Large-Eddy Simulations for Peak Loading of Tall Buildings - Two Case Studies

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Introduction

At present, a wind engineering toolbox consists of wind tunnel testing of scaled models, field measurements, and mechanical load testing. In recent years, the application of computational fluid dynamics (CFD) in this field have made the numerical evaluation of wind loading a more appealing method. However despite the popularity and progression of computational methods, the problem of simulating a fully developed turbulent flow at a reasonable expense is a continuing issue. A common method is to implement periodic boundary conditions to the model. This method achieves a reasonable simulation of a fully developed turbulent flow and deduction of the 'peak loading' on the surface of a bluff body situated in the flow but at times can be an expensive process. More recent research has focused on an inlet condition which leads to a more accurate assessment for peak loading and at a cheaper computational expense. Presented here are the abstracts for two case studies where the evaluation of the peak loading for a single (CAARC building) and an array of obstacles are used for discussion.

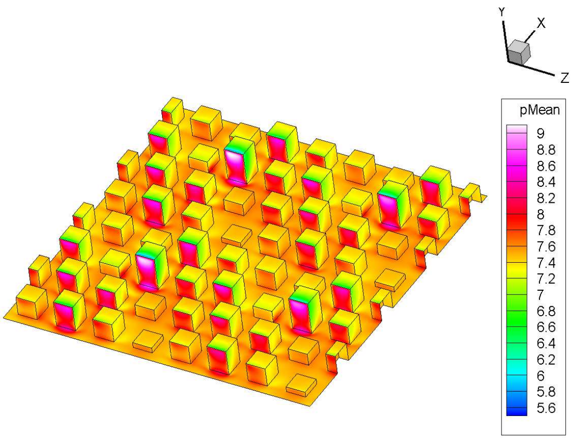
Abstract

Case Study 1: The Flow over Staggered Obstacles of Random Height

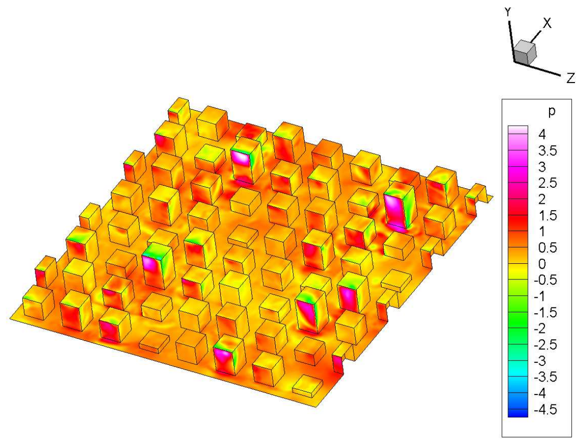
The investigations of the flow over a staggered array of obstacles by Xie et.al[1, 2] have been readdressed in this study with the aim of gaining deeper insight into Large-Eddy-Simultation, and post-processing which will be applied to future research. The study includes the use of the Open-source software OpenFOAM rather than in the previous studies which were conducted using commerical software (ANSYS FLUENT, STAR-CD, and CFX). Along with this, unlike the previous research, the numerical method used in this investigation specifies a constant 'mass flux' over the whole domain rather than specifying a'driving force' $\partial\langle P\rangle/\partial x$ over each cell. The Reynolds number (with resect to the average height of the obstacles h_m and free stream velocity) was set to $Re = 3000$ as presented by the comparative study.

A further study of the quality of the results was conducted focusing on the sensitivity of the calculations to the quality of the mesh. This was achieved using a uniform (structured) and a comparative 'stretched' mesh above the canopy in the vertical direction, with stretching ratio 1.03 for the latter. In comparison to the previous studies, it was found that the use of OpenFOAM with its different numerical scheme achieved a similar result for the velocity profiles and Reynolds stresses. However there were differences in the pressure distribution between the front and back of the obstacles, with a difference in 'peak loading' both in magnitude and position on the obstacle's surface, particularly for the tallest structure.

Following this research, the possibility of sampling the pressure distributions on the surface of the obstacles, particularly a more efficient way of calculating the p_{rms} are discussed.



(a) A contour diagram of the Mean Pressure p_m (Pa)



(b) A contour diagram of the pressure fluctuation p' (Pa)

Figure 1: A study of the pressure distribution over the array using a uniform mesh

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Case Study 2: The Application of the Forward-Stepwise Inlet Condition on the CAARC standard tall building model

Following the research and application of an inlet condition for Large-Eddy-Simulations (LES) by Kim et.al [3, 4, 5] a simulation of the flow over the CAARC (Commonwealth Advisory Aeronautical Council) standard tall building using this inlet condition is performed in this present work. A preliminary model using the inlet condition presented by Xie et.al[6] and a model with periodic boundary conditions have been simulated for comparison.

At present, the objective of this research is to obtain the peak loading on the structure using the above inlet condition. The Reynolds number (with resect to the height of the structure) was set to $Re = 3 \times 10^5$. This Reynolds number is within the range presented by several authors for the validation of wind-tunnel testing. In these studies the inlet conditions for the computational analysis were based on the velcocity power law and values from an equivalent wind tunnel test. For this study, in accordance to the anaysis of Dagnew et.al[7, 8] and Huang et.al[9] the mean velocity was modelled using a power law with ($\alpha(exponent) = 0.16$). The turbulence statistics were derived using the turbulence intensity empirically derived from the wind-tunnel testing from Dagnew et.al with the ratios between the $\overline{u'u'}$, $\overline{v'v'}$, and $\overline{w'w'}$ components derived using the ratios presented for urban meteorology by Xie et.al[10]. The efficiency of this new inlet condition in contrast to previous studies is discussed.

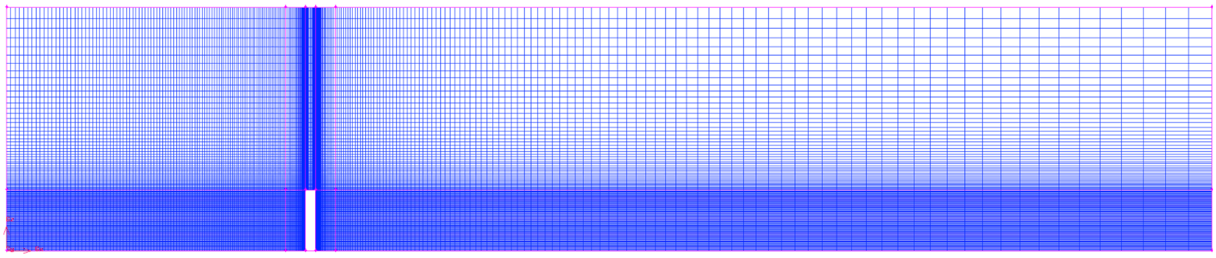

Figure 2: The mesh used for the preliminary investigations.

Acknowledgements

This project is supported by an EPSRC Case studentship and partly sponsored by Arup and Partners Ltd. We thank Dr Steven Downie, Dr Ender Ozkan and Dr N Yeung of Ove Arup and Partners Ltd for their support throughout this project. The computations were performed on Iridis3 computational system, University of Southampton.

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