New Zealand Economy Report on Wind Engineering Activities for APEC-WW 2010

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ABSTRACT: This paper summarises the major wind engineering activities that have been undertaken in New Zealand over the past year. Wind Engineering activities are carried out by universities, government organizations, and also by private companies. In the past year there have been one new project that has started, and three major activities that have continued. The new project is being run under the Natural Hazards Platform, and is a collaboration among GNS Science, NIWA, Opus International Consultants, and the University of Auckland. Two of the continuing projects are full-scale building monitoring projects. The first project is a collaboration among GNS Science, NIWA and the University of Auckland. The second project is a collaboration between Opus International Consultants and the University of Auckland. The third major activity is the Riskscape project being carried out by GNS and NIWA. In addition there are a number of smaller research projects that are underway at the University of Auckland, being done by faculty and students. We are pleased to report that the collaboration on pedestrian level winds between the Centre of Excellence in Disaster Mitigation & Management at the Indian Institute of Technology Roorkee and the University of Auckland is continuing.

KEYWORDS: New Zealand, pedestrian level winds, cross-wind excitation, internal pressures, CFD, wind turbine, riskscape, natural hazards, wind flow over hills.

1 INTRODUCTION

This report summarises research and other work carried out in New Zealand over the period 2010 since the previous APEC-WW 2009 [1] meeting at the Grand Hotel, Taipei, Taiwan and at Tamkang University Lanyang Campus, I-Lan County, Taiwan. It is based on information received from active Wind Engineers in various organisations in New Zealand. Because it is a report on various wind engineering activities, it is not particularly detailed, due to the length that such detail would require. Interested readers who would like further information are encouraged to contact the authors of this report, or the organisations and individuals mentioned in it.

2 WIND TUNNEL INVESTIGATION OF CROSS-WIND EXCITATION OF BUILDINGS

2.1 *Introduction*

This research has been progressed further by a masters student, Mr Alexander Judge, under the supervision of Prof. Richard Flay at the University of Auckland, and is a continuation of the masters research project by Bhatt [2]. The current method used in New Zealand to determine the cross-wind excitation and response is described in AS/NZS1170.2:2002 [3] One determines the reduced velocity, $V_r = V_h/(Bn_c)$ (where V_h is the wind speed at the top of the building, B is the building width normal to the wind, and n_c is the first mode cross-wind natural frequency) and then reads off the generalised force coefficient C_{fs} from an appropriate graph.

C_{fs} is a function of aspect ratio and only a few aspect ratios are available. Often the aspect ratios required are more ‘slab-like’ than those provided, such as the 51m:23.5m:7.4m (6.9:3.2:1) shape proposed for Auckland’s CBD. This causes problems as the most common method for getting C_{fs} information uses the High Frequency Force Balance method which requires models to be as light and stiff as possible so that the model/balance natural frequency is well above the frequencies of interest. ‘Slab-like’ models are generally less stiff than conventional more compact shapes and thus can have first mode natural frequencies that lie within the region of interest of reduced velocities. Determining C_{fs} from multi-channel pressure measurements offers an advantage for investigating the generalised force spectrum for ‘slab-like’ aspect ratio buildings because the upper frequency range is not dependent on model stiffness, but on the frequency response of the tubing system. Thus potentially, high frequencies, corresponding to low reduced velocities are obtainable.

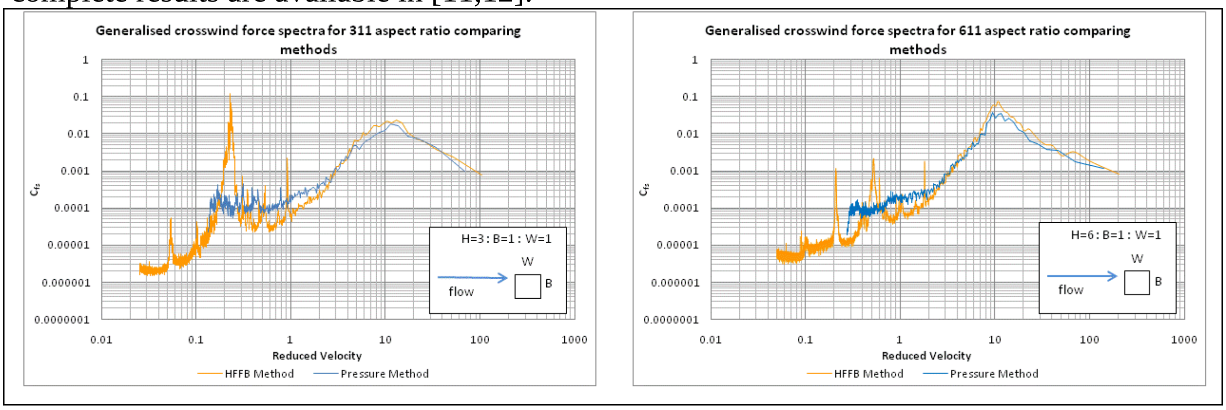
Thus the aim of this investigation was to measure C_{fs} for lower reduced velocities for aspect ratios available in the standard, as well as for more ‘slab-like’ shapes, and also to compare the spectra measured from the HFFB method with those obtained from multi-channel pressure measurements.

2.2 *Experimental procedure*

All the testing carried out for this project used the de Bray wind tunnel, located in the Faculty of Engineering at the University of Auckland. The wind tunnel tests were carried out at a model scale of 1/400 using a reference model height of 240mm which represents a 96m tall building, as previous studies [4,5] have had success using models with heights between 240mm and 187mm. The wind tunnel flow was set up in the usual manner [6,7] using blocks etc to get flow expected over urban terrain roughness. Measurements were made using a commercially available High Frequency Force Balance (HFFB) designated the JR3. The models were constructed of foam covered in fibreglass reinforced tape and were 240 mm in height. An Electronically Scanned Pressure System was also used to measure surface pressures on models of aspect ratios: 3:1:1, 3:1:2, 3:2:1, 3:1:3, 3:3:1, 6:1:1, 6:2:1 and 6:3:1. A digital recursive filter was used to correct the pressures for distortion effects from the tubes [8,9] in order to meet Australasian quality assurance standards [10] for wind engineering studies. The pressure studies were carried out as it is somewhat easier to obtain results at low reduced velocities using pressure measurements compared to force measurements.

2.3 *Results*

Some example results are shown in Figs. 1 and 2, and show good agreement between the HFFB and the pressure measurements. Some new results for “slab-like” shapes are also shown in Fig. 2. These shapes are commonly used for apartment buildings in NZ. More complete results are available in [11,12].



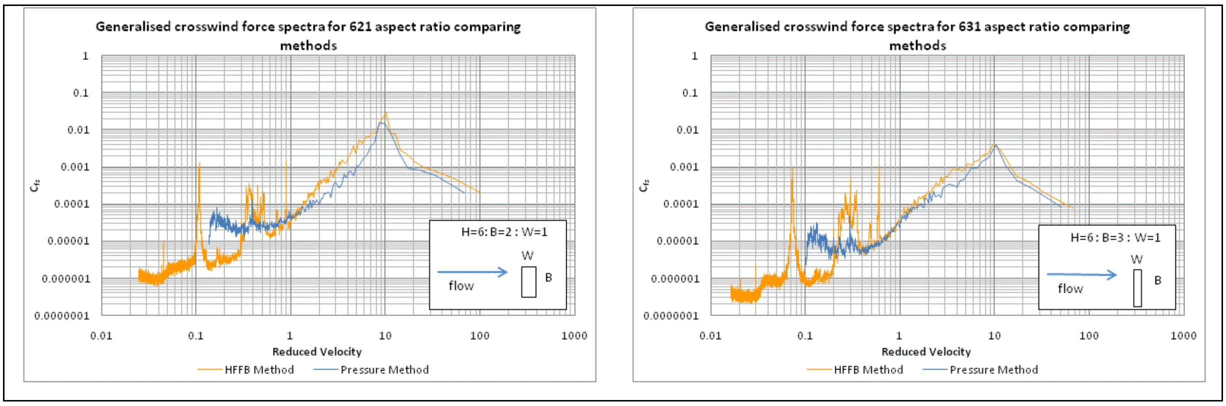


Fig. 1: Plots showing comparison between HFFB method and pressure measurements for identical aspect ratios

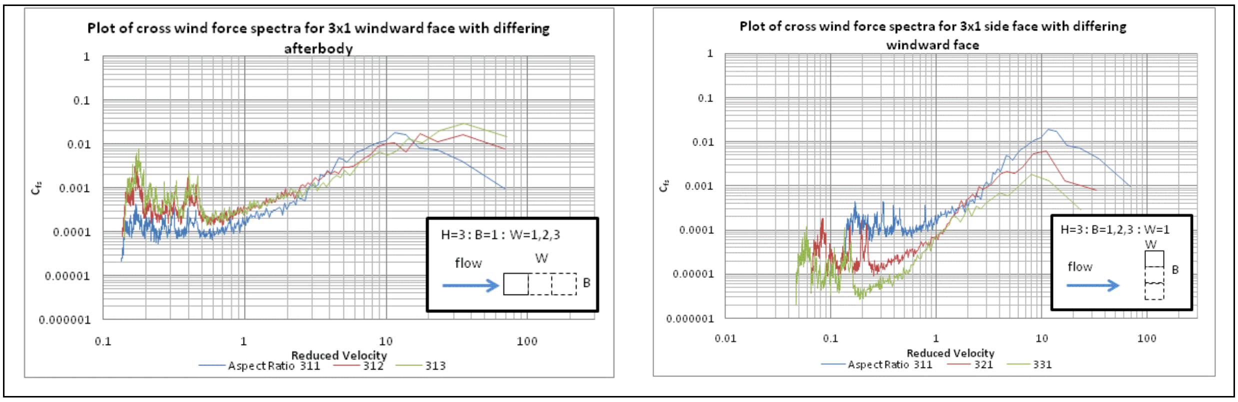


Fig. 2: Plots showing 'slab like' aspect ratios not currently covered in the wind loading standard [1] (3:1:2, 3:2:1, 3:1:3, 3:3:1)

2.4 *Conclusions*

The spectra calculated using the Pressure System appeared to match well with those obtained though the use of the High Frequency Force Balance System. This confirms the suitability of the pressure method for calculating crosswind force spectra.

Crosswind spectra for 'slab like' aspect ratios 3:1:2, 3:2:1, 3:1:3 and 3:3:1 not included in the current AS/NZS1170.2:2002 wind loading standard [3] were tested using the pressure method and gave reliable data to reduced velocities 1.0, 0.5, 1.0 and 0.35 respectively. Tests like these will enable more data on cross-wind excitation to be provided for design purposes in codes and standards.

3 INTERNAL PRESSURE IN LOW AND MEDIUM RISE BUILDINGS SUBJECTED TO HIGH WINDS

As reported in the 2009 APEC-WW NZ Economy report [1], Research on internal pressures in low and medium rise buildings is being carried out by Mr Tushar Kanti Guha for his PhD, under the supervision of Dr R.N. Sharma and A/Prof. Peter J. Richards. The research currently underway combines wind tunnel testing with some full scale tests. Some data were gathered at full scale on the large instrumented Tamaki wind tunnel building, with and without the roller door open. Wind tunnel tests are looking at the influence of background leakage, secondary openings, flexible envelope, and internal partitioning on characteristics of internal pressure; to be compared with code provisions. This research has resulted in a number of publications [13-16] since the last report.

4 STUDY OF PEDESTRIAN LEVEL WIND ENVIRONMENT IN THE VICINITY OF TALL BUILDINGS

This study is being carried out by Prof. K. Mohan, a Research Scholar at the Centre of Excellence in Disaster Mitigation and Management at IIT, Roorkee, India, in collaboration with the University of Auckland. Prof. Mohan is being supervised by Associate Professors Ajay Gairola, Mahua Mukherjee and Naveen Kwatra. The collaboration has involved a visit by Prof. Mohan to the University of Auckland during August to October 2009 to carry out several wind tunnel tests using the erosion technique in the de Bray wind tunnel at the Mechanical Engineering Department, University of Auckland, under the guidance of Prof. Richard G.J. Flay.

This research has continued in 2010 with further analysis of the wind tunnel results, the preparation of a publication [17], and field studies.

The analysis of the erosion contours of the tests done in the de Bray wind tunnel gave a lot of information such as amplification factors, which according to Beranek should be termed a discomfort parameter. This gave the erosion contours a quantitative value which was not assigned earlier. Furthermore the wind tunnel data were analysed to show the effect of mitigation measures, as illustrated in Figs. 3 - 4. In Fig. 4 the area of red (suitable for walking slowly) is reduced by the mitigation measures, and the small are of blue on the left (suitable for walking fast) is eliminated by the mitigation measures.

The field studies were carried out by Prof. Mohan in Mumbai as most of the tall buildings today in India are in Mumbai. He studied many tall buildings in Mumbai and took measurements of winds speeds at the base of these tall buildings of around 35 storeys with a hand held anemometer. These field studies have helped to illuminate the problem of downwash around tall buildings, which has a significant effect on pedestrians.

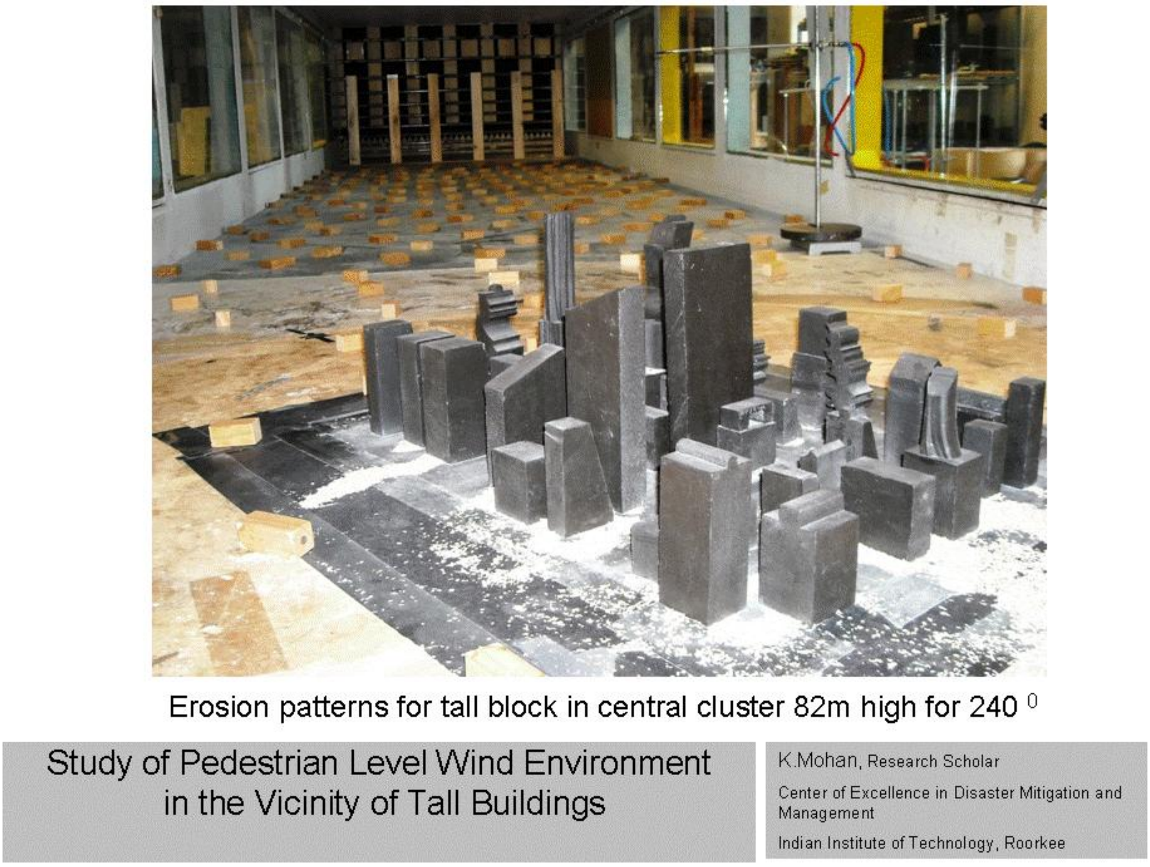


Fig. 3 Model in wind tunnel showing erosion of bran

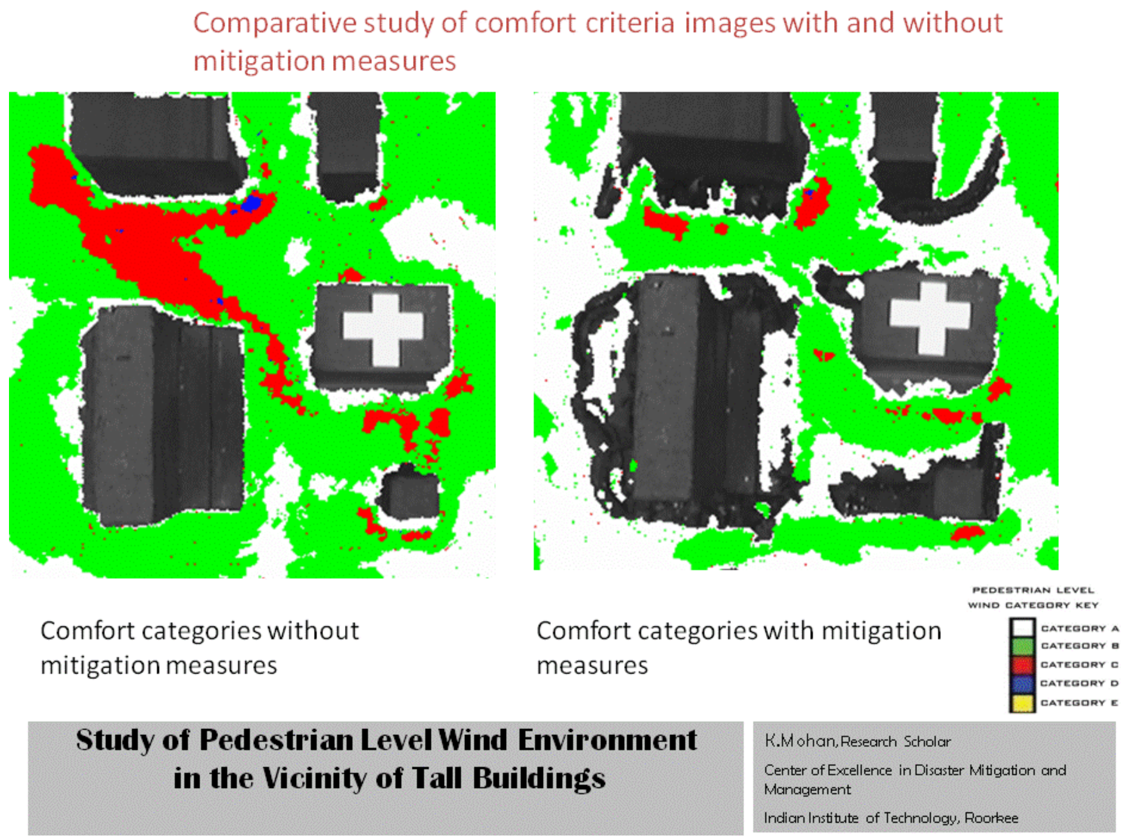


Fig. 4 Images showing the effect of mitigation measures.

5 FULL-SCALE MONITORING PROGRAMME TO MEASURE ACCELERATIONS OF BUILDINGS

This research project is aimed at monitoring the wind-induced building motion of several tall buildings in Wellington, and one in Auckland, and comparative wind tunnel studies. Since the 2009 APEC-WW report, the monitoring of three buildings in Wellington has been completed. A suitable building for monitoring in Auckland has been identified, and the acceleration monitoring equipment will be installed in mid-October 2010, and accelerations monitored for a period of about two months. The aim of the research is to obtain improved procedures for prediction of wind-induced building motion. The results of analysing the acceleration records from the three Wellington buildings were presented at the 14th Australasian Wind Engineering Society Workshop in Canberra [18].

The research is being done as a collaboration between Opus International Consultants and the University of Auckland. The research is funded by the Building Research Association of New Zealand (BRANZ).

6 NATURAL HAZARDS RESEARCH PLATFORM

Late in 2009 the New Zealand Government announced that it had allocated funding for natural hazards research. The funding is for New Zealand-specific research for all natural hazards - including volcanoes, earthquakes, weather, oceans and others - and is also for research into social impacts and engineering. The Natural Hazards Research Platform provides for long-term, complex research projects, involves different research organisations working closely together, supports strengthened connections across different science disciplines, and focuses on linking research teams with the people and organisations who will use the results.

A group comprising GNS Science, NIWA, Opus International Consultants, and the University of Auckland worked together to prepare a submission, and were successful in getting a research programme entitled: “Modified wind flow effects on towers and pylons due to topographic effects” funded.

The aim of the research is to reduce the vulnerability of New Zealand’s infrastructure to wind damage through provision of improved design wind speed procedures. New Zealand’s hilly, often mountainous, terrain trends north~south along the spine of both islands. New Zealand’s latitude in the ‘Roaring 40s’ positions it directly in the path of the strong, predominantly westerly, winds that spawn in the sub-Antarctic regions and sweep across New Zealand. At landfall the wind flow is strongly influenced by the topography over which it passes, with both valleys and hill crests experiencing stronger, in some cases much stronger, wind speeds than flat terrain. This research is aimed primarily at trying to get more information on the acceleration of the wind over hills and in complex terrain.

A site for full-scale measurements has been identified near Wellington, known as Belmont Hill, and is shown in Fig. 5. It will also be modelled in the Opus wind tunnel and the speed-up measurements compared with those from full-scale. It is also intended in this research programme to try to obtain more full-scale wind data from wind farm developers and operators, to try to ascertain how the topography affects the results.

At October 2010 there has not been a great deal of progress on this project. Funding has been obtained, instruments for full-scale monitoring have been made available, and some preliminary CFD runs have been carried out. The wind tunnel investigation has not started yet.

Fig. 5 Site for full-scale measurements of wind flow over hills (Natural Hazards Research Platform)

7 AERODYNAMICS OF TELESCOPIC BLADE WIND TURBINE

This project was reported on in the 2009 APEC-WW NZ Economy report [1]. Briefly, it concerns a possible way for improving the power output of a turbine by controlling the swept area, i.e. the diameter of the rotor. Ideally the wind turbine designer will use the long term mean wind speed to design and establish the rated power output of the wind turbine. The stochastic nature of wind will fluctuate the power output of the turbine. Therefore to maintain the design rated power of the turbine, the telescopic wind turbine concept can be used. When the wind speed drops, the telescopic blades extend in order to maintain the power output, and when the wind speed increases, the telescopic blades retract in order to reduce the loads on the system. By telescoping the blades, the capacity factor of the wind turbine is thus enhanced. Work on this research has made good progress both in theoretical development, and also in wind tunnel testing.

8 CONCLUSIONS

The New Zealand Economy Report shows that there are a number of interesting research projects being carried out in New Zealand, in spite of the low level of research grants that are available to fund such work. They encompass a range of wind engineering activities from laboratory work by students, to extensive full-scale activities such as the Natural Hazards Platform Research project being carried out by GNS, Opus International Consultants, the University of Auckland and NIWA.

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