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Natural Hazards Research Platform

Contest 2012

Title: Establishing reliable and accurate code methods to enable engineers to estimate wind speed-up variations in complex terrain

Leader: Dr Michael Revell
Organisation: NIWA
Total funding (GST ex): $420,000

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Contest 2012 – Final Report

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Programme Leader: Dr Michael Revell

Affiliation: NIWA

Key message for media: Why are these findings important? 2-3 sentences.
The design wind speeds which are specified in the Australian/New Zealand Standard "Structural Design Actions, Part 2: Wind Actions" AS/NZS 1170.2 are fundamental to the design of all buildings and structures in New Zealand. In a hilly country like ours, on the hillside building sites which are common, the hill-shape multiplier is the most important factor contributing to the calculation of the design wind speeds, and consequently to achieving a safe level of structural design for the building. Our research has established that the calculation method which is currently provided in the standard is inadequate and can substantially underpredict the correct design wind speeds, and has provided the basis for recommendations to the technical committee responsible for the standard to address this deficiency.

Abstract:
More robust and accurate guidance on the impact of hill-slopes on wind-gusts within the AS/NZS design wind standards have been obtained following the analysis of mast measurements during strong wind events over the Belmont Hills. The analysis has been augmented by high-resolution computational fluid dynamics simulations, wind-tunnel measurements, and results compared against estimates obtained by methodologies of the standards used in seven different countries. This analysis has been used to provide the basis for recommendations to the standards committee for the loadings standard AS/NZS 1170.2 to provide a much improved calculation of hill-shape multiplier for engineers. This will overcome location-specific confusion in interpreting the current loadings standard. It will lead to more transparency in determining wind actions on structures and provides underpinning literature for future revisions of the standard. The results have also provided improved understanding of wind flows over hills relevant to wind turbine siting and wind power forecasting in New Zealand.

Keywords: Design wind speeds, gusts, Wind loads, Wind engineering, Infrastructure, Building standards, AS/NZS 1170.2

Objective No. 1

Objective Title: Establish terrain elements controlling local speedup effects problematic to the wind engineering standard
Budget: 220K
Objective Achieved? Yes

The aim of the research has been to provide an improved method for the analysis of design wind speeds on hilly sites typical in New Zealand. A range of methods were used to measure and analyse the wind speeds and estimate the topographic speed-up factors. These included:

1. Field site observations were undertaken by NIWA using cup anemometers and direction vanes, at a series of locations on the study site, at heights (at different times) of both 5 m and 10 m. The study site is in the Belmont Regional Park near Wellington, between the towns of Porirua and Lower Hutt. This area is typical of much New Zealand hill country where important infrastructure is located. The topography consists of low flat ground close to sea level towards the northwest, rising through complex terrain to a maximum height of 382 m in an area of high ground towards the southeast, over a distance of about 4 km. The measurement locations were mostly located in a more or less straight line along a spur which rises up towards the southeast, along approximate bearing 150 – 330 degrees. Wind speed data was recorded over a period of 2 years. The analysis focussed on winds blowing from the northerly and north-westerly directions.

2. A wind tunnel model study at a scale of 1:2000 was undertaken by Opus Research. For each of the field site observation locations, wind speeds were measured for a range of wind directions which were similar to the wind directions in the mast observations, and for a range of heights above ground between 5 m and 500 m. Wind speed-ups were calculated by comparing the wind speeds on the hill locations to the wind speeds on a flat surface with the same surface roughness i.e. restricting the comparison to the effects of hill-shape only.

3. High resolution computational fluid dynamics (CFD) analysis was done by NIWA using the program Gerris, which uses a time-varying adaptive grid to solve the Navier Stokes equations. The Gerris model resolution was 5 m in the vertical and 20 m in the horizontal direction at the highest resolution in the vicinity of the observation points. The analysis was done for a range wind directions similar to the wind tunnel study.

4. An analysis was done by NIWA using the commercial software WAsP (Wind Atlas Analysis and Application Program) which is designed for the analysis of wind speeds for wind energy applications.

The wind speeds obtained from the field site observations, the wind tunnel study and the Gerris analysis were generally similar. Each method was able to provide a contribution to the overall analysis, so that the analysis of the true wind speed multipliers for the site is obtained by combining the results from the three methods. The wind speeds measured at

the various measurement locations on the complex study site were compared with previous studies for simple hill shapes. The wind speeds measured at the summit of the test site were similar to wind speeds for a simple hill shape, but at other locations the measured speeds were substantially influenced by the influence of local topography variations.

Outputs
Refer to Objective 2
End Users
Refer to Objective 2

Objective No. 2
Objective Title: Establish more reliable and accurate code methods to enable engineers to estimate wind acceleration variations across complex, hilly terrain

Budget: 200K
Objective Achieved? Yes

Examination of the accuracy of methods provided to calculate wind hill-shape multipliers in wind loading standards was done by GNS Science and the Department of Mechanical Engineering of the University of Auckland. The highest wind speed-ups measured in the study for Objective 1 were similar to the highest hill-shape multipliers (Mh) specified in the wind loading standard AS/NZS 1170.2. However, when AS/NZS 1170.2 was used to obtain wind speeds for the site, some of the resulting calculated wind speed-ups were very poor – e.g. a speed-up of 1.1 calculated by AS/NZS 1170.2 compared to a measured speed-up of 1.7. This is caused by the method of interpretation and simplification of a complex hill shape that is specified in AS/NZS 1170.2. In this case the measured wind speeds were greater than the speeds calculated by AS/NZS 1170.2 by a factor of 1.55, and the resulting wind loads were therefore greater by a factor of 2.4. This represents a gross underprediction of the correct wind speeds by the wind loading standard.

Seven different international standards have been reviewed to compare their calculations of hill-shape multiplier. The standards all use similar approaches to estimate topographic effects, with slight variations from one another. Therefore, the resulting calculations are essentially similar. In comparison with the full-scale test speed-up factors, none of the standards provided adequate factors to account for changes in the wind speed over the complex terrain of Belmont Hill. This is, in part, because of necessary assumptions made to simplify the geometry into the standard shapes considered in the standards.

The assumptions used in the wind loading standard have been analysed. This analysis has provided the basis for recommendations to the standards committee of AS/NZS 1170.2. It recognised that an accurate detailed wind speed calculation is difficult in the format of the current standard. However the improved analysis will ensure that standard does not grossly

underestimate the correct wind speeds. The resulting calculation will err on the side of overestimating wind speeds. The user will be directed to obtain specialist advice where necessary. In the absence of simple and easy-to-use formulae to calculate topographic factors, contoured maps of such factors could be pre-computed and made available in the standards. Such maps could be derived from numerical analyses or wind tunnel tests. This would also provide a consistent approach across all designers for calculating such factors.

In the longer term, we anticipate that CFD methods such as Gerris will be used to provide detailed maps of design wind speeds for all of New Zealand. CFD requires calibration, and this research has provided calibration input into Gerris and has also provided both field site and wind tunnel measurements which can be used to calibrate the CFD methods.

Outputs:

The full report for this research programme is:

Revell M, Carpenter P, Flay RGJ, King AB, Nayyerloo M, Cenek PD, 2015. Establishing reliable and accurate guidelines for engineers on estimating wind speed-up in complex terrain. NIWA Client report WLG2015-46.

Additional reports, papers and publications include:

Carpenter P, Cenek PD, Revell M., Turner R, Flay RGJ, King AB, 2012. Study of wind speeds over hilly terrain using full-scale observations, wind tunnel simulation and CFD. AWES15, 15th Australasian Wind Engineering Society Workshop, Sydney, February 2012.

Carpenter P, Jamieson NJ, Cenek PD, 2015. Wind speed hill shape multipliers – wind tunnel study. AWES17, 17th Australasian Wind Engineering Society Workshop, Wellington, February 2015.

Carpenter P, Jamieson NJ, Flay RGJ, Nayyerloo M, King AB, Revell M, 2015. Investigation of Wind Speed Hill-shape Multipliers. ICWE14, 14th International Conference on Wind Engineering, Porto Alegre, June 2015.

Flay RGJ, Turner R, Revell M, Carpenter P, Cenek PD, King AB, 2012. Wind speed up over hills and complex terrain, and the risk to infrastructure. 18th Australasian Fluid Mechanics Conference, Launceston, December 2012.

Flay RGJ, Turner R, Revell M, Carpenter P, Cenek PD, King AB, 2013. Wind Speed-Up Measurements Over Belmont Hill in Complex Terrain. 6EACWE, 6th European and African Conference on Wind Engineering, Cambridge, July 2013.

Flay RGJ, Carpenter P, Revell M, Cenek PD, Turner R, King AB, 2013. Full-scale wind engineering measurements in New Zealand. APCWE8, 8th Asia-Pacific Conference on Wind Engineering, Chennai, December 2013.

Flay RGJ, Nayyerloo M, King AB, Revell M, 2015. Comparison of Wind Speed Hill-shape Multipliers Calculated by Seven Wind Loading Standards. AWES17, 17th Australasian Wind Engineering Society Workshop, Wellington, February 2015.

Flay, RG J, King AB, Revell M, Carpenter P, Turner P, Cenek PD. Wind speedup measurements and predictions for Belmont Hill. Submitted to the Journal of Wind Engineering and Industrial Aerodynamics.

King AB, Carpenter P, Cenek PD, Revell M, Turner R, Flay RGJ, 2012. Modified wind speed due to topographic effects. GNS Science Consultancy Report 2012/07.

Nayyerloo M, King AB, Flay RGJ, 2014. Comparison of wind speed hill shape multipliers calculated by seven different national and international standards. GNS Science Report 2014/52.

End Users

- Technical committees of AS/NZS standards (including BD-006 and EL052-2) where wind speeds and wind loads are considered.
- Technical committees for international standards.
- Structural design engineers and practitioners, and the building industry.
- Wind engineering researchers.
- The wind energy industry.

Conclusions & Recommendations:

The design wind speeds which are specified in the Australian/New Zealand Standard “Structural Design Actions, Part 2: Wind Actions” AS/NZS 1170.2 are fundamental to the design of all buildings and structures in New Zealand. In a hilly country like ours, on the hillside building sites which are common, the hill-shape multiplier is the most important factor contributing to the calculation of the design wind speeds, and consequently to achieving a safe level of structural design for the building. Our research has established that the calculation method which is currently provided in the standard is inadequate and can substantially underpredict the correct design wind speeds. This analysis has been used to provide the basis for recommendations to the standards committee for the loadings standard AS/NZS 1170.2 to provide a much improved calculation of hill-shape multiplier for engineers. This will overcome location-specific confusion in interpreting the current loadings standard. It will lead to more transparency in determining wind actions on structures and provides underpinning literature for future revisions of the standard. The results have also provided improved understanding of wind flows over hills relevant to wind turbine siting and wind power forecasting in New Zealand. In the longer term, we anticipate that CFD methods such as Gerris will be used to provide detailed maps of design wind speeds for all of New Zealand. CFD requires calibration, and this research has provided calibration input into Gerris and has also provided both field site and wind tunnel measurements which can be used to calibrate the CFD methods.

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