynamics (CFD), Machine Learning, Optimization, Typhoon, Wind Loading

Acknowledgements

Financial support from NSFC (Grant No. 52078425) and the Foreign Young Talents Program of the Ministry of Science and Technology in China (Grant No. QN2022166003L) is greatly appreciated. All opinions presented in this article are those of the authors and do not necessarily represent those of the sponsors.