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ORIGINAL ARTICLE

New Zealand Country Report 2021

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ABSTRACT – This paper summarises the activities that have taken place in wind engineering in New Zealand since 2012 when the previous APEC-WW took place in Hanoi, Vietnam. Since that date there have been considerable activities in wind engineering in New Zealand, ranging from an increase in government funding for wind hazard research, an analysis of historical wind data throughout New Zealand which has been used to update the regional wind speeds and directional multipliers for the 2021 version of the wind loading standard, and the construction of a large boundary layer wind tunnel with a computer-controlled three dimensional traversing rig at the University of Auckland that has allowed extensive wind tunnel investigations to be carried out. In addition, this period has seen a strong link to Chinese universities develop through CSC-funded research students that have come to study in New Zealand. Finally, the very successful 9th Asia-Pacific Conference on Wind Engineering (APEC-WW) was held at the University of Auckland in December 2017.

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INTRODUCTION

This New Zealand Country Report for the past nine or so years up to and including 2021 has been compiled from summaries submitted by active wind engineering researchers in New Zealand and China. Thus, it has sections that are self-contained. The authors acknowledge the large amount of help that was received from their colleagues in preparing this paper.

9TH ASIA-PACIFIC CONFERENCE ON WIND ENGINEERING

The Ninth Asia-Pacific Conference on Wind Engineering was held at the University of Auckland, Auckland, New Zealand in December 2017 under the chairmanship of Prof. Richard Flay.

The Asia-Pacific Conferences on Wind Engineering [1] are international events conducted every four years under the umbrella of the International Association for Wind Engineering (IAWE). They began with the First Asia-Pacific Symposium on Wind Engineering at Roorkee, India in 1985 [2], and are held in the Asia-Pacific region mid-way between the four-yearly International Conferences on Wind Engineering. The APCWE conferences are international events regularly attended by 200 – 300 wind engineering researchers and practitioners from around the Asia-Pacific regions. The previous conferences were held in Roorkee India, Beijing China, Hong Kong, Gold Coast Australia, Kyoto Japan, Seoul Korea, Taipei Taiwan, and Chennai India in 2013.

APCWE-9 was attended by academicians, engineers, scientists, technologists and architects who actively participated by exchanging state-of-the-art research findings and practical applications in all areas of wind engineering, which further enhanced international collaborations. Fig. 1 is a photograph of the conference networking session on Auckland Harbour, and Fig. 2 is a photograph of Professor Bill Melbourne with delegates from New Zealand and Australia, after he received the Davenport Medal, presented by Prof. Giovanni Solari, at the conference dinner.

Figure 1. APCWE9 delegates enjoying networking on the Waitemata Harbour in Auckland, New Zealand.

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Figure 2. Photograph of Australian and New Zealand delegates at APCWE9, with Professor Bill Melbourne, after he received the Davenport Medal.

UNIVERSITY OF AUCKLAND BOUNDARY LAYER WIND TUNNEL

The Boundary Layer Wind Tunnel at the University of Auckland – the largest and fastest of its kind in New Zealand – was constructed at the Newmarket Campus in 2015. The wind tunnel test section is 20 m long, 3.6 m wide and 2.5 m high, and it has a maximum speed of 20 m/s. It is designed as a general-purpose wind tunnel and has facilities for testing model buildings in wind engineering studies, the drag and power of cyclists on a special balance/dynamometer, and model vehicles on a moving belt ground plane. It may also be used for measuring the drag of bodies like traffic signs, and the loads and performance of wind turbines.

For Wind Engineering studies, its boundary layer development test section enables the wind simulation to be controlled so that a range of scales from 1:100 to 1:1500 can be used, and it can simulate the flow above smooth surfaces like water to rough surfaces like cities by suitable combinations of blocks, barriers and spires. Coupled with the 512-channel high frequency pressure system, and several sensitive high frequency force balances, it is a powerful facility for investigating loads, pressures and vibrations on models of buildings and other structures like stadium roofs. With its computer-controlled data acquisition system, turntable and 3D traversing rig, more testing can be carried out in an automated manner. Fig. 3 shows a schematic diagram of the wind tunnel.

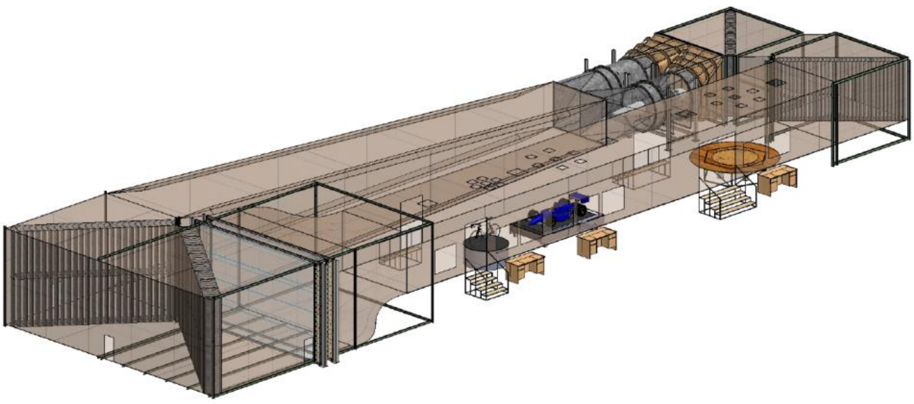

Figure 3. A schematic diagram of the boundary-layer wind tunnel at the University of Auckland.

WSP (NZ) WIND TUNNEL

WSP New Zealand (formerly Opus International Consultants) is actively conducting research in wind engineering, particularly wind environment testing of proposed buildings in Wellington. Following their relocation from the research laboratory at Gracefield, Lower Hutt, to Petone, in 2014, WSP constructed a new three-quarter open-jet boundary layer wind tunnel for wind engineering investigations, as shown in Fig. 4. Its open-jet design helps eliminate blockage issues and simplifies the installation of models and instrumentation. WSP, the University of Auckland, Transpower and the National Institute of Water and Atmospheric Research (NIWA) have been collaborating on wind hazard research for more than ten years. Some of these activities are highlighted in detail in this paper.

Figure 4. WSP ¾ open-jet boundary layer wind tunnel at Petone, Wellington, New Zealand.

NEW ZEALAND'S DESIGN WIND SPEED ESTIMATES FOR AS/NZS1170.2:2021

Improvement in the design wind load estimations is a critical feature of structural design optimisation, particularly in a country like New Zealand that experiences strong winds and has mountainous and complex terrain, which influence the wind characteristics. In addition, safety considerations must be balanced against the additional cost of over-design in any design project. Therefore, accurate estimations of design wind speeds are highly beneficial for safety as well as for optimising the design and minimising the costs.

This study aimed to estimate design wind speeds and associated directional multipliers, also lee-zone multipliers for New Zealand through the analysis of historical wind data recorded at meteorological stations, utilising a high-resolution convection-resolving numerical weather prediction model known as the New Zealand Convective-Scale Model (NZCSM), and lastly comparing the performance of two global weather reanalysis products. New Zealand's historical wind data have not been analysed in the past two decades for design wind-load purposes. In addition, no attempt has been made to thoroughly homogenise the mean and gust wind speed data recorded prior to the 1990s and to convert them to equivalent Automatic Weather Stations (AWS) records. Furthermore, lee zones, i.e. areas affected by the wind speed-up due to the presence of mountains, can significantly influence the design wind loads, thus, it is crucial to estimate the spatial extent and magnitude of the lee multiplier accurately. In this study, the wind data were initially subjected to a robust homogenisation algorithm, which accounts for changes in both instrumentations and signal processing procedure, and also eliminates the effects of local topography. Extensive wind-tunnel and theoretical investigations were conducted to study the response characteristics of anemometers as well as the effects of various gust durations on the maximum wind speeds. Correction factors were proposed to convert the wind gust measurements with a certain gust duration to equivalent measurements of other gust durations of interest. The influence of hills and local topography on airflow was studied through wind-tunnel experiments and numerical simulations of 2D and 3D single isolated hills and also consecutive multiple hills.

Fig. 5 shows the results of the historical wind data for the revised wind loading standard. Fig. 5(a, b) shows the large difference between the regional gust wind speeds and directional multipliers in the 2011 version of the standard, and the new values. This resulted in a new region being added at the southern end of the South Island (Fig. 5(c)). Directional multipliers throughout New Zealand were also updated, as can be seen in Fig. 5(b) for the bottom of the South Island.

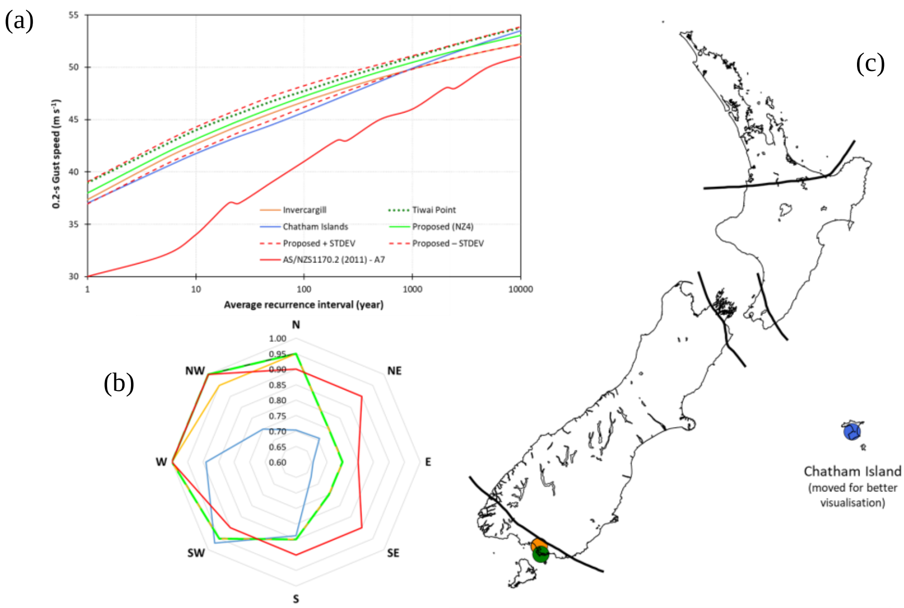

Figure 5. Comparison between the previous and proposed design wind speeds and directional multipliers for the southern end of the South Island.

Fig. 6(a) shows the setup in the University of Auckland boundary layer wind tunnel to investigate the response characteristics of a cup anemometer in highly turbulent flow, and in Fig. 6(b) to measure speed ups over a 2D bell-shaped hill.

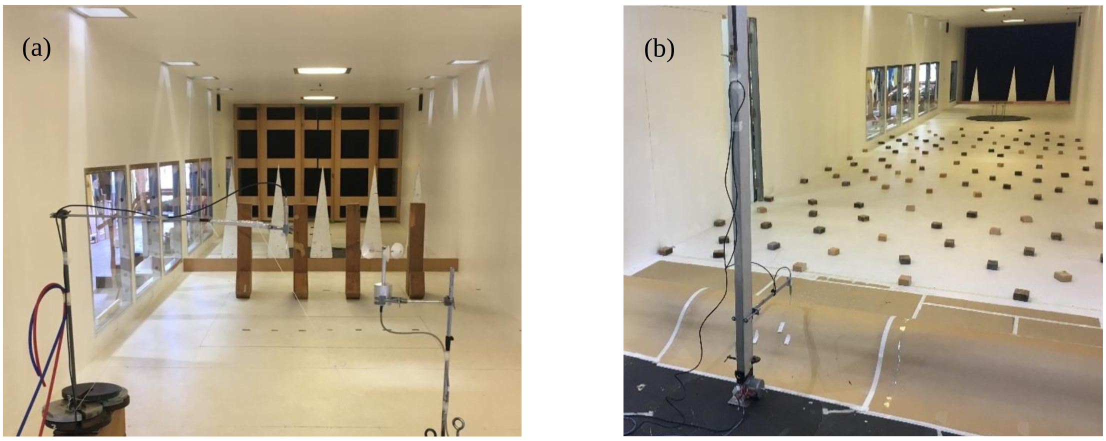

Figure 6. Wind tunnel setup to study: left: the response characteristics of a cup anemometer in turbulent flow; right: airflow over a bell-shaped 2D hill.

WIND HAZARD RESEARCH PROJECTS

A consortium comprising the University of Auckland, NIWA, WSP and Transpower was granted government funding for two wind hazard projects in the Weather and Wildfire science programme of the "Resilience to Nature's Challenges Kia manawaroa – Ngā Ākina o Te Ao Tūroa" (RNC2) scheme. The two wind hazard projects are: (1) A study of loads on New Zealand transmission lines, and (2), A study of the effects of ex-tropical cyclones making a direct hit on Auckland City.

Wind Hazard Project 1: Transmission line loading

The effects of wind and ice loading on transmission lines can be catastrophic failures and destruction. The impact would be disastrous if a vital link in New Zealand's transmission network were to fail during an icing or wind event. Possible failure modes include but are not limited to electrical flashover failure from the melting of the ice or conductor blowout, both leading to dangerous outages. Also, the accumulation of ice on cables not only increases the static cable tension from the added mass, but also increases the dynamic tension from the increase in surface area exposed to the wind. This can result in conductor galloping, which is high-amplitude low-frequency vertical oscillations, resulting from the asymmetric profile of the iced conductors, which enable "lift" forces normal to the wind direction to occur. The effects are related to two main factors. Firstly, the thermodynamic accumulation of ice which depends on the topographical, meteorological and environmental conditions as they establish the intensity, nature and duration of icing and wind events. Secondly, the mechanical, thermal and electrical characteristics of the transmission lines themselves influence how they can withstand these effects. These characteristics are influenced by cable size and composition, span length, tower strength and flexural stiffness and instantaneous electrical loads. The purpose of this research is to establish verified and validated models to be used in both the design and disaster management of the transmission lines.

Several theoretical icing models which could be integrated into NZCSM, NIWA's Numerical Weather Prediction (NWP) software have been reviewed and one model implemented to create maps of the predicted mass of ice accretion on transmission lines throughout New Zealand. A rig to measure ice accumulation during severe winter weather has been designed and is shown in Fig. 7. It comprises a 2-m long hollow tube mounted centrally on a load cell. Fig. 8 shows preliminary results from the ice prediction model that has been developed. The ice accumulation is mainly in the mountainous regions and is shown in blue. The transmission line routes are shown in red.

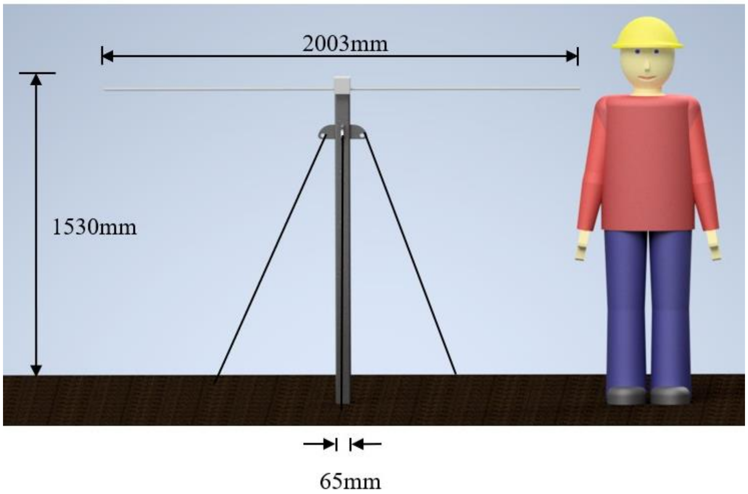

Figure 7. Ice accumulation field instrument.

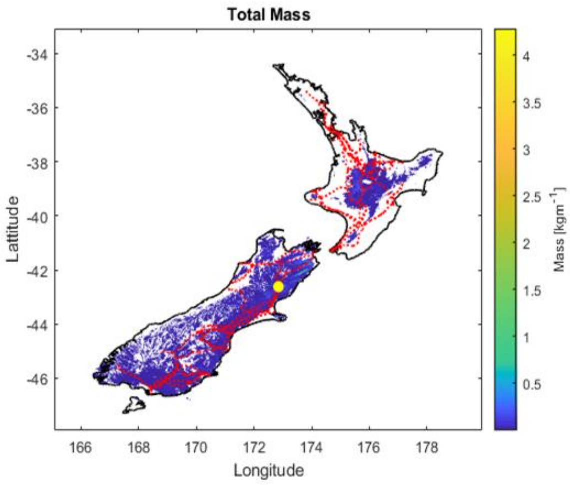

Figure 8. Preliminary results from the icing model for New Zealand.

The wind loads was investigated through a combination of full-scale measurements on a special "training" section of transmission line comprising three towers linked by two sections of transmission line, and wind tunnel measurements. The objective of this part of the research is primarily to verify the accuracy of the span reduction factor used in current design practice. The span reduction factor allows a reduction in transmitted forces to the conductors as the span length increases due to the reduction in wind speed correlation as the separation distance increases.

Finally, an experimental investigation of wind flow over complex terrain, such as mountainous regions, will be conducted to test the validity and replicability of the procedures developed through this research so that the changes proposed to the current procedures used by trans-power for determining wind loading on conductor spans in such terrain can be confirmed.

Wind Hazard Project 2: Modelling Tropical Cyclones for Prediction, Planning & Mitigation

The current prediction capabilities for High Impact Weather (HIW) over complex terrain common in New Zealand, are inadequate with outdated models being used. Planners are concerned about Auckland's vulnerability to adverse weather, particularly to ex-tropical cyclones (ETCs) that can cause vast structural damage to buildings and infrastructure. Thus, an elaborate investigation to assess its vulnerability to ETCs is imperative, particularly with the expected increases in ETC frequency due to climate change. This research project, funded by RNC2, focuses on computational fluid dynamics (CFD) to model and simulate ETC conditions in the Auckland CBD. This analysis will predict the wind speed-ups and the pressure distributions generated by ETCs. To date, a horizontally homogeneous atmospheric boundary layer (HH-ABL) in ANSYS Fluent has been developed; the first stage of the ETC modelling. This means that an empty computational domain free of unwanted disturbances has been modelled. Currently, only two other researchers have achieved an HH-ABL using ANSYS Fluent, so this progress is very promising. The next step is to simulate ETC conditions in the Auckland CBD for a particular test case from an historical ETC. The CFD simulation results will be validated in the University of Auckland boundary layer wind tunnel. The outcome of this research will yield results which are intended to inform the current disaster prediction, planning and mitigation measures for Auckland, and possibly for the wider New Zealand region as well.

WIND TUNNEL TEST METHOD FOR SEGMENTED RIGID MODELS OF SUPER-TALL BUILDINGS

When buildings become very tall with very high (height/width) aspect ratios it is difficult to design a wind tunnel model with sufficient space to fit enough pressure tubes inside it, while having it fit inside typical wind tunnels, say about 2 m high. Therefore, this research project is investigating a new wind tunnel testing methodology aimed at determining a rigorous method of combining the results from several rigid sectional model results from separate tests of different parts of the prototype design in order to determine the overall dynamic wind loads. Using this approach, each model section can be made sufficiently large to achieve a larger Reynolds number and to allow for more pressure taps. Since the correlation between the aerodynamic forces from each segmented model results is lost when they are tested separately, this research is developing a correlation reconstruction method using pressures measured from overlapped regions. This is the primary challenge of this research.

A preliminary wind tunnel experiment on a pressure-tapped circular cylinder model was carried out in the boundary layer wind tunnel at the University of Auckland as depicted in Fig. 9. The circular cylinder was tested with flow corresponding to a range of Reynolds numbers, turbulence intensities and integral length scales. Fig. 10 shows the drag cross correlation coefficients across all levels for $Re = 5.12 \times 10^4$. Further experiments on a range of sectional shapes with a range of overlaps will be analysed and used to refine the loading combination algorithm that yields building response predictions closest to reference results obtained from tests on a complete model tested in one piece.

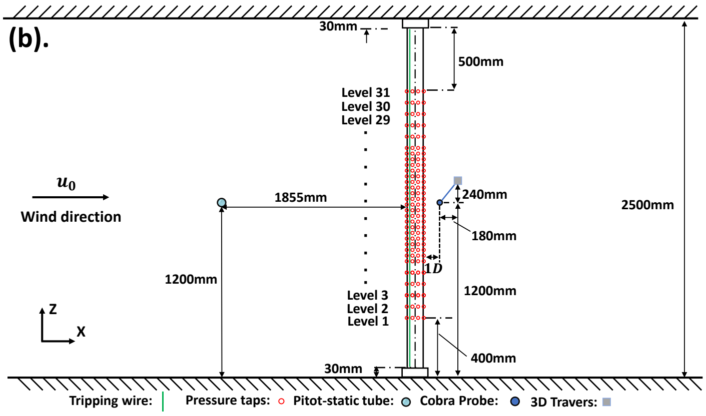

Figure 9. Sketch showing the pressure tapped circular cylinder experimental setup: side view.

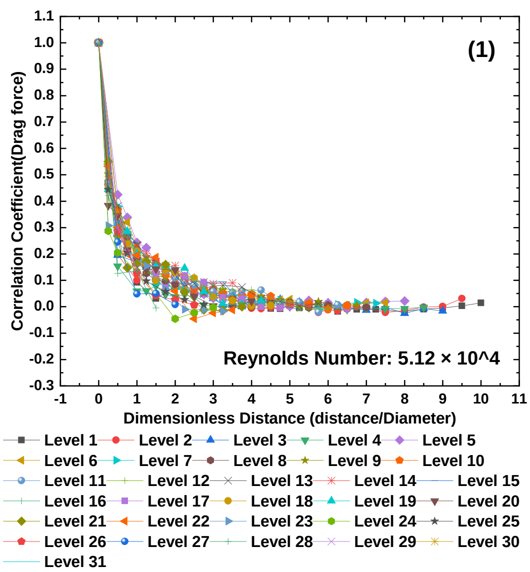

Figure 10. Correlation coefficients across all the levels of the cylinder for $Re = 5.12 \times 10^4$.

TIME HISTORY WIND LOADING APPROACHES FOR SUPERTALL BUILDING STRUCTURAL DESIGN

Although there are widely accepted experimental techniques for obtaining wind loads on tall buildings from wind tunnel tests, they are time-consuming for the pre-concept design stage when a quick turnaround is needed by the structural engineer. Therefore, structural engineers are interested in applying approximate in-house derived wind loads for this early stage of the design cycle. The aim of this research is to fill this gap and to develop simple methods for obtaining sufficiently accurate loading distributions up the height of the building for pre-concept design. Two benchmark buildings (APEC-WW Buildings A and B) were chosen to develop this method, as published wind loading results are available. Firstly, the across-wind loads of the building B were predicted using the loading standard AS/NZS 1170.2, and two different base moment spectrum approaches. The preliminary results from this work are shown in Fig. 11. Subsequently, high frequency force balance (HFFB) and high frequency pressure integration (HFPI) wind tunnel tests were carried out to provide the validation results for testing against the approximate predictions. Building B has planar linear mode shapes while Building A has 3D combined sway and twist non-linear mode shapes. Therefore, Building A gives rise to much more complicated challenges to predict the response with HFFB data. Fig. 12 shows Building A in The University of Auckland BLWT. Using these experimental results, different schemes, e.g., gust loading factors and semi-empirical, stochastic simulations, and time series analysis approaches are being investigated to generate wind loads on these two tall buildings.

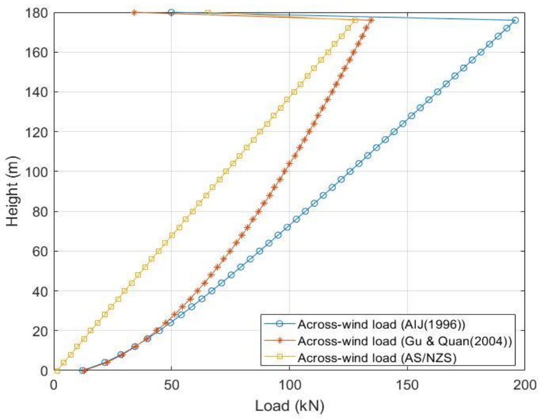

Figure 11. Comparison between across-wind loads using three different prediction methods for Building B.

Figure 12. Building A model set up for HFFB tests in the University of Auckland BLWT.

WINDCATCHER VENTILATION SYSTEMS

Windcatchers are ancient-based ventilation towers usually connected to a building. They capture the incoming wind at high levels allowing it to ventilate the building interior. Modern ones are like chimneys and are placed on building roofs. Although windcatchers have been researched for over 30 years, the present research presents a new perspective on windcatcher studies. The investigation considers the surrounding external flows and their effects on the windcatcher ventilation behaviour. Furthermore, the research is concerned with the effect of unsteady turbulent flow on ventilation.

Wind tunnel experiments and CFD simulations were conducted to achieve the research objectives. The model is based on a generic building with a roof-top windcatcher (shown in Fig. 13), and all the data were normalised to enable valid comparisons with full-scale conditions. The results show that the ventilation system performs efficiently when the openings are placed at the opposite sides of the building, enhancing cross-ventilation between the windward tower opening and the leeward window opening. Additionally, steady ventilation was dominant for direct incoming wind flows (relative to the building openings). On the other hand, unsteady ventilation dominated for indirect winds due to the penetration of generated eddies through the building openings.

Figure 13. Windcatcher building model in the University of Auckland BLWT wind tunnel.

LARGE EDDY SIMULATION OF WIND TURBINE WAKE INTERACTIONS AND FATIGUE LOADING IN VARIOUS INFLOW CONDITIONS

The fatigue loading of wind turbines in a wind farm is strongly influenced by the atmospheric inflow. The characteristics of the wind can be influenced significantly by atmospheric stability, which can range from stable, through neutral to unstable conditions. While the characteristics of dynamic loads on upstream turbines is determined by wind shear and atmospheric turbulence, those on the downstream turbines are dominated by wake turbulence.

This research project evaluates the effects of atmospheric stability on wind turbine wake flows and fatigue loading using a coupled Large Eddy Simulation (LES) and turbine aeroelastic code. This two-way Fluid-Structure Interaction simulation offers insights into the structural loads of dynamically controlled wind turbines when wake effects are taken into account. Atmospheric wind profiles and turbulence were modelled by a precursor simulation that used a pressure-driven periodic boundary condition for an empty flow domain. The results of the precursor are then used as wind farm inflow boundary conditions. A wind turbine array comprising four-inline turbines with a spacing of 7 rotor diameters has been investigated. Fig. 14 shows instantaneous iso-surfaces of vorticity coloured by the stream-wise velocity illustrating the wake regions of multiple in-line wind turbines.

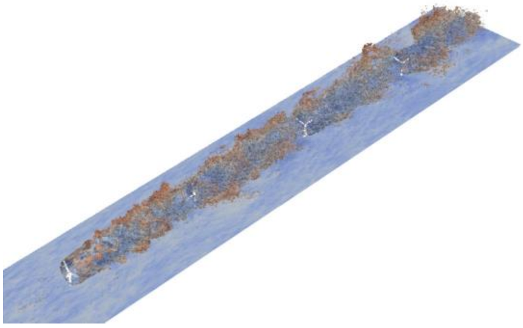

Figure 14. Instantaneous iso-surfaces of vorticity coloured by the stream-wise velocity illustrating the wake regions of multiple turbines.

WIND ENGINEERING RESEARCH COLLLABORATIONS WITH CHINESE UNIVERSITIES

These collaborations have resulted mainly from CSC and Chinese university-funded PhD students spending a year, or their entire PhDs at the University of Auckland. This collaboration has also been encouraged through one of the authors being a Guest Professor at Central South University in Changsha, participation in the Project 111 conferences at Chongqinq University and the 15th International Conference on Wind Engineering that was held in Beijing in 2019 [3].

Numerical Investigation of Flow Structures and Aerodynamic Interference Around Stationary Parallel Box Girders

Central South University, Changsha

In this study, a wide range of gap-width ratios (0-15) for parallel box girders were selected to investigate the aerodynamic interference using three-dimensional large eddy simulation at zero wind attack angle. Specific aerodynamic characteristics, including the flow structures, pressure distributions, mean values and standard deviations of the force coefficients, Strouhal numbers as well as spanwise correlations of the aerodynamic coefficients were examined with various gap-width ratios. The detailed comparison work demonstrates good agreement with the experimental work. The simulation results reveal that all the aerodynamic characteristics are significantly influenced by the gap-width ratio. The three regions are bounded by critical gap-width ratios of G/B=0.25 and G/B=5. There are large changes in behaviour at G/B=0.25, whereas, for G/B>5, interference effects are not evident. The interference effects on both mean and fluctuating aerodynamic coefficients of parallel box girders are also quantified and summarised. An example of the results can be seen in Fig. 15, which shows the effect of gap to breadth ratio on drag and lift interference effects. It can be seen in Fig. 15 that three regions are bounded by critical gap-width ratios of G/B = 0.25 and G/B = 5.

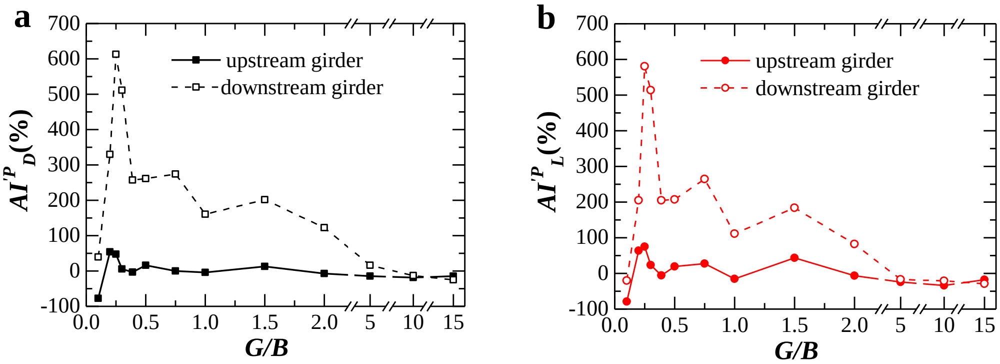

Figure 15. Standard deviations of aerodynamic interference effects on parallel box girders with different gap-width ratios. (a) Drag aerodynamic interference effects. (b) Lift aerodynamic interference effects.

The flow mechanisms have been illustrated through CFD images. There is no vortex shedding in the gap for small gap-width ratios, especially *G/B* = 0.1~0.2. Above *G/B* = 0.25, there are vortices shedding alternately from both sides into the gap, and the downstream bridge is embedded in the turbulence flow from the upstream bridge. After the gap-width ratio exceeds 5, the aerodynamic interference basically disappears.

The Non-Homogeneous Wind Characteristics along a Bridge Deck in Complex Terrain Chang'an University, Xi'an

This work is aimed at investigating the airflow over two unusual terrains, namely a converging-channel terrain and an idealised deep valley in a mountainous area, and mainly focuses on the spatial variation of the wind characteristics along a bridge embedded in the complex terrain.

As shown in Fig. 16(a), the converging-channel terrain comprises a deep valley on the up-river side and a flat plain on the down-river side. Through a computational fluid dynamic study and a long period of field measurements from a Sodar system and 2D ultrasonic anemometers, the results show that a wind speed-up was generated in the valley and its exit, whose magnitude is sensitive to the approaching wind direction. The wind speeds and directions along with the entire bridge structure, including the spanwise deck and the bridge towers, are non-homogeneous due to the effects of the complex terrain, as shown in the CFD output in Fig. 16(b).

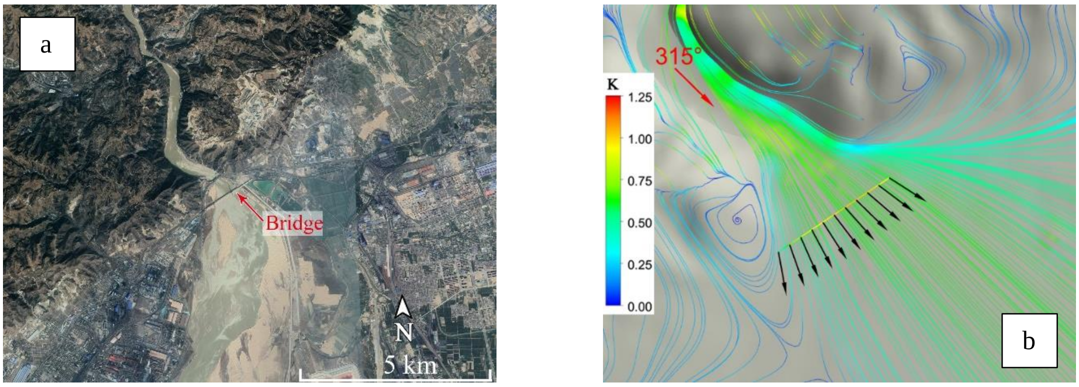

Figure 16. (a) The converging-channel terrain; (b) Non-homogeneous wind characteristics.

In the CFD analysis the V-shaped deep valley was simplified by extruding it as a section of the sine function. The CFD simulation with k-ω turbulence model was employed to model the airflow over the valley. The results show spatially varying wind characteristics in the valley, resulting in the wind speed, wind inclination angle, and yaw angle changing along the bridge span. The non-homogeneous wind characteristics appear to be affected by the slope of the valley, approaching flow direction and the curving valley.

Wind Tunnel Study on the Fluctuating Internal Pressures Induced by Tangential Flow Across Building Openings Tongji University, Shanghai

In this work, wind tunnel tests were conducted to investigate the fluctuating internal pressures induced by tangential flow over building openings. This was to examine whether the fluctuating internal pressures at certain oblique wind angles are greater than those produced when the wind is normal to the orifice face. A wind tunnel test on a 1:25 scale model of the TTU building with several adjustable openings was conducted (Fig. 17). The study explored the phenomenon of a sudden increase in the fluctuating internal pressures and Helmholtz resonance, combined with vortex shedding of the incoming flow. In addition, several variables including turbulence intensity, wind speed, opening size, opening location, opening shape and background porosity were investigated to determine their effects on the fluctuating internal pressures. The results show that apart from the opening shape, all the other factors influenced the fluctuating internal pressures to varying degrees. Furthermore, it was found that there is a "sudden increase" in the fluctuating internal pressures at certain oblique wind angles (typically around 60° to 80° from the surface normal). These fluctuations are greater than those produced when the wind is normal to the orifice face and the turbulence intensity is low. It is demonstrated that the responses of vortex-excited resonance and Helmholtz resonance are responsible for the sudden increase in the fluctuations, and the separated shear layer causing the vortex-excited resonance emanates from the windward corner.

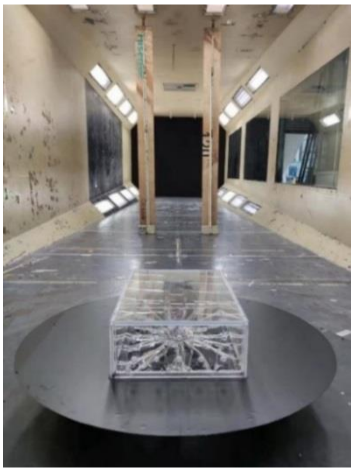

Figure 17. Photograph of the model in the Tongji wind tunnel showing the upstream barriers used to generate uniform turbulent onset flow.

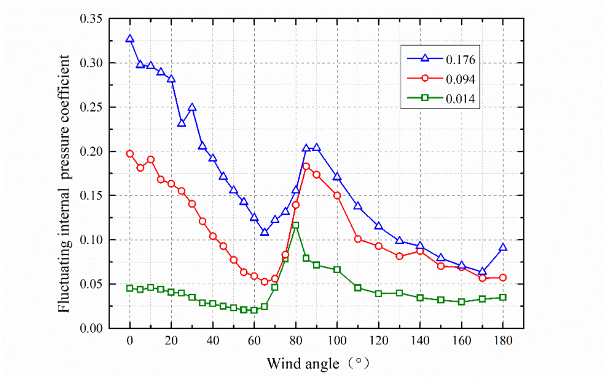

Figure 18. Fluctuating internal pressure coefficients as a function of wind direction with three different approach flow turbulence intensities.

Fig 18 shows that the fluctuating internal pressure coefficients increase with increase in the turbulence intensity, and that th.ere is a "sudden increase" in the fluctuating internal pressure coefficients at oblique wind angles in all wind fields. When the turbulence intensity is relatively high (0.094 and 0.176), the peak value of the fluctuating internal pressure occurs when the flow is normal to the face, i.e. at 0°. However, when the turbulence intensity is decreased to 0.014, the peak value of the fluctuating internal pressures occurs at 80° and is therefore excited by flow that is essentially tangential to the opening and is approximately 2.5 times higher than the fluctuating internal pressure resulting from flow normal to the face with the opening.

Investigation on the Effects of Twisted Wind Flow on the Wind Loads on a Square Section Mega-Tall Building Harbin Institute of Technology, Harbin

In most wind load codes and standards, the wind direction is assumed to be the same along the building height. But actually, due to the Earth's rotation (Coriolis force), the wind direction in the atmospheric boundary layer (ABL) changes along the height, particularly around low-pressure systems. This twisted wind flow (TWF) will obviously make a difference to the wind loads on mega-tall buildings. In this study, two kinds of TWFs with total wind twist angles of 25° and 15° were generated in a boundary layer wind tunnel, Fig. 19(a). The effects of TWFs on wind pressures, Fig. 19(b), and aerodynamic forces acting on a square section mega-tall building model were investigated. It was found that the TWF significantly changes the distribution of wind pressure, and the wind force that acts on the mega-tall building vary is found to vary with the total wind twist angle. It was interesting to also find that the peak in the power spectrum of the lateral wind force was also sharp in TWF. The wind direction where the sharp peak occurs merely changes from that of the corresponding equivalent straight wind flow (SWF). Also, the magnitudes of the correlation coefficient and coherence of wind forces in TWF are almost as strong as those in SWF. These factors further indicate that a relatively small wind-induced response may not necessarily be expected in TWF. The results of this study led to a comprehensive understanding of the effects of TWF on the characteristics of the wind loads on a square section mega-tall building.

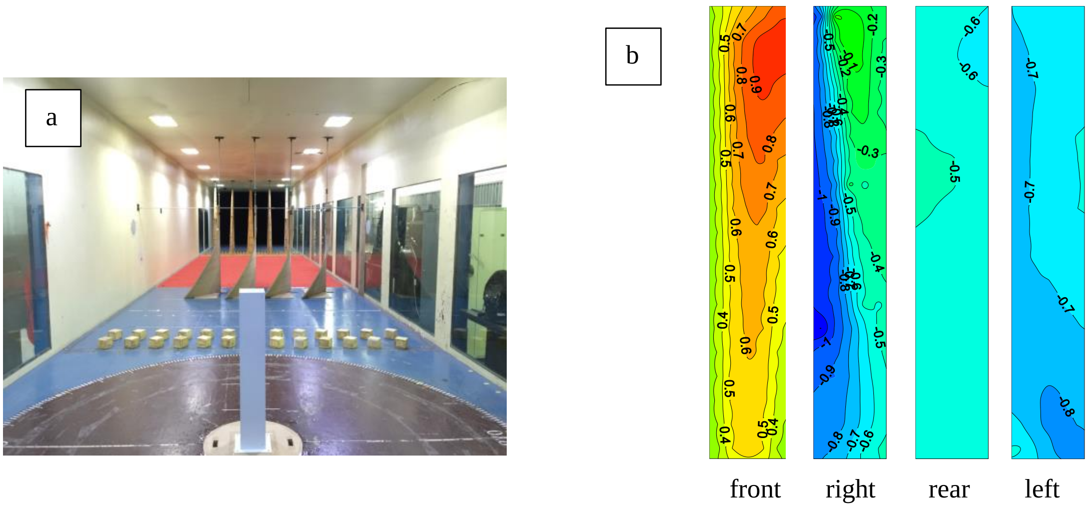

Figure 19. (a). The square section building model in the Harbin Institute of Technology wind tunnel with 25° twisted wind flow; (b). Pressure coefficient distributions on the façade surfaces of the building model in 25° twisted flow.

WIND ENGINEERING CONTRACT RESEARCH ACTIVITIES AT THE UNIVERSITY OF AUCKLAND

Apart from academic research, the boundary layer wind tunnel in the Department of Mechanical and Mechatronics Engineering at the University of Auckland has carried out many wind-environment tests of scaled models of proposed buildings in Auckland for four decades. The experimental techniques for such tests have evolved from hot-wire anemometry in the 1980s, to particle erosion in the 1990s, and subsequently automated with machine vision and digital processing in the 2000s. With the commissioning of the new boundary layer wind tunnel in 2015, the department has manufactured ~130 surface level Irwin sensors in order to align the hardware and procedures for these tests with the best industry practice. Fig. 20 shows photographs of a model of Auckland in the wind tunnel ready to be tested using Irwin probes to ascertain the pedestrian level wind environment.

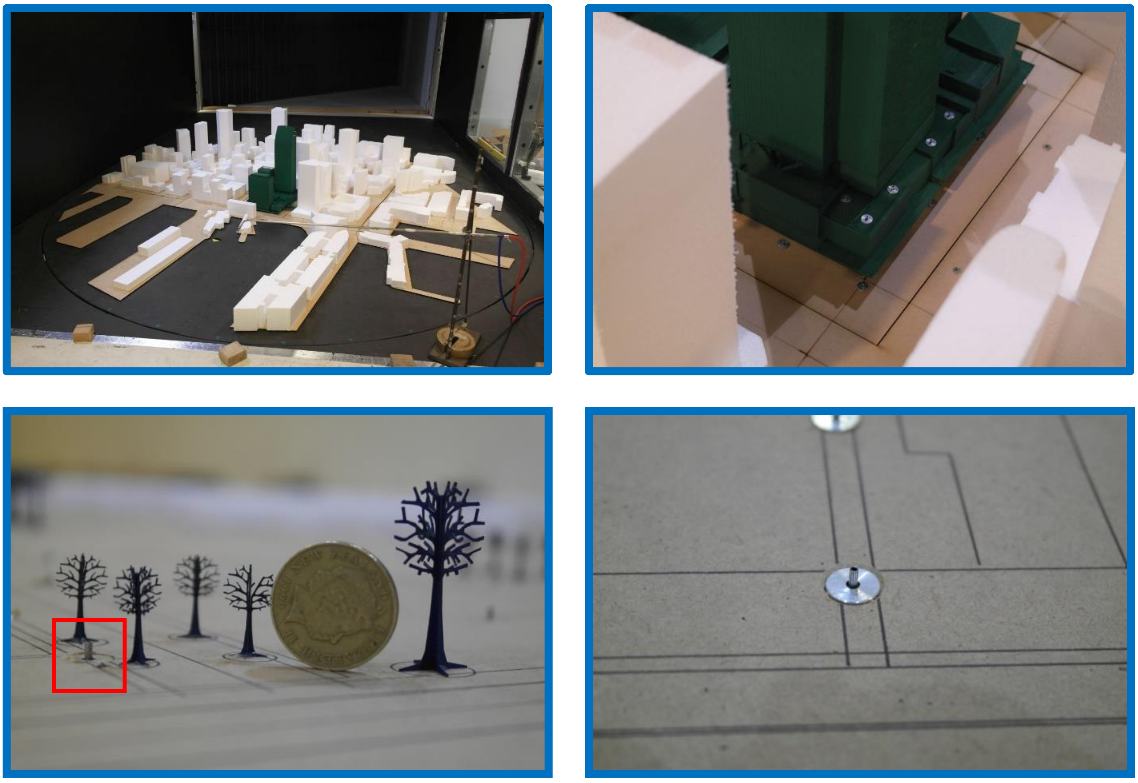

Figure 20. Photographs of a model of Auckland City in the University of Auckland BLWT, showing Irwin probes and surface modelling details.

Another addition to the wind tunnel in recent years has been a fully automated 3-dimensional traverse rig in 2019, which extended the capability of users to routinely obtain wind tunnel flow characteristics for their experiments. It allows the flow quality in the wind tunnel to be surveyed within the space of a 20 m (L) x 3 m (W) x 1.6 m (H) rectangular box with a resolution of 1 mm which enables wind speeds over complex topography or the wake behind a wind turbine to be surveyed in detail. The 3D traversing rig is shown in Fig. 21. This rig has enabled a commercial study of the turbulence characteristics along the approach path of an aircraft runway, and the flow around an elevated HVAC exhaust on a building to be carried out. It also enables other possible investigations such as the safe operation of helipads on proposed buildings, wind speeds through the exposed truss structures of stadia, and the impact of a proposed development on the sailing experience of a nearby sailing school.

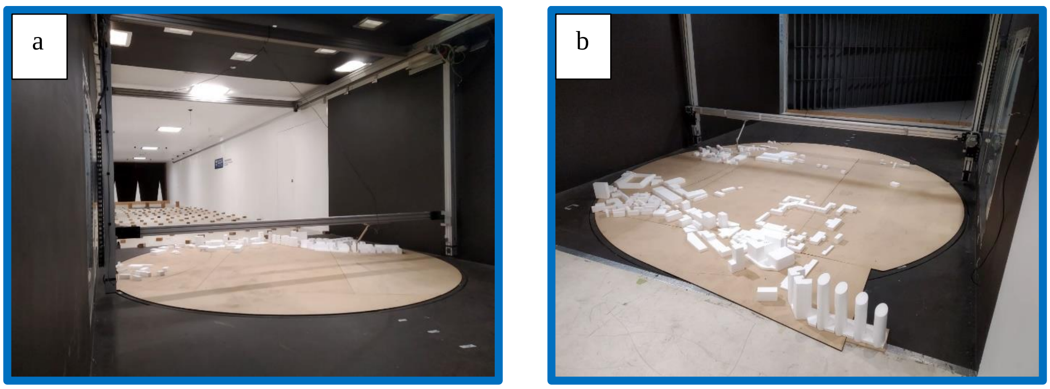

Figure 21. Photographs of the 3D traversing rig and models in the UOA BLWT:
(a) looking upstream; (b) looking downstream.

Apart from the wind environmental work which the University of Auckland has been serving the industry with for the past 40 years, it also undertakes contract research on wind loading. For example, the University of Auckland has recently undertaken an interactive study for the building industry in the Middle East to optimise the massing of a super-tall (>500 m) tower (see Fig. 22). Using the high frequency force balance technique pioneered by Tschanz in the 1980s, which allows rapid evaluation of the model loads, enhanced with a streamlined system of data processing, the laboratory was able to inform the designer of the performance of the massing while they were exploring different design options.

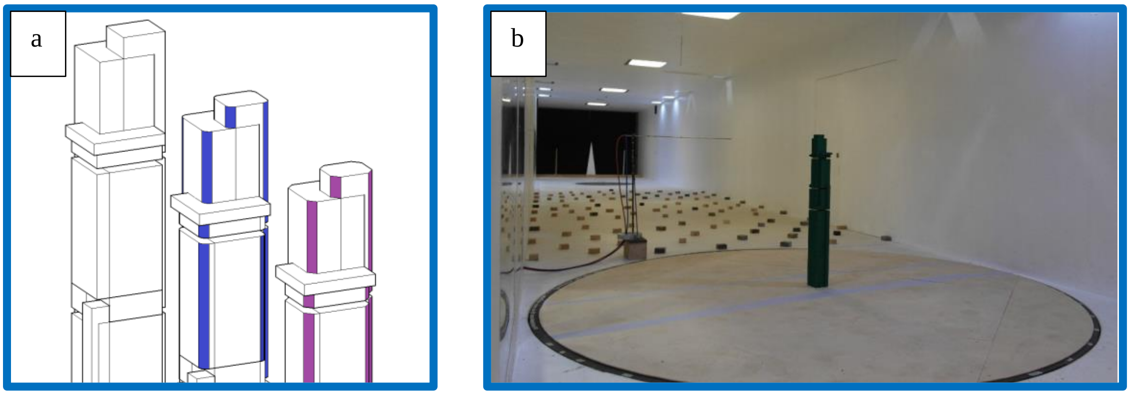

Figure 22. Wind tunnel massing study of a proposed supertall building: (a) Details of the building top; (b) Photograph of the model in the wind tunnel.

The Yacht Research Unit at the University of Auckland is very well known for its research in high performance yachting, particularly sail aerodynamics using the Twisted Flow Wind Tunnel. In 2016 the laboratory explored experimentally the aerodynamic performance of the innovative “cyclors” on the foiling catamaran yachts for Emirates Team New Zealand (ETNZ) for their 35th America’s Cup campaign in Bermuda. Fig. 23 shows the cyclors located in a mock-up of part of the yacht in the wind tunnel. ETNZ went on to win the America’s Cup in Bermuda in 2017.

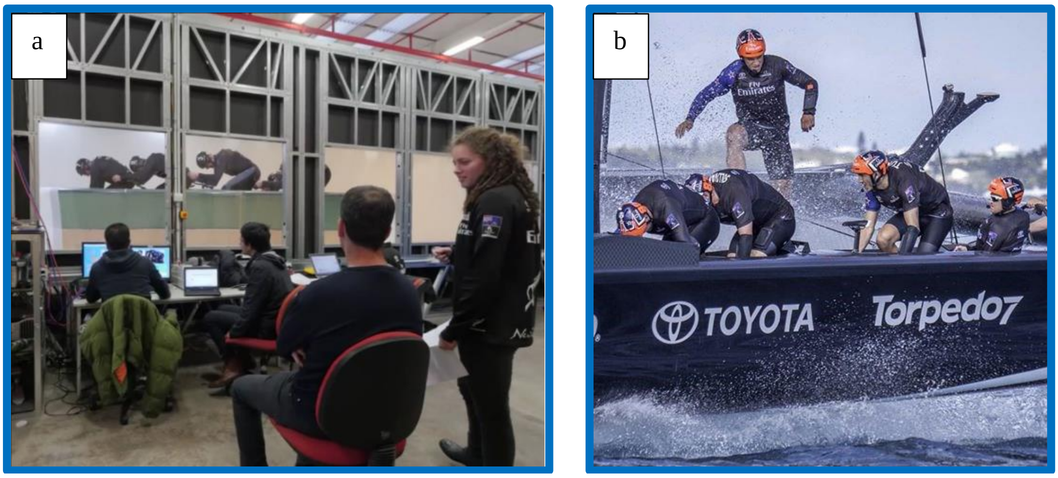

Figure 23. (a) Cyclors in a mock-up yacht hull in the wind tunnel; (b) Cyclors active in the ETNZ yacht.

CONCLUSIONS

This paper summarises much of the wind engineering activities that have taken place in New Zealand since the previous APEC-WW in Hanoi, Vietnam in 2012. It has been a period of significant progress, with national collaborations on wind hazard investigations within New Zealand, and international collaborations with Chinese universities. A highlight was the very successful 9th Asia-Pacific Conference on Wind Engineering which was held in Auckland in December 2017 under the chairmanship of Professor Richard Flay. Other significant achievements in this period have been the construction of two new boundary layer wind tunnels (one in Auckland and one in Wellington), and the rigorous analysis of more than 20 years of wind data to enable the regional wind speeds, directional multipliers, and lee zones to be updated and included in the recently released wind loading standard AS/NZS 1170.2:2021.

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