New Zealand Economy Report for APEC-WW 2009

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ABSTRACT: This paper summarises the major wind engineering activities that have been undertaken in New Zealand over the past two years. Wind Engineering activities are carried out by universities, government organizations, and also by private companies. In the past two years there have been three major activities that have started. Two are full-scale building monitoring projects. One project is a collaboration among GNS Science, NIWA and the University of Auckland. The other is a collaboration between Opus International Consultants and the University of Auckland. The other 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. Finally we are pleased to report that a collaboration between the Centre of Excellence in Disaster Mitigation & Management at the Indian Institute of Technology Roorkee and the University of Auckland has begun to research pedestrian level winds. Experimental work on a model of a suburb in New Delhi, India, has been carried out in the boundary layer wind tunnel at the University of Auckland.

KEYWORDS: New Zealand, pedestrian level winds, scour, erosion, hot-wire, cross-wind excitation, internal pressures, CFD, wind turbine, riskscape, natural hazards.

1 INTRODUCTION

This report summarises research and other work carried out in New Zealand over the period 2008 and 2009 since the previous APEC-WW 2007 meeting at Tongji University in Shanghai, China. 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 is being carried out 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 [1,2]. The aim is to undertake further work to determine the cross-wind excitation of various models, at a scale of 1:400, using both multi-channel simultaneously scanned pressure measurements as well as the standard high frequency force balance method to better understand wind induced excitation in buildings. In particular the research will look at excitation in buildings where the acceleration results are affected heavily by uncertainty about how peaks in different modes interact. The pressure measurements will be analysed in the time domain, and thus the accelerations can simply be combined for a given time rather than having to estimate the best way to combine the peaks. Further details about time domain analysis techniques can be found in [3].

2.2 *Force Balance Measurements*

The high frequency force balance method used at the University of Auckland involves recording the forces and moments from the balance at rates of around 5 kHz. This high sampling rate is used to avoid any aliasing problems. These data are then transformed into spectra from which peak acceleration estimates can be obtained, as well as other quantities such as overturning moments, peak shear forces etc. The best method for converting the spectra into peak acceleration estimates is not entirely clear, with several differing approaches being described in the literature. A significant problem is knowing how to add the acceleration components from several different modes. This issue is discussed in [4].

2.3 *Pressure measurements*

Multi-channel pressure measurement systems eliminate much of the uncertainty on how to combine peak accelerations as they allow analysis in the time domain. Each mode can be analysed separately, and the modal accelerations, for example, can be added together vectorially at locations of interest on the building. A pressure analysis system usually consists of a model with a few hundred pressure taps. Each tap is connected to a pressure transducer via a length of tubing that then sends its measured pressure to a computer. Pressure measurement systems are becoming quite common in wind engineering laboratories, but are still quite expensive. The University of Auckland has built its own system, and this is described in the next section. A photograph of two of the four 64-channel modules being used in a recent test are shown in Fig. 1.

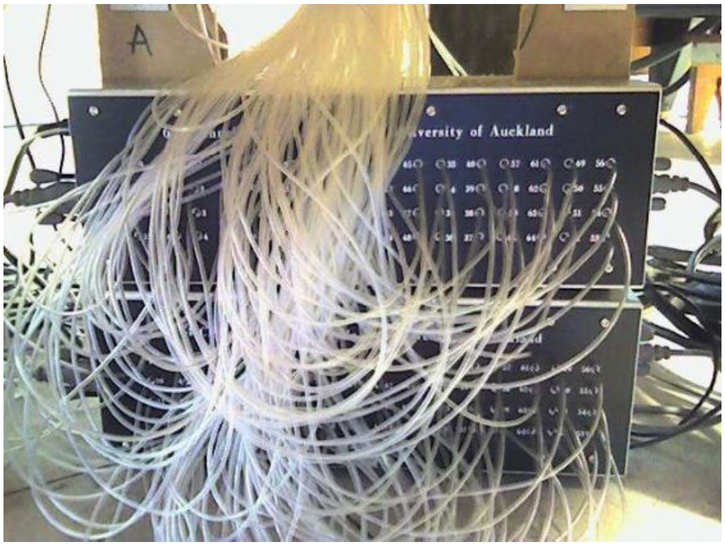


Figure 1: Two University of Auckland 64-channel pressure modules shown with tubing attached.

2.4 *Details of planned investigation*

It is planned that this research will investigate several building shapes using both the HFFB method, and high speed multi-channel pressure measurements. The model scale is 1:400, which is the standard scale used in the wind engineering laboratory for most wind tunnel investigations. Preliminary investigations have been carried out on some simple shapes that whose cross-wind force spectra are available in the Australia/New Zealand wind loading Standard, AS1170.2 [5], and which were also investigated by Bhatt, and Locke & Cenek [6]. These shapes are: H:D:B = 6:1:1, 3:1:1. It is also intended that "slab-like" building shapes will be investigated, as these are a common building shape, and there is no information on them in [5]. The intention is to obtain cross-wind force spectra down to reduced velocities of 1, which is half of the value of 2 in [5]. This should be relatively straightforward for the pressure investigations, as one can obtain a flat pressure tube frequency response up to 200 Hz without difficulty, but the demands on force balances are much more onerous, as discussed in [1,2].

Testing these slab-like shapes may prove to be too difficult with the HFFB method as a very stiff and light models of these shapes may be impractical. However the building shape does not affect the pressure modelling to a significant degree. It will be very useful to obtain further information on such pressure models.

3 DESCRIPTION OF ELECTRONICALLY SCANNED PRESSURE SYSTEM (ESPS) DEVELOPED AT THE UNIVERSITY OF AUCKLAND

Research such as that described in the previous section is enhanced significantly if instantaneous pressure distributions can be measured simultaneously over model surfaces. Because of this, much effort has been expended by the Wind Engineering Research Group at the University of Auckland to build such a system, as funds to purchase one were not available. Work on developing a reliable pressure system has been underway since 2000, and an earlier version of the system, as described in [7] has been used for several investigations. However, the availability of relatively inexpensive new technology, such as high speed multi-channel analogue to digital converters, has enabled the earlier pressure system to be rebuilt in a simpler fashion. Whereas the previous multi-channel pressure system was based on pressure modules of eight transducers connected in series, with data transmission and communication with the computer via the printer port, the present system has units of 8 eight-channel modules combined together, to make more compact 64-channel modules. Two of these modules are shown in Fig. 1. Hardware and Labview data acquisition software design for the ESPS was carried out by the Aerodynamics Laboratory Technician in the Mechanical Engineering Department, Dr N. Velychko.

The pressure transducer used is the XSCL04DC manufactured by Honeywell. A photograph of the transducer is given in Fig. 2, and a photograph of a 64-channel module with the cover removed can be seen in Fig. 3. The ADC used in the design is the NI PCI-6254 DAQ, and high speed 32 channel multiplexers are used as the input to each of the ADC channels to give a maximum channel capability of 2048 channels, although the present design has 512 channels. The system was first tested and used in 2009 and has been found to be very reliable.

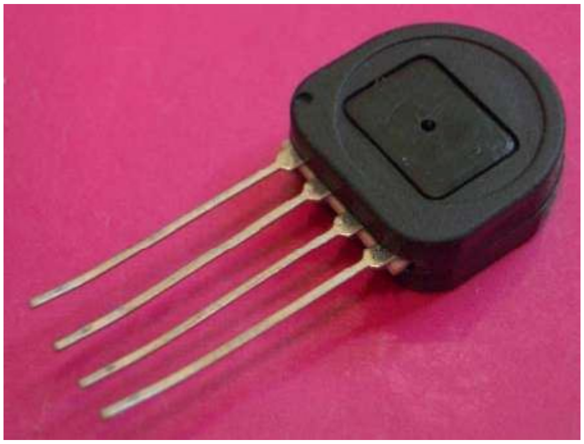


Figure 2 Photograph of pressure transducer XSCL04DC.

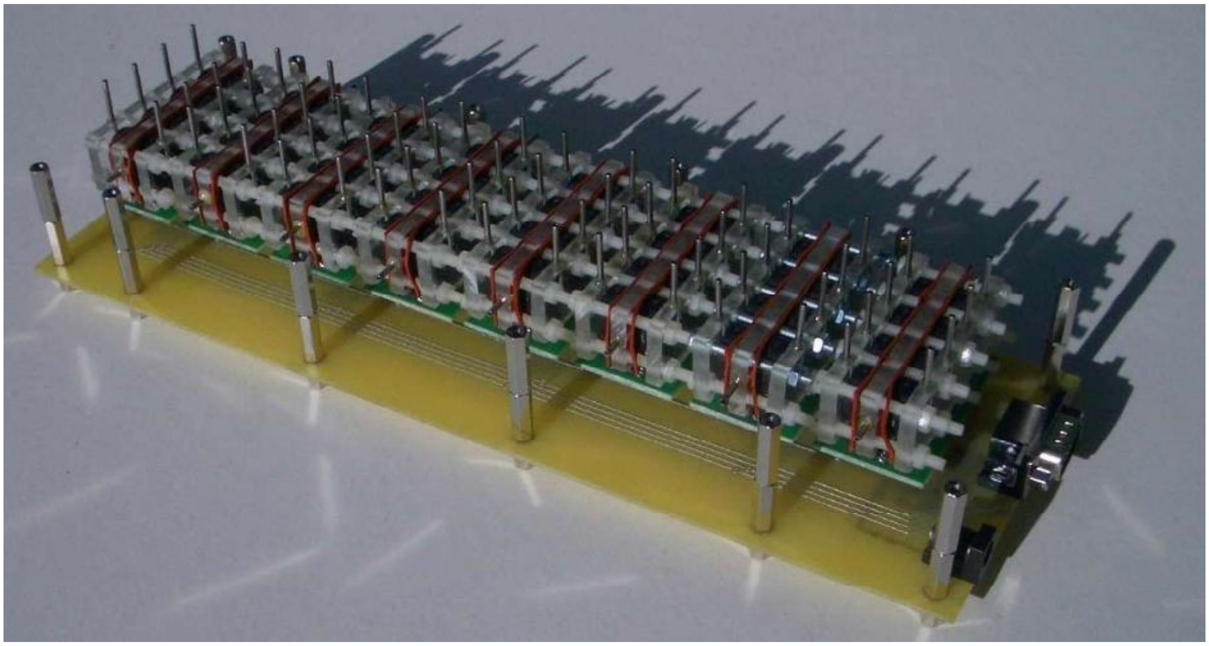


Figure 3 Photograph of a 64-channel pressure module with the cover removed.

The specifications of the pressure system are given in Table 1 below.

Table 1 Specifications of the University of Auckland electronically scanned pressure system, ESPS.

Maximum Number of channels	512
Configuration	8 pressure modules; 2 interface units
Pressure Range	±450 Pa, minimum
Maximum Overpressure	3 psi
Pressure Resolution	9.25 mV/Pa, typ.
Maximum Sampling Rate	1953 samplers/sec/channel (for 512 channels)
Expandability	up to 2048 channels (4 DAQs)
Power Consumption	1200 mW, typ. (for 1 pressure module)
Media Compatibility	DRY GASES ONLY. Media must be compatible with epoxy based adhesive

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

4.1 *Introduction*

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. Such work is very important, as it is now a recognized fact that the integrity of a building structures depends as much on internal pressure as it does on external pressure in strong winds. Internal pressure induced through opening(s) during high wind events impact directly on the performance of individual building components (walls, roof and internal partitions) and claddings, and therefore has an indirect influence on the safety of the entire structure. The importance of internal pressure on the safety of buildings first came to light during the investigations conducted in the aftermath of cyclone Tracy in 1974. In spite of this being followed by a sudden impetus in research during 1980's and 1990's, scope for further understanding of its effects continues to be repeatedly felt during major post-cyclone forensic investigations around the world even today. The fact is that the scale of research on internal pressure has been significantly lower than that of external pressure and not surprisingly internal pressures still continue to be one of the major contributors to wind related damage around the world. The primary objective of this research work is thus to investigate the influence of internal pressure in low to medium rise buildings under high wind conditions.

4.2 *Experimental approach*

The approach taken for this research involves analytical, wind tunnel, CFD and most importantly full scale studies. While there are merits and demerits of each of these approaches, an exhaustive survey of literature reveals that the full scale investigations of internal pressure of typical range of buildings as well as environmental conditions encountered in practice are few. As a result, the wind loading provisions of internal pressure of different countries based mainly on wind tunnel and idealized full scale setups are not representative of the actual scenario in most cases. Furthermore, considerable debate and confusion exists among practising engineers regarding the design philosophy and risk consideration of internal pressures resulting in different approaches adopted by different wind loading standards. Hence the data and knowledge gained from the full scale tests aided by complimentary analytical, wind tunnel and CFD studies will be synthesised to propose unified provisions that could be implemented in wind loading standards.

The full scale test facility at the Twisted Flow Wind Tunnel building (TWFT) at Tamaki, Auckland consists of a warehouse with approximate dimensions of 38 m by 25 m by 7 m with a roller door of size 5m by 4m ($f_{HH} \approx$ 1.21 Hz with door fully open) housing an open circuit twisted flow wind tunnel (with a hollow test section of 9 m by 7m by 3.5 m). The upwind fetch (predominant wind direction is from SW) of the building has a variable roughness consisting of cargo containers, fences, small trees and bushes and a small hillock (Mt. Wellington), the conditions being vastly different and more representative of real buildings compared to other full scale test setups already in use for long term wind engineering investigations around the world. It provides an excellent opportunity to investigate some of the factors (such as the effect of background leakage, building flexibility, volume occupancy and internal partitioning) believed to influence internal pressure in real buildings.

Figure 4: Full Scale test site, TFWT (UoA) warehouse at 3 Hannigan Drive, Tamaki, Auckland, NZ.

4.3 *Interim results from internal pressure investigation*

While full scale investigations are still in progress, some analytical and CFD work already completed have been reported [8-12] in wind engineering conferences.

5 WIND TUNNEL INVESTIGATION OF EROSION AND POINT MEASUREMENTS TO DETERMINE WIND COMFORT LEVELS

5.1 *Introduction*

One of the outcomes of the APEC-WW in China, 2007 [13] from the "Wind Environment and Air Pollution" Working Group, were various resolutions concerning air pollution, and the pedestrian level wind environment. The resolutions concerning the pedestrian level wind environment could be summarised as follows.

APEC-WW/WG of "Pedestrian Wind Environment" agrees to conduct further enquires to obtain more information on assessment criteria and statutory requirements in APEC countries. Thermal effects should be considered in the assessment of wind comfort criteria. APEC-WW/WG will look into the use of peak gust wind speed in both wind tunnel experiments and assessment criteria. Concepts and investigation methods for pedestrian winds using a standard building and prescribed onset flow is an item that should be discussed at a future APEC-WW. A standard building arrangement consisting of two identical towers side by side, and a prescribed onset flow was also specified in an Appendix III. This building arrangement is shown in Appendix A.

In order to provide information on the wind patterns around this building arrangement, some preliminary research was carried out in a final year BE(Hons) project by R. McCardle and R. Stubbing in 2008 [14,15] under the supervision of Prof. R.G.J. Flay. A summary of their investigation is presented herewith.

5.2 *Experimental investigation*

The test model of the hypothetical building defined at the APEC-WW 2007 meeting [13] shown in Fig. 5 (also in Appendix A) was built to a scale of 1:400. It can be seen in Fig. 6 after an erosion test with the wind in line with the two buildings.

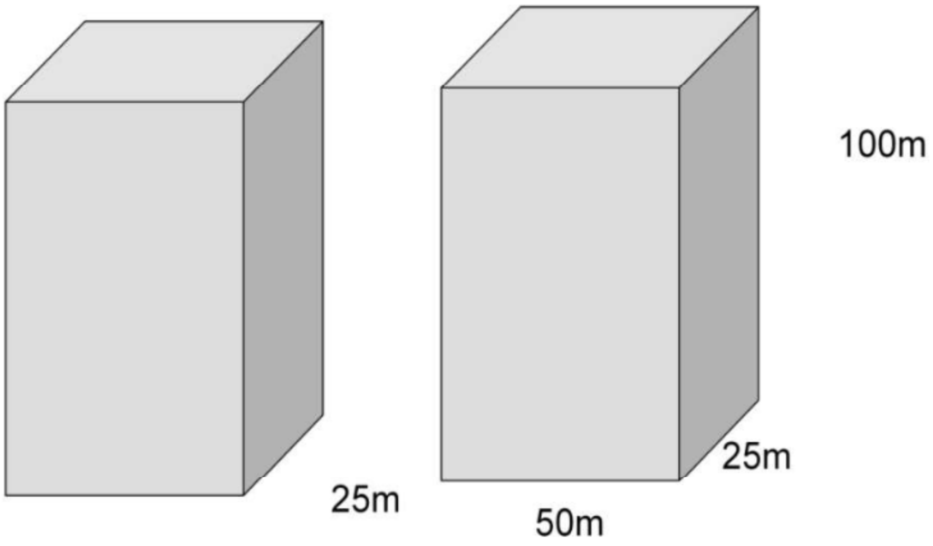


Figure 5 The hypothetical reference building layout proposed at APEC-WW 2007 in China.

Figure 6 The 1:400 scale models in the wind tunnel during a bran erosion test.

In order to compare the wind environment determined from erosion methods and hot-wire measurements, a very detailed grid of points was set up, as shown in Fig. 7, and measurements were made at each point for 1 minute using a hot-wire. Because of the large number of points, a computer controlled traversing rig was used.

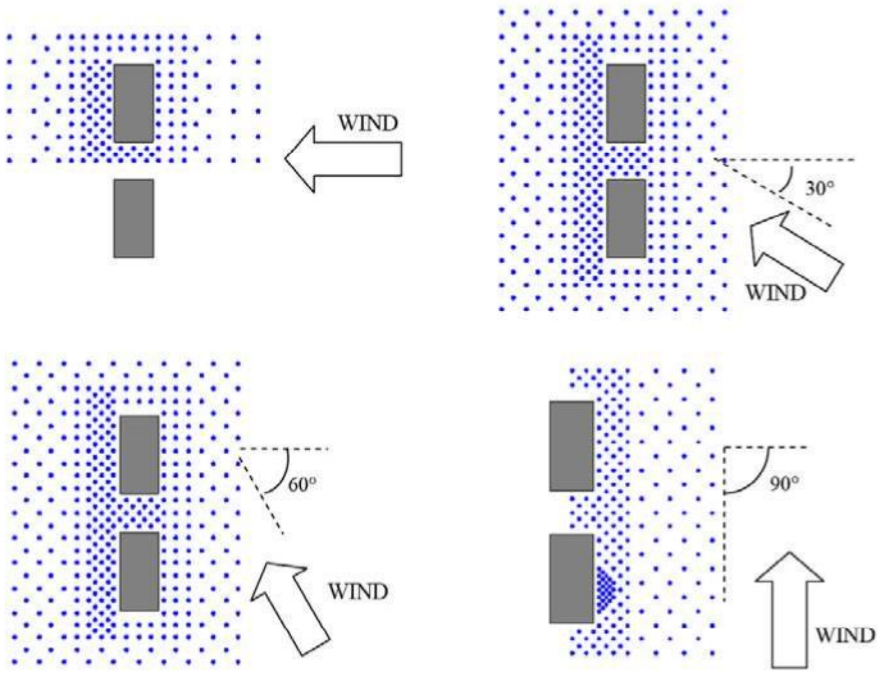
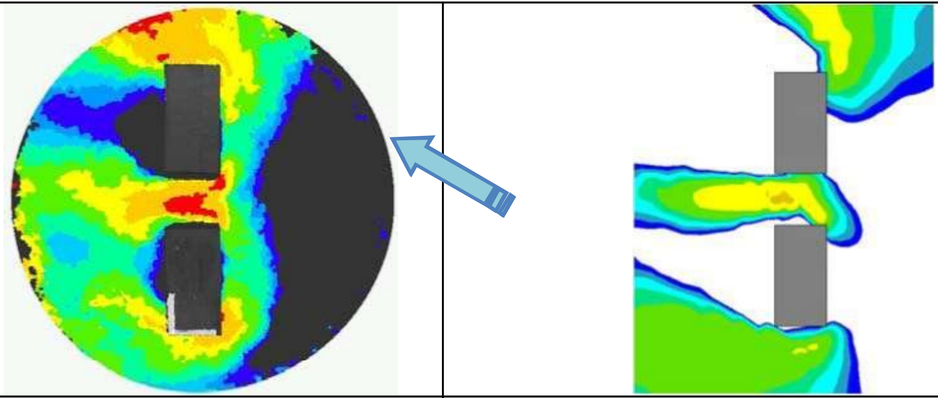
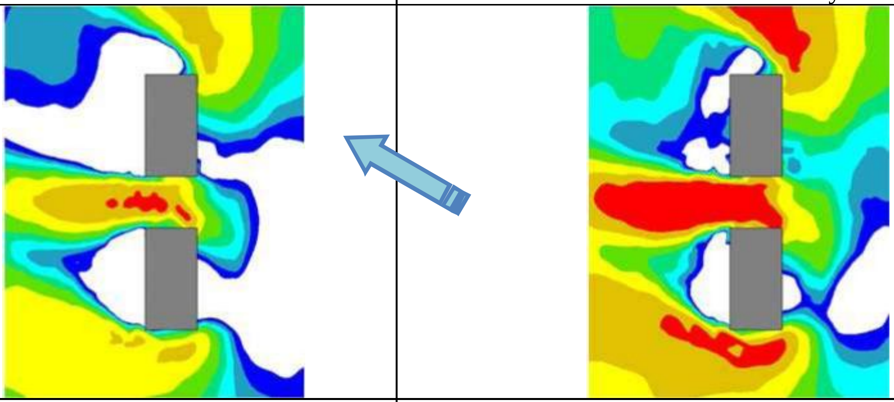


Figure 7 Points at which hot-wire measurements, at an equivalent height of 1.5m in full-scale, were made around the 1:400 model, for the 4 wind directions tested.



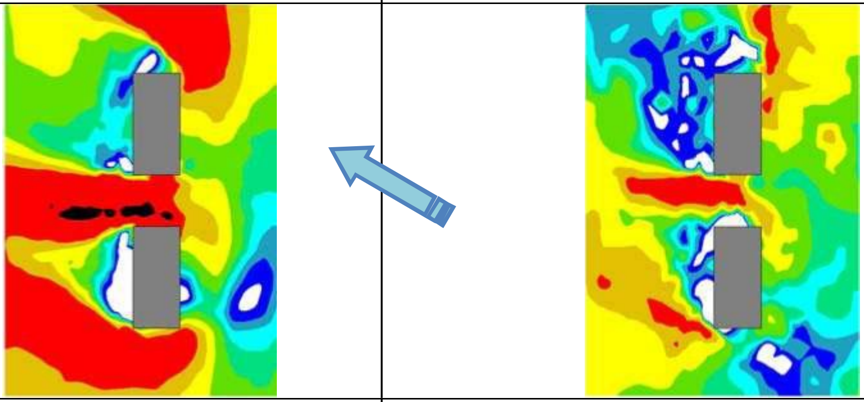
Erosion test

Mean flow velocity



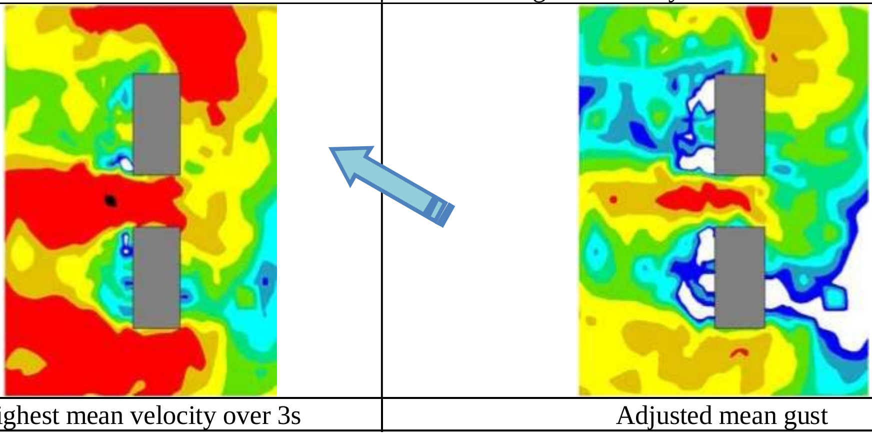
Mean +1 standard deviation

Mean +2 standard deviation



Mean +3 standard deviation

Highest velocity exceeded for at least 3s



Highest mean velocity over 3s

Adjusted mean gust

Figure 8 Comparison of erosion and hot-wire point measurement data, at 30° onset flow.

5.3 *Comparison of erosion and hot-wire results*

One of the objectives of this study was to try to understand more completely how hot-wire and erosion results can be compared. In order to do this, the hot-wire data were analysed in several different ways, and the results compared to the erosion maps. This was to see, for example if the erosion maps were similar to the mean wind speed contour map measured by the hot-wire, or by the measured peak gusts, or by some combination in between. A comparison of the results from the investigation at a wind direction of 30° is shown in Fig. 8.

It was found in this preliminary study that no obvious relationship was apparent between the local wind flow and the bran erosion, except that it was evident that the bran erosion was more sensitive to gust velocities than the mean velocities. Thus no analysis method was found that could be applied to the hot-wire anemometer output which would yield results similar to the erosion maps in all conditions. Thus there are still some interesting research questions to be addressed in this area. Further work to examine some of these questions is being carried out as described in the next section.

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

6.1 *Introduction*

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.

Tall buildings provide the potential for increased accommodation for living and working around public transport nodes and also influence the sky line of major cities. However tall buildings tend to deflect the wind into previously sheltered areas. The resulting increased wind speed near the ground are annoying and at times dangerous to pedestrians. One area of increasing concern to architects, planners, developers and engineers, which forms the focus of this study is the pedestrian level wind environment at the base of high-rise buildings.

6.2 *Need for the study*

India is witnessing a major spurt in tall/high rise building activity in many of its major metropolitan cities like Mumbai, Delhi, Gurgaon, Calcutta, Bangalore Hyderabad, etc. Problems related to pedestrian level winds are bound to surface in the future. Hence it becomes important to carry out studies related to the pedestrian wind environment around tall buildings.

The San Francisco Wind Ordinance is the first U.S. Wind Code containing specific legal and technical requirements for compliance which address both comfort and safety at pedestrian level. The Auckland and Wellington City Councils in New Zealand have adopted pedestrian level wind criteria for various types of activity which define acceptable wind conditions for those activities.

The Indian Wind Code does not contain any provisions with regard to the wind environment in the vicinity of tall buildings. Systematic studies related to the pedestrian level wind environment would help in formulating suitable guidelines and assessment criteria for inclusion in future revisions of the Indian Wind Code.

6.3 *Literature Review and Field Survey*

A literature review of tall building aerodynamics and building configurations which result in wind amplification, wind ordinances, and various criteria related to pedestrian wind environment, instrumentation and techniques for assessing pedestrian level winds and strategies for the mitigation of adverse pedestrian wind effects has been carried out as part of this research.

A field survey of some tall buildings in Dwaraka, Indirapuram, Ghaziabad,Greater Noida, and Gurgaon was carried out to examine the potential for wind amplification effects by these buildings. The objective was to examine building configurations which have the potential for creating adverse or positive wind effects.

6.4 *Objectives*

The main objectives of the study are listed below:

- To examine the influence of different building configurations and surroundings that can lead to wind speed amplification at pedestrian level around tall buildings.
- To study various wind speed criteria for assessment of pedestrian comfort and safety.
- To carry out wind tunnel studies to investigate the pedestrian level wind environment in the vicinity of tall buildings.
- To examine the role of landscaping elements for ameliorating excessive wind speeds at pedestrian level.

6.5 *Experimental work carried out at the University of Auckland*

Techniques commonly used in wind tunnels for investigating pedestrian level winds are normally classified as Point Methods and Area Methods. Point methods includes such techniques as hot-wire or hot film anemometry , pressure measurement using Irwin probes, and thermistors. These methods measure wind conditions at discrete points around the model. The Scour or Erosion Technique is an area method for determining the windiness of a project site. In this technique a granular material (bran at the University of Auckland) [16-19] is spread uniformly over the area of interest. The wind speed is then slowly increased in increments. The areas where the granular material is scoured away first are the windiest areas, while areas that are scoured later as the wind speed increases represent progressively less windy areas. This technique is favoured by architects as it gives a qualitative assessment of the wind environment around a test site covering large areas. A wind tunnel investigation is currently in progress at the University of Auckland, mainly using the scour technique, but a less extensive investigation using a Cobra Probe has also been carried out.

6.6 *Experimental Set Up*

A 1:400 scale wind tunnel model of a representative neighbourhood in the environs of Delhi comprising nine clusters was studied for pedestrian comfort in the low speed section of the de Bray wind tunnel (Fig. 9). A parametric study was made by varying the height of a tall building, introducing a void in the tall building, varying the configuration of the surrounding blocks and by changing the roughness blocks surrounding the detailed model in one case. Further tests have examined the role of landscaping as mitigation measures in areas found to be excessively windy.

Monthly wind data from Delhi for a period of 13 years were analysed by fitting Weibull distributions (by obtaining appropriate values of the coefficients k, A and c) for all the eight predominant directions tested. These values, in combination with the wind tunnel data (which gives velocity ratios between pedestrian and reference locations [20-21]) were incorporated into an image processing program developed at the University of Auckland to yield probability of exceedance maps of different wind speeds at the test site.

The assignment of pedestrian criteria requires the proportion of time that certain wind speeds are exceeded for all directions and this value is calculated by summing the proportion of time that wind speed exceeds a certain speed at each point for all directions. The resulting values are then compared against the pedestrian comfort criteria for a number of mean wind velocities (4, 8 and 12 m/s in this case) for assigning various comfort categories.

6.7 *Expected Outcomes from the Study*

The results of the study are expected to help in formulating criteria with regard to assessment of pedestrian level wind environment by regulating authorities prior to granting permission for construction of tall buildings. The results will also be of use to architects and urban designers during the planning stage for ensuring a safe and comfortable pedestrian level wind environment in the vicinity of tall buildings. It is particularly hoped that this information will be of assistance to the appropriate regulatory authorities in India, since tall building construction in India is now commonplace.

Figure 9 Photographs of the model in the de Bray wind tunnel, University of Auckland, showing erosion patterns.

7 DEVELOPMENT OF A COMPUTER CONTROLLED POINT MEASUREMENT SYSTEM FOR WIND TUNNEL INVESTIGATIONS OF PEDESTRIAN LEVEL WINDS AROUND BUILDINGS.

7.1 *Introduction*

This research is a continuation of that reported at the APEC-WW in China, 2007 [22], and is being carried out by Mr Pierre Spandre for his masters degree under the supervision of Prof. R.G.J. Flay. Several methods of wind tunnel measurements can be used. These belong to two main categories: the "point" methods and the "area" methods. Point methods are based on finite numbers of measurement points, and usually use either hot-film or hot-wires as the sensor. They have been used in the wind tunnel at the Department of Mechanical Engineering at the University of Auckland, as well as by many other laboratories. Previous projects in the boundary layer wind tunnel have been done to set up a computer controlled traversing rig which would allow the automation of the wind measurements. A probe holder is moved by three stepper motors allowing 3D displacement within the wind tunnel. The motors are controlled by a LabView program. The traversing has been tested and has been shown to work quite successfully. Nonetheless, one aspect still needs to be improved, and that is the ability to repeatably position the probe at exactly the same height above local ground level at any location. This is the focus of the present research project.

7.2 *Details of research project*

In order to reliably record pedestrian level winds using a wind tunnel model, the z (i.e. vertical) position of the probe is very important. An average chest height of around 1.5m (full scale) corresponds to a height of 3.75mm in the wind tunnel for a model scale of 1:400. Several problems have been raised in previous research on probe positioning.

1. The measurement point locations, especially the height are difficult to set with the existing joystick (high speed, relatively low accuracy) which controls motion of the traverse rig.
2. The turntable on which the model is positioned is not smooth or perfectly flat, which causes its height to alter when the turntable angle is modified.
3. The traversing rig sags slightly, so that the probe is lower in the centre of the wind tunnel compared to the sides.

To overcome the above problems, a new approach was conceived. This was to use the computer to drive the probe to a location vertically above the measurement point (using the traverse rig like a robot arm) and then to move the probe vertically downwards until a sensor made contact with the model surface. The sensor would then stop the motion. The probe would be at the correct height, and a pedestrian level wind measurement could be made.

7.3 *Software and hardware design*

This project has proceeded by redesigning the traverse rig control software according to Fig. 10. The control software is written in LabView, which is commonly used in Laboratory situations.

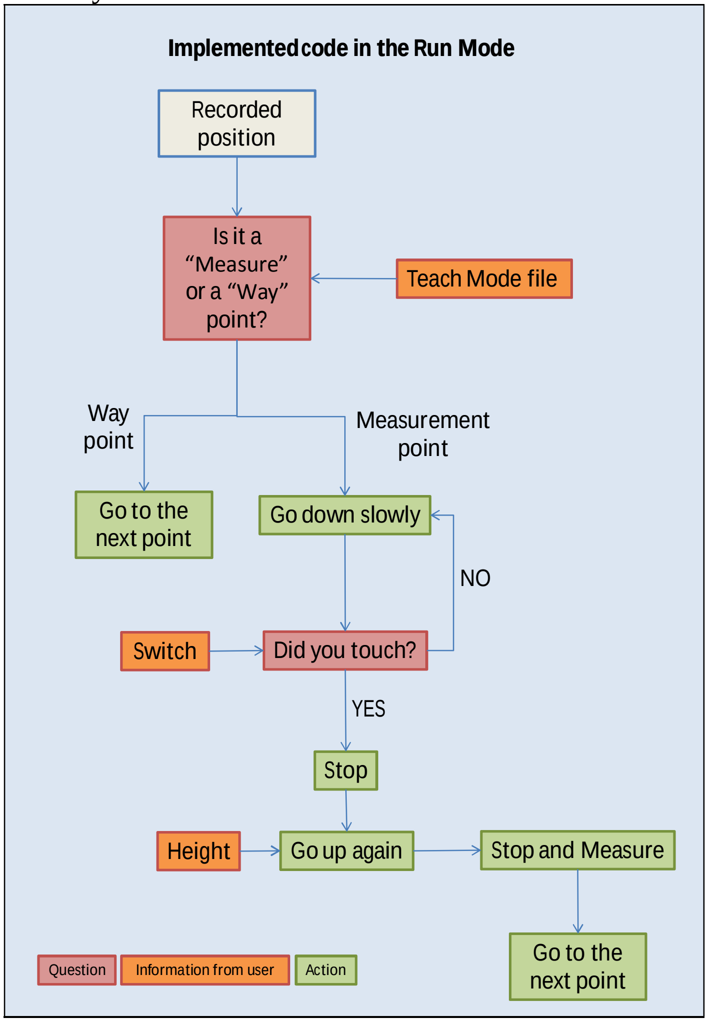


Figure 10 Flow chart of LabView software for wind tunnel traverse rig.

The mechanical design associated with this project is the addition to the traverse rig of a vertical support to enable a hot-wire probe to be located 4 mm above the floor while the rest of the rig is generally clear of the tops of building models. The probe holder and switch positioning system had to meet the following requirements:

It should hold the probe. It should use the existing traversing rig. It should contain a switch which would be switched off when the probe is down. The probe as well as the switch should be mechanically protected in case the traversing rig does not stop properly while going down. It should be easy to set up and to remove by someone who does not know it. It should be strong enough to stop the traversing rig from going down if the switch did not work. It should be done as simply as possible with as few components as possible.

The probe holder, and a drawing of same can be seen in Figs. 11(a) and 11(b) respectively. This system once completed and tested will allow detailed investigation of the wind environment around models without any supervision from a technician, after it has been taught the test locations initially. This will considerably increase the repeatability and the accuracy of such measurements as well as saving a lot of technician time. The time histories of wind speed measured by point probes such as hot-wire anemometers will also enable additional research to be carried out on refining the measurement to determine the amount of wind discomfort. Should it be based on a mean speed, peak gust speed, or the mean plus one or more standard deviations. These questions have interested wind engineers for many years, and the answers are still not entirely clear.

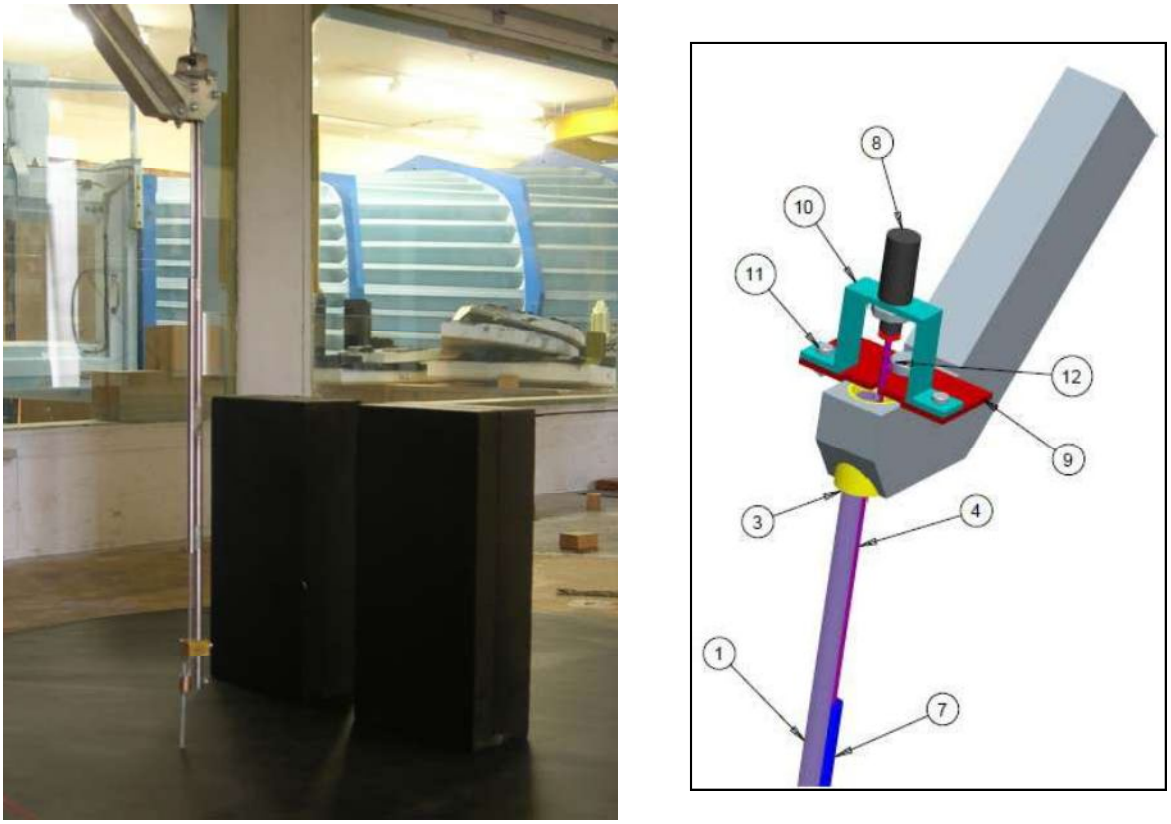


Figure 11 (a) Photograph of traversing rig with vertical arm near a model building (left) and (b) drawing of probe holder and switch mechanism (right).

8 OPUS INTERNATIONAL CONSULTANTS

Opus International Consultants have the only other boundary layer wind tunnel in NZ, apart from the University of Auckland. They have been involved in various projects over the past two years, as summarised below.

8.1 *A full-scale monitoring programme involving one Auckland building, and two Wellington buildings.*

The full-scale acceleration measurements are going to be compared with wind tunnel predictions using both the Opus and University of Auckland wind tunnels. This research project is being funded by the Building Research Association of NZ (BRANZ). Work on this project has started with the accelerations of one building in Wellington currently being monitored

8.2 *Revisions to the Wellington City Council District Plan Wind Rules.*

This work is aimed at helping the WCC develop wind environment rules for the city which endeavour to enhance the amenities of the city, and to ensure public safety, while being fair to developers.

8.3 *Testing of the VirtualWind and Gerris software packages*

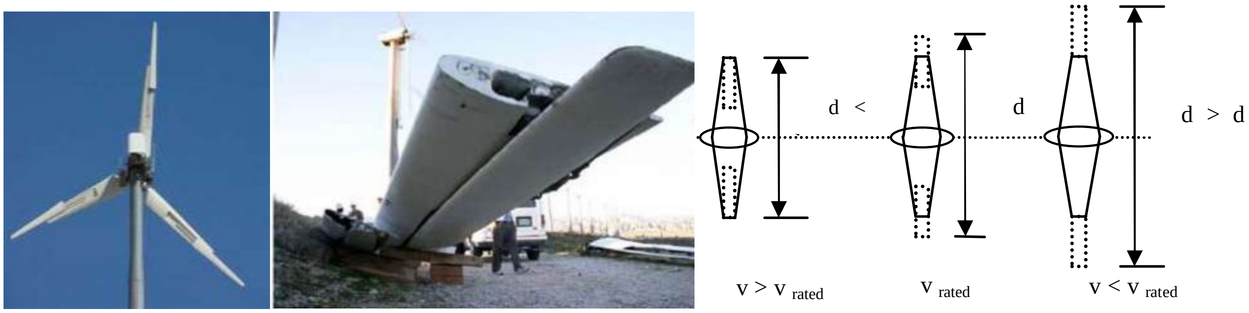
Opus is currently running trial simulations using this software.

8.4 *Jet blast measurements*

Opus has carried out jet blast measurements at Wellington Airport, and is currently negotiating with Queenstown Airport concerning similar tests.

9 AERODYNAMICS OF TELESCOPIC BLADE WIND TURBINE

The reduction in cost of energy (COE) of wind turbines requires many technical contributions from all areas in Wind Energy Conversion System (WECS). The variations of the wind characteristics (Diurnal, Monthly, Seasonally and Long term) as normally shown on the probability density distribution directly affect the wind turbine characteristics. The turbine power output is dependent upon a number of variables, and a lot of research has been carried out to increase the power coefficient that has an upper limit of 0.593 called the Betz Limit. A possible way for improving the power output of a turbine is to control the swept area and in other words to control 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 WECS. 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 WECS is thus enhanced. The telescopic blade concept is illustrated in Fig. 12.



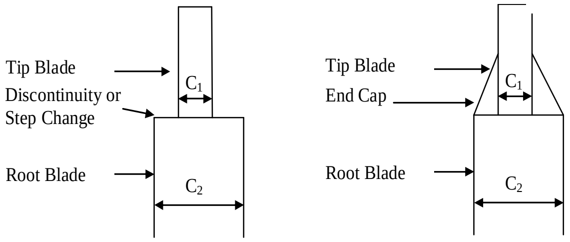


Figure 12 The telescopic blade concept

The telescopic blade concept inevitably introduces a discontinuity between the fixed (root) and movable (tip) sections of each blade. The aerodynamics of such a discontinuity or even a step change along the blade appear not to have been investigated, as published literature cannot be found in either the wind energy domain or in the broad fluid and aerodynamics area. There are likely to be additional losses to the blade efficiency similar to the tip and hub losses which are incorporated in turbine design models. The step change in chord presents an opportunity for the ‘underside’ positive pressure fluid particles to ‘bleed’ around the step to the ‘topside’ suction pressure regions.

In the development of the telescopic blade concept, gaining an understanding of the aerodynamic characteristics of the discontinuity region is important for a number of reasons. Firstly, it will enable quantification of the level of loss of aerodynamic efficiency, if any, and secondly it will aid in the minimization of the loss through modifications to the design of the region. Generation of such information would also be helpful from the modelling point of view. Realistic losses could be incorporated with the modelling process that should then enable improved predictions based around the use of the telescopic blade concept. Furthermore, Reynolds number effects are likely to be significant as the root and tip blades will have different chord lengths. Only when such effects are accounted for in the modelling process will the predicted turbine characteristics be close to reality. Optimization can then be carried out with much confidence.

This research will involve experimental, computational and analytical studies of the aerodynamics of the telescopic blade wind turbine rotors. The analysis is expected to include the following:

Performance tests (Wind Tunnel)

Aerodynamic analysis of the step change in telescopic blade (Wind Tunnel and CFD)

The primary measurements during the tests will include the turbine shaft torque τ using a torque transducer, the shaft rotational speed ω using a optical-sensor, the thrust of the wind turbine T using strain gauge technique, and the wind speed V using standard wind tunnel anemometry. From these measurements, the turbine shaft power $P_t = \tau\,\omega$, power coefficient $C_P = P_t / ½\rho V^3 A$, tip speed ratio $\lambda = \omega R / V$, and the thrust coefficient $C_T = T / ½\rho V^2 A$ will be established, together with performance (C_P versus λ) and power (P_t versus V) curves.

9.1 *Results*

The results presented in this brief review are available in more detail in a number of publications [23-25]. The power output of a turbine with extended blade reduces with the introduction of losses associated with the blades. Step loss due to step change is largely dependent on the chord ratio and has a detrimental effect on the power output of an extended blade wind turbine.

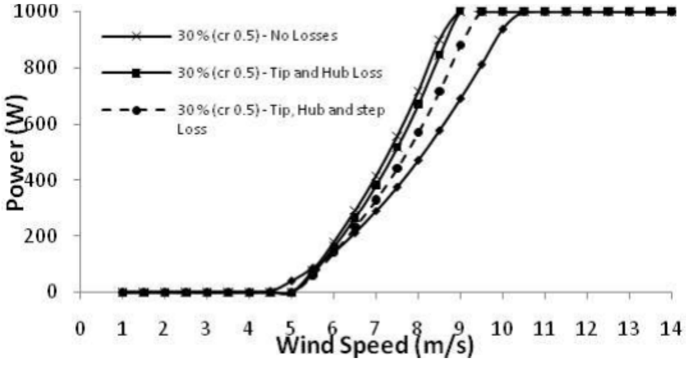


Figure 13 Power curves with and without losses

As discussed previously, an extended blade introduces a discontinuity along the blade length which may incur losses. Fig. 13 shows power curves for several loss scenarios. These show that the extended blade turbine performance reduces with reduction in chord ratio, and the benefits of the extended blade idea could be nullified somewhat if the chord ratio between the tip and root blades are low. It should be noted however that the chord ratio has been used to quantify step losses, based on the assumption that these losses would be similar to tip and hub losses. While this first assumption might be valid in gaining some insight into its influence on power output, these need to be validated by experiments in controlled conditions such as a wind tunnel testing. Nevertheless, the chord ratio and the associated losses at the interface between the tip and root blades are likely to be important. Research therefore needs to be directed into understanding these better, in order that its detrimental effects could be mitigated. The power output of the wind turbine with extended blade increases with the increase in blade length as is shown in Fig. 14.

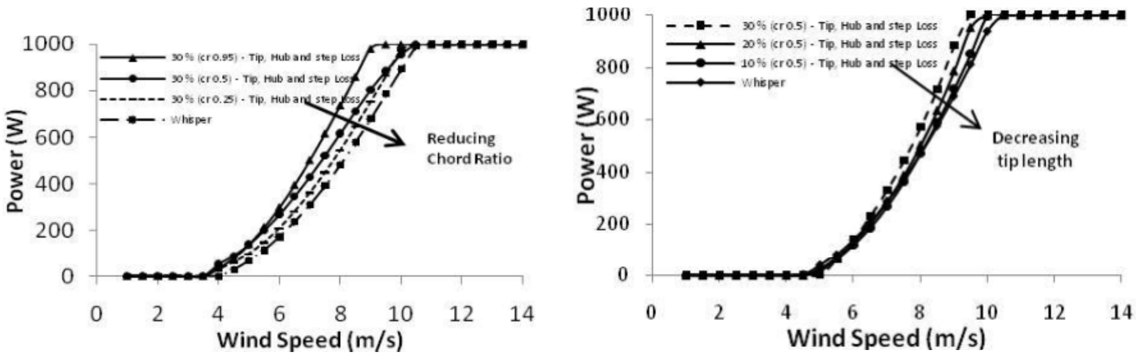


Figure 14 Power curves for a telescopic blade WT with varying chord ratio and extension

10 RISKSCAPE – A RISK MODELLING TOOL FOR WIND (AND OTHER NATURAL HAZARD) IMPACTS

Over the past 4 years the NIWA (National Institute for Water and Atmospheric research) and GNS Science have been preparing a regional risk assessment tool, RiskScape, for use in New Zealand. This is a multi-hazard Regional Loss evaluation tool which is to apply to multiple natural hazards to which New Zealand is exposed. During the initial development five hazards have been modelling and included in the tool. These are severe wind, river flood (NIWA) earthquake (shaking), volcanic ash (distal) (GNS Science) and tsunami (NIWA and GNS). Three study areas were considered within the evaluation pilot model, namely Westport (3000 people), central Hawkes Bay (30,000) and Christchurch (300,000). The assets exposed to each hazard model included buildings, people and infrastructure (roads, bridges, rail networks, telecommunications, pipe networks and power supply). Losses ascertained related to direct costs (replacement costs), injuries, disruption costs and downtime.

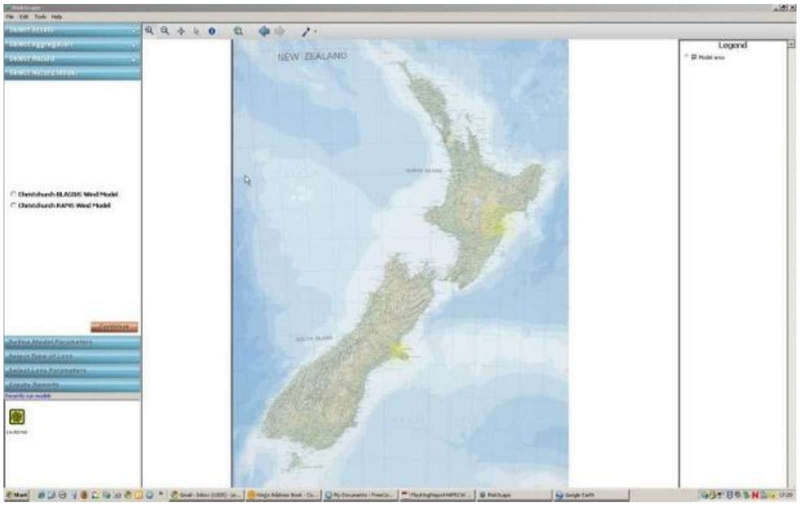


Figure 15 Selection of preferred loss model (and regions available)

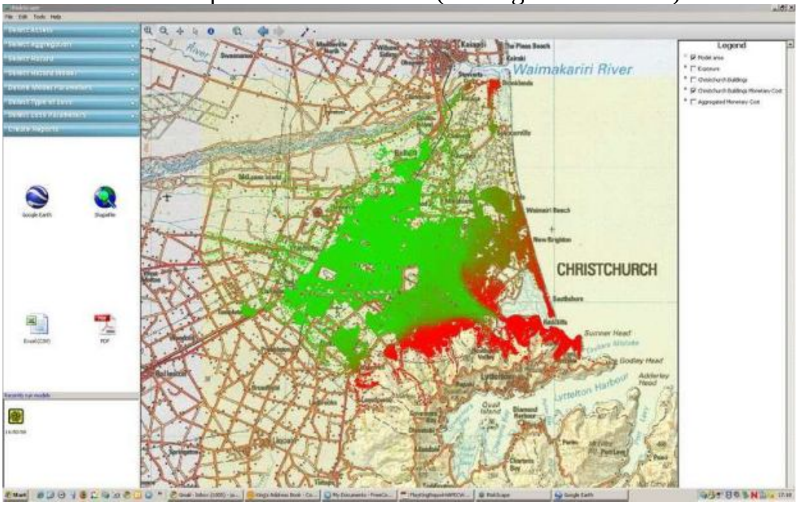


Figure 16: Distribution of wind storm related losses (individual buildings)

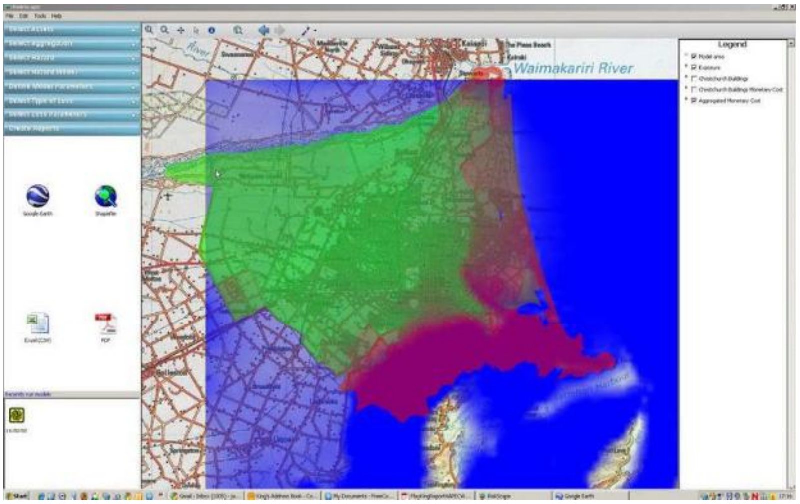


Figure 17: Distribution of wind storm related losses (Meshblock Aggregation)

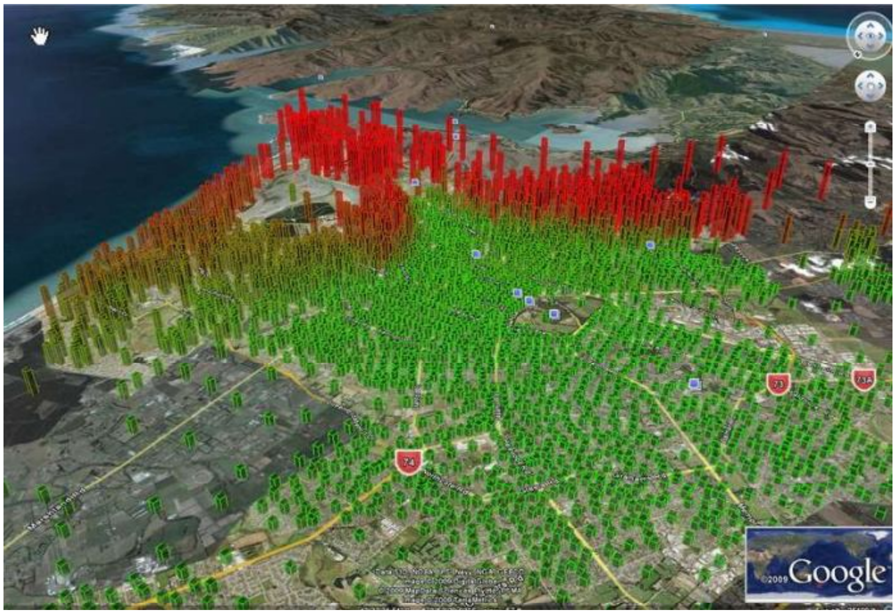


Figure 18: 3D Google Earth loss distribution

Figure 19: Christchurch Topography underpinning wind enhancement

11 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 Riskscape assessment being carried out by GNS and NIWA.

12 REFERENCES

1 R.G.J. Flay, & J. Bhatt, Cross-wind force spectra for building geometries commonly proposed for New Zealand cities, Asia-Pacific Economic Co-operation Wind Workshop APEC-WW, 2nd Workshop on Regional Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific

Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies, Hong Kong University of Science and Technology, 5-6 December 2005, pp 19-30.

2 R.G.J. Flay, & J. Bhatt, Cross-wind force spectra for low values of reduced velocity commonly required for New Zealand buildings, Australasian wind engineering society workshop, Queenstown, New Zealand, *2-3* February, 2006 1

3 R.G.J. Flay & Y.F. Li, On predicting accelerations in tall buildings from wind tunnel model tests using spectral and time history methods, In Proc. 12th Int. Conf. on Wind Engineering, Cairns, Australia, 1-6 July 2007, pp. 1215-1222.

4 J. Xie & P.A. Irwin, Application of the force balance technique to a building complex, J. Wind Eng. and Ind. Aerodyn., 77&78 (1998) 579- 590.

5 Standards Australia/Standards New Zealand. Structural design actions. Part 2 Wind actions, AS/NZS 1170:2, Standards Australia, Sydney, NSW, 2002.

6 N. Locke & P. Cenek, "Wind Tunnel Study of Cross-wind Force Spectra for Low Aspect Ratio Buildings". HERA Report R4-123, June 2004, Heavy Engineering Research Association, HERA House, 17-19 Gladding Place, Manukau City, New Zealand.

7 Y. F. Li, R. G. J. Flay & P. J. Richards, An excitation model for a square prism with leading edge flaps in low turbulent flow, J. of Wind Eng. and Ind. Aerodyn., 94 (2006) 151-172.

8 T.K. Guha, R.N. Sharma, P.J. Richards, CFD Modelling of transient internal pressure response following a sudden opening in building/cylindrical cavities, Proceedings of the 6th WSEAS International Conference on Heat and Mass Transfer (HMT '09), Ningbo, China, 2009) pp. 13-18.

9 T.K. Guha, R.N. Sharma, P.J. Richards, Analytical and CFD Modeling of transient internal pressure response following a sudden opening in building/ cylindrical cavities, Proceedings of the 11th Americas Conference on Wind Engineering, San Juan, Puerto Rico, 2009.

10 T.K. Guha, R.N. Sharma, P.J. Richards, The effect of background leakage on wind induced internal pressure fluctuations in a low rise building with a dominant opening, Proceedings of the 11th Americas Conference on Wind Engineering, San Juan, Puerto Rico, 2009.

11 T.K. Guha, R.N. Sharma, P.J. Richards, CFD modeling of wind induced mean and fluctuating external pressure coefficients on the Texas Technical University building, Proceedings of the 5th European & African Conference on Wind Engineering, Florence, Italy, 2009.

12 T.K. Guha, R.N. Sharma, P.J. Richards, The effect of background leakage on wind induced internal pressure fluctuations in low rise buildings with dominant openings, Proceedings of the 5th European & African Conference on Wind Engineering, Florence, Italy, 2009.

13 Y. Tamura, Wind Effects Bulletin Wind effects on buildings and urban environment, Vol. 9, February 2008, Wind Engineering Research Center, Graduate School of Engineering, Tokyo Polytecnic University, Atsugi, Japan.

14 R. Stubbing, Wind tunnel investigations of erosion and point measurement to determine wind comfort levels, Project Report 2008-ME74, Mechanical Engineering Department, the University of Auckland, New Zealand, 2008.

15 R McCardle, Wind tunnel investigations of erosion and point measurement to determine wind comfort levels, Project Report 2008-ME50, Mechanical Engineering Department, the University of Auckland, New Zealand, 2008.

16 M. Eaddy, Pedestrian level wind comfort categories using the erosion technique and image processing. ME Thesis, Mechanical Engineering Department, The University of Auckland,1998.

17 M. Eaddy & R.G.J. Flay, Image processing applied to pedestrian level wind investigations, Institution of Professional Engineers New Zealand Annual Conference, Auckland Aotea Centre, 12 - 16 February 1998.

18 M. Eaddy & R.G.J. Flay, Image processing applied to pedestrian level wind investigations, IPENZ Transactions, Vol. 25, No. 1/EMCh, 1998, pp 37- 45.

19 M. Eaddy & R.G.J. Flay, Pedestrian level wind investigations using the erosion technique and computer image processing, 7th Australasian Workshop on Wind Engineering, Auckland, 28-29 September 1998.

20 , Improving wind tunnel prediction techniques for pedestrian level winds investigation through comparison with full-scale measurements, Master of Engineering Thesis, Mechanical Engineering Department, the University of Auckland, 2003.

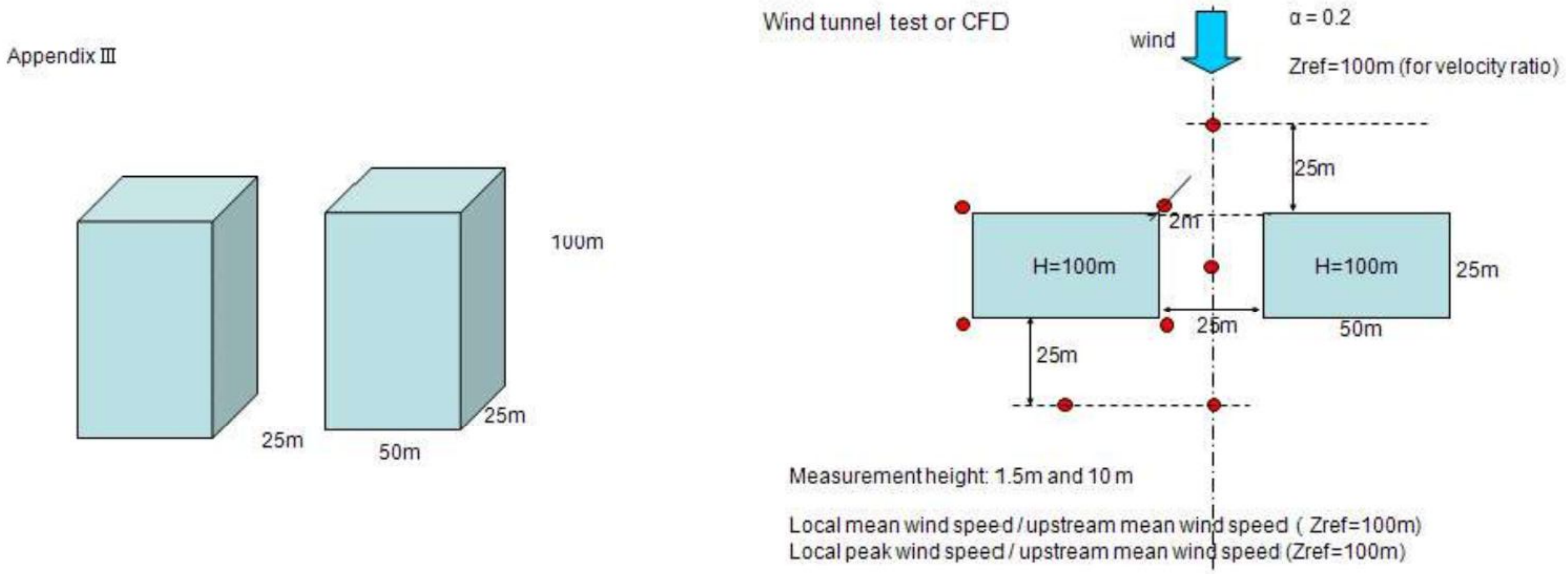
21 C. Chiappini & R.G.J. FLAY, Comparison of wind tunnel prediction techniques for pedestrian level winds with full-scale measurements, 11th Australasian Wind Engineering Society Workshop, Darwin, Australia, 28-29 June, 2004.

22 R.G.J. Flay & A King. New Zealand report on wind engineering activities, 2006 to 2007. Proc. of the 4th Workshop on Regional Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies (APEC-WW 2007), Tongji University, Shanghai, China, 19-20 November 2007, 106-117.

23 M. Imraan, R.N. Sharma, and R.G.J. Flay, Telescopic Blade Wind Turbine to Capture Energy at Low Wind Speeds, Renewal Energy Journal (under review).

24 M. Imraan, R.N. Sharma, and R.G.J. Flay, Telescopic Blade Wind Turbine to Capture Energy at Low Wind Speeds. Renewable Energy Asia – An International Conference & 4th Sustainable Energy and Environment Forum Meeting. 2008. IIT Delhi, India. pp 539-547.
25 M. Imraan, R.N. Sharma, and R.G.J. Flay, Telescopic Blade Wind Turbine to Capture Energy at Low Wind Speeds. ASME 3rd International conference on Energy Sustainability, 2009. San Francisco, California, July 19-23, 2009.

Appendix A APEC-WW Reference Model Specification



Appendix Ⅲ

Wind tunnel test or CFD

$\alpha = 0.2$

Zref=100m (for velocity ratio)

Measurement height: 1.5m and 10 m

Local mean wind speed / upstream mean wind speed (Zref=100m)
Local peak wind speed / upstream mean wind speed (Zref=100m)