Wind Engineering Joint Usage/Research Center
FY2019 Research Result Report

Research Field: Wind Hazard Mitigation
Research Year: FY2019
Research Number: 19192004
Research Theme: Time history analysis of supertall buildings to predict dynamic responses and associated inertia loads

Representative Researcher: Prof. Richard G.J. Flay, University of Auckland

Budget [FY2019]: Yen 200000JPY (for travel to Japan in March2020– not spent)

*There is no limitation of the number of pages of this report.
*Figures can be included to the report and they can also be colored.
*Submitted reports will be uploaded to the JURC Homepage.

1. Research Aim

Time history analysis of supertall buildings to predict dynamic responses and associated inertia loads. There are a number of specific topics in this research field associated with wind hazard mitigation.

1.1 To investigate the feasibility of using Computational Fluid Dynamics (CFD) simulation to carry out a surface level wind study to ascertain the pedestrian level wind hazard in the vicinity of tall buildings and deliver commercial results. To understand the strength and weakness of the conventional wind tunnel and CFD techniques.

1.2 Improve the design process for very tall buildings subject to wind excitation by:
  Generating synthetic wind signals
  Conducting HFFB and HFPI tests
  Working on suitable assumptions in the HFFB tests for wind loading distributions
  Examine the number of wind signals required in HFPI tests

1.3 Develop methods to wind tunnel test mega-tall towers by developing rational approaches to undertaking wind tunnel tests on sectional models, rather like very large bridge testing

1.4 Wind resistance design of thousand-meter scale megatall buildings in non-tropical cyclone areas (Collaboration with Prof. Chaorong Zheng at Harbin Institute of Technology and visiting CSC-funded PhD student at the UoA)

2. Research Method

All the specialized research areas follow the same basic research method comprising: Literature review, preparation of hypotheses, analytical investigation, CFD investigation, wind tunnel test, validation and verification by comparison with published results, extension of investigation beyond published data, publication and presentation in conferences and journals.

2.1 The University of Auckland has carried out pedestrian level wind tunnel studies commercially in order to support the industry and the local city council to ascertain the wind conditions around proposed development to ensure that the conditions are suitable for their intended purpose and not dangerous. This study repeats the investigation of surface level wind speeds for a typical site in Auckland with CFD techniques for various wind directions and the results were compared with those obtained from the established technique.

2.2 Stochastic and empirical models for generating synthetic wind signal
HFFB method to estimate vertical variation of wind loading.
HFPI method to estimate vertical variation of wind loading.

2.3 Wind tunnel test several sectional rigid pressure models.
Develop methods for combining the results from the sectional models.
Predict the response of the overall building by inputting the pressure data into a structural model using a time domain approach.

2.4 Develop methods to obtain twisted flow in a solid wall wind tunnel – at HIT.
Carry out wind tunnel measurements on a model 1000 m tall building in both twisted and straight flow – at HIT.
Compare the wind loads and the response of the full-scale prototype when subjected to twisted and straight flow and prepare publications – at U of Auckland.

3. Research Results

3.1
The mean speed results from the CFD in general agreed well, both qualitatively and quantitatively, with wind tunnel results made using Irwin probes.
Discrepancies between the 2 techniques appears most pronounced when a specific location is subjected to strong downwash.
The CFD technique can readily produce full coverage of the entire test domain while conventional wind tunnel measurements are made at discrete points and requires experience of the wind engineer to design a measurement location scheme to cover a finite number of key test locations.
The time for meshing and computation for a CFD study using RANS with SST model is comparable to the modelling and testing time using the wind tunnel.

3.2
This research is at the beginning stages so there are no research results yet.

3.3
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3.4
It has been found that twisted flow significantly changes the distribution of wind pressures along the height of the building, and it makes the wind force that acts on the megatall building no longer a specific value, but to vary with the total wind twist angle.

4. Published Paper etc.
[Underline the representative researcher and collaborate researchers]
[Published papers]
1. Pirooz, A.A.S., Li, Y.F., and Flay, R.G.J., *Numerical and Wind-Tunnel Investigation of Wind Flow over Urban Areas – Part I: Potential Windborne Debris*, Journal of Structural Engineering Society New Zealand (Accepted).
2. Li, Y.F., Pirooz, A.A.S., and Flay, R.G.J., *Numerical and wind-tunnel investigation of the potential for windborne debris in an urban area*, in *BBAA IX*. 2020: Birmingham, the United Kingdom (accepted).
3. Liu, Z., Zheng, C., Wu, Y., Flay, R. G. J., & Zhang, K. (2019). Investigation on the effects of twisted wind flow on the wind loads on a square section megatall building. *JOURNAL OF WIND ENGINEERING AND INDUSTRIAL AERODYNAMICS*, *191*, 127-142. doi:10.1016/j.jweia.2019.06.003

4. Liu, Z., Zheng, C., Wu, Y., Flay, R. G. J., & Zhang, K. (2019). Wind tunnel simulation of wind flows with the characteristics of thousand-meter high ABL. *BUILDING AND ENVIRONMENT*, *152*, 74-86. doi:10.1016/j.buildenv.2019.02.012

[Presentations at academic societies]
1.
2.

[Published books]
1.
2.

[Other]
Intellectual property rights, Homepage etc.

5. Research Group
1. Representative Researcher
Prof. Richard G.J. Flay

2. Collaborate Researchers
1. Dr Yin Fai Li (University of Auckland)
2. Dr Quincy Ma (University of Auckland)
3. Prof. Masahiro Matsui (TPU)
4. Prof. Chaorong Zheng (Harbin Institute of Technology)
5. Amir Ali Safaei Pirooz (UoA PhD student)
6. Zhao Liu (HIT PhD student)
7. Mohammad Mahdi Salehinejad (UoA PhD student)
8. Zhenhua Jiang (UoA PhD student)

6. Abstract (half page)

Research Theme: Wind Hazard Mitigation
Representative Researcher (Affiliation) Prof. Richard G.J. Flay, University of Auckland, New Zealand
Summary・Figures

6.1
The study investigates one of the major causes of damage in severe wind events in urban areas: windborne debris, using a case study of a location in the Auckland city centre, New Zealand. The probability and risk of paving stone ballast becoming windborne from the podium of a tall building was evaluated through wind-tunnel experiments and numerical simulations. These results were used to determine: the local wind speeds at the location of the stones; overall wind behaviour in the urban area; the threshold wind speed at which the stones start rolling or becoming windborne debris. These results were combined with long-term Auckland Meteorological data to predict the expected probability of the “rolling” and “take-off” wind speeds being exceeded in the vicinity of the case study building. It was found that there was a very low risk of stone ballast being blown off the podium.

6.2
This research is aimed at mitigating the wind hazard by improving the design process for very tall buildings subject to wind excitation. It is at the early stages. The plan is to develop methods for the structural engineer to apply wind loads fairly early in the design process in order to provide feedback on the structural system. There are three levels being studied:

synthetic wind pressures, approximate wind pressures extrapolated from HFFB wind tunnel tests, and refined wind pressures from HFPI wind tunnel tests.

6.3

The record for the tallest building in human history has been broken over and over again since Jenney designed the first building to be called a skyscraper in 1884. This is attributed to the innovation and progress of building technology and building materials, which promotes the rapid development of the civil engineering structure industry. On the other hand, as the global economy, population and cities grow, the number and height of tall buildings are on a strong and steady upward trend.

This brings new challenges for wind engineers. How to control the movement and acceleration at the top of tall buildings and improve the comfort of people living in them is a crucial consideration. Wind tunnel test is one of the most effective and advantageous ways to study the wind load of buildings. However, the general wind tunnel size has not been able to meet the requirements of the wind tunnel test of these extremely high aspect slender structures. It takes a lot of manpower and money to build a large-scale wind tunnel test platform.

6.4

In most wind load codes, the wind direction is assumed to be the same along the height in the atmospheric boundary layer (ABL). But actually, due to the Earth's rotation (Coriolis force), the wind direction in the ABL changes along the height. This twisted wind flow (TWF) will obviously make a difference to the wind loads on megatall buildings. In this study, two kinds of TWFs with total wind twist angles of 25° and 15° are generated in a boundary layer wind tunnel. The effects of TWFs on wind pressures and aerodynamic forces acting on a square section megatall building model are investigated. It is found that the TWF significantly changes the distribution of wind pressure, and it makes the wind force that acts on the megatall building no longer be a specific value, but to vary with the total wind twist angle.