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An approach for benchmarking pedestrian wind effects assessments

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ABSTRACT

Pedestrian wind affects assessments require predictions of wind speeds, typically in ground level urban areas in the vicinity of proposed developments. As with many wind engineering studies, the complexity of the wind flows generated in urban environments can make accurate prediction of resulting wind speeds a complex task.

Benchmarking the results of any assessment is crucial for quality control especially when the outcome is dependent on many variables such as those found in urban wind flows. A simple and reliable benchmark that allows the results to be readily audited for quality would be good for maintaining industry standards and keeping a level playing field for all.

This study attempts to outline a method of benchmarking the results of pedestrian wind effects assessments.

1. Introduction

Similarly to other wind engineering studies of cladding pressures and structural loads, ground level wind speeds in built-up urban areas are sensitive to many variables including building heights, topography, building forms, upstream terrain, building spacing, details of facades and more. Due to the number of variables involved, results can potentially vary widely from one pedestrian wind effects assessment to the next and even from one test location to the next, making benchmarking difficult.

The sensitivity of results to multiple variables may be especially significant when a wind engineer produces a “desktop” pedestrian wind effects assessment which is typically based on their experience, judgment and empirical data but not based on specific testing

In scale model wind tunnel testing of pedestrian wind effects, as with other types of wind tunnel study, there is the additional complexity of the instrumentation and data acquisition. Instrumentation often used to measure wind speeds in turbulent flows in scale model testing is, by nature of the testing, small and sensitive and so is often fragile, prone to tubing blockages and/or leaks (Irwin sensors) or contamination by fine particles (hot wires). Many common problems with Irwin sensors and hotwires such as blocked tubing and getting caked in debris tend to result in the instrument still appearing to work but having lower frequency response and so under-reading the fluctuating component of wind speeds.

In addition to instrumentation condition are all the instrumentation settings (e.g. filter frequencies, acquisition rates) as well as calibration accuracy, all of which can potentially affect the accuracy of results.

In summary, the wind speeds in the vicinity of a subject building can be difficult to predict, which is why wind engineers often resort to building scale models and testing them. This also means that it can be hard to judge the veracity of the results generated. So, without a robust benchmarking exercise, the predicted wind speeds cannot be verified and quality cannot be guaranteed

2. Benchmarking examples in other types of wind engineering studies

The pressure tappings and instrumentation of cladding pressure models can be checked for accuracy by placing the subject building model in a vessel and applying known pressures to the entire model and instrumentation. Mean stagnation pressures on exposed facades can be checked against the target boundary layer mean dynamic pressure at the same height, thus providing a spot check of both instrumentation and terrain model.

Base-balance testing usually involves calibration of the base balance with the scale model in place in the wind tunnel by applying known forces. Mean drag force on exposed models (or with the near-field model removed) can often be benchmarked against experimental data for similarly shaped buildings.

3. Description of suggested benchmark

Looking at the problem of benchmarking the results of scale-model testing of environmental wind speeds, the modeling can be broken down into its components and some of those components can be readily benchmarked.

For example, Figure 1 shows a schematic representation of a scale-model wind tunnel test of a subject building (filled-in) with the approach-flow boundary layer modeled and the “near-field” buildings modeled.

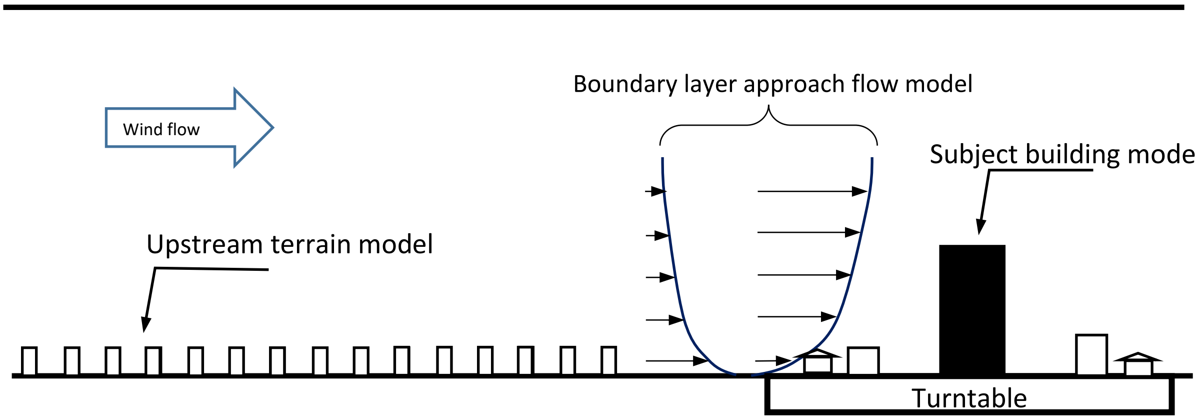

Fig. 1. Schematic representation of a boundary layer wind tunnel scale-model test.

While the pedestrian height wind speeds in the vicinity of the subject building are not known, the pedestrian height wind speeds in the model approach flow can be determined with some accuracy. If the test anemometers were placed at pedestrian height in the model approach flow (see Figure 2), their output should match the predicted values well and this would be a fairly rigorous check of both the model approach flow at pedestrian height and the test instrumentation. Testing accuracy of the subject building would then come down to the geometric accuracy of the scale model which can be readily be verified.

In order to be useful, a benchmark test should be able to be readily conducted in the wind tunnel, ideally just prior to the scale model test to ensure the accuracy of equipment and set up for that test. As shown in Figure 2, the suggested benchmarking exercise is possible just prior to installing the scale model in the wind tunnel (i.e. the turntable is empty).

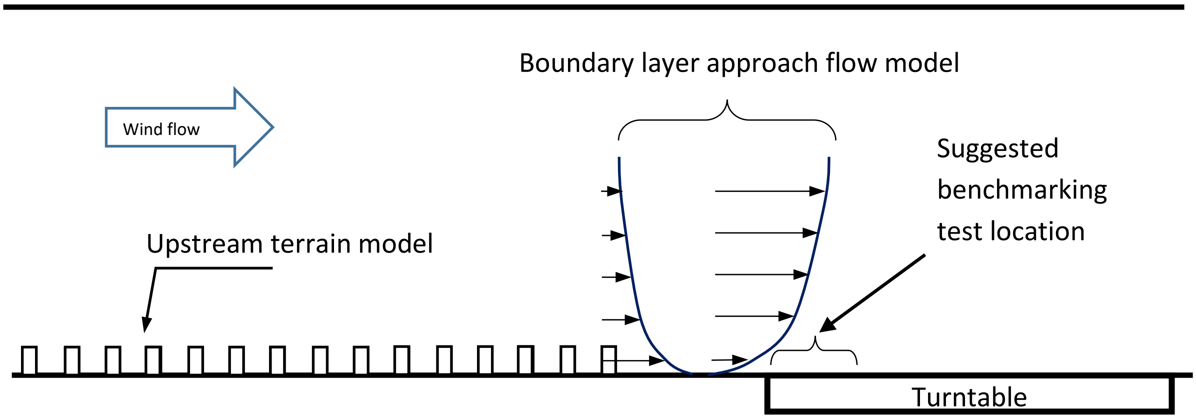

Fig. 2. Schematic representation of the wind tunnel test setup without the near-field model and test subject building showing suggested benchmarking test location.

4. Suggested wind tunnel test benchmark method

The suggested benchmarking exercise involves locating the test anemometers at pedestrian level (scaled height of 1.5m to 2m above ground level) near the upstream edge of the turntable as shown in Figure 2, i.e. where the model approach-flow boundary layer profile meets the near-field model on the turntable. Measurements of wind speeds at this location should match the corresponding values of the target approach flow boundary layer profile in terms of mean wind speed, turbulence intensity and peak gust wind speeds.

Values of mean wind speed at pedestrian height could be extrapolated from the target boundary layer profile using a power-law fit of the measured data as shown in Figure 3.

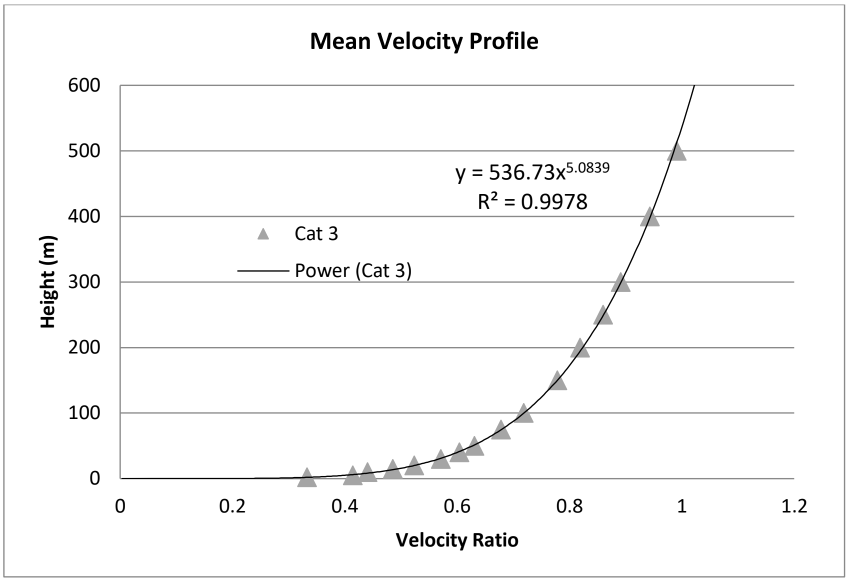

Fig. 3. Terrain Category 3 boundary layer mean velocity profile from Standards Australia (1989) extrapolated to 2m height.

In the case of Terrain Category 3, using the mean boundary layer profile from Standards Australia (1989) (or from Standards Australia (2011) and back-working from the gust profile), a power law fit of the data and extrapolated to 2m height gives a velocity ratio value of approximately 0.33 at pedestrian height.

Using the corresponding turbulence value from Standards Australia (2011), a typical 3s peak gust wind speed value can be predicted corresponding to a scaled 1 hour mean wind speed value by

$$\hat{V}_{3s\ 2m} = \bar{V}_{1h\ 2m}(1 + gI_z) \quad (1)$$

Where

$\bar{V}_{1h\ 2m}$ is the mean wind speed from the target boundary layer profile, e.g. 0.33 from the above example.

g is a peak factor dependent on the gust averaging period, e.g. circa 3.0 for a 3s gust

I_z = is the turbulence intensity from the target boundary layer profile, e.g. 0.271 for TC3

then

$\hat{V}_{3s\ 2m}$ =0.6, i.e. 0.6 × $\bar{V}_{1h\ gradient}$

Provided the model of the target boundary layer is reasonable, the instrumentation is working well and the data acquisition settings are correct, both the measured peak gust and mean wind speeds should compare reasonably with predicted values (e.g. to within ±10%).

As it may be awkward with some instrumentation to set up anemometers near the upstream edge of the wind tunnel turntable, a similar test could be conducted with the anemometers close to the middle of the turntable if the model boundary layer is brought to the middle of the turntable using roughness elements on the turntable in place of the near-field model as shown in Figure 4.

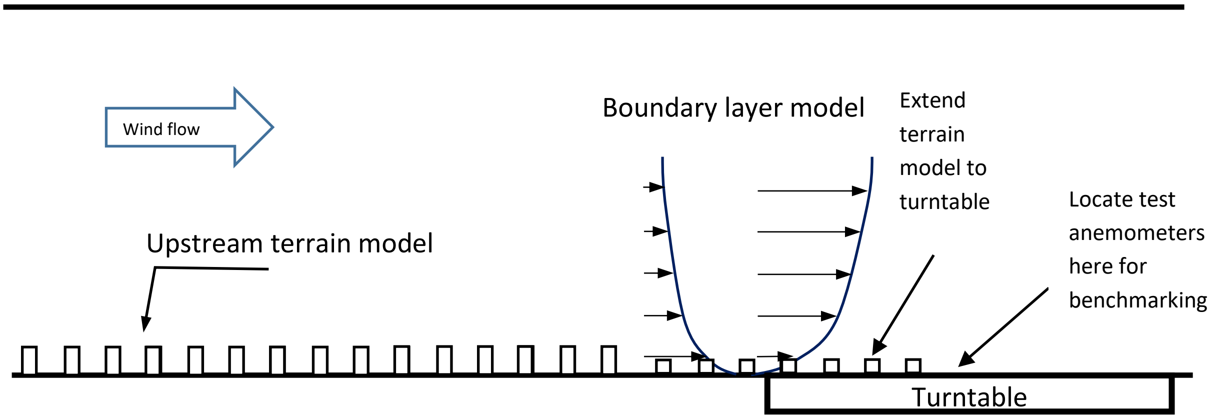

Fig. 4. Schematic representation of a benchmarking terrain model and instrumentation in the centre of the turntable.

In some cases where the near-field model is similar to the surrounding terrain, the wind tunnel test including the boundary layer model and instrumentation could be checked by doing a “Bare Site” wind speed measurement. That is, by removing the subject building model and measuring wind speeds at the site of the subject building at pedestrian height as shown in Figure 5.

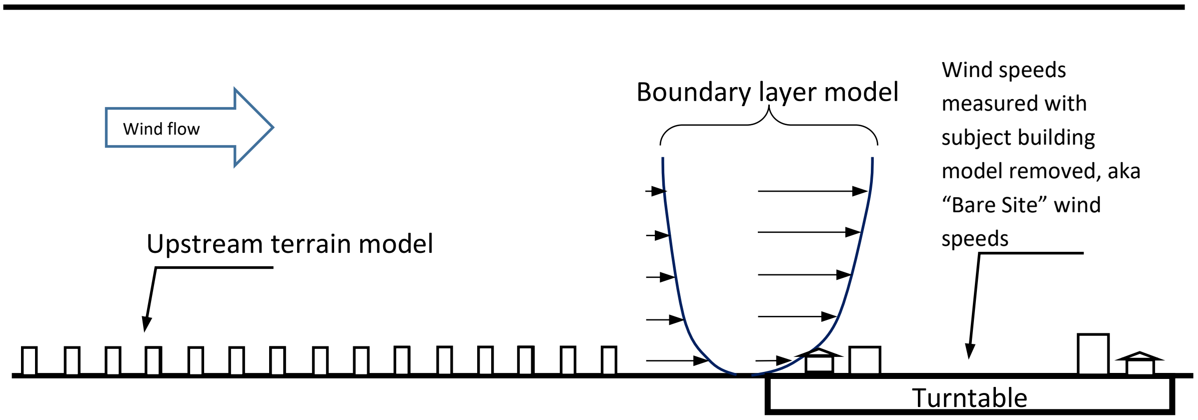

Fig. 5. Schematic representation of a test of a “Bare Site” wind speed test.

The Bare Site wind speeds, when measured in this scenario at pedestrian height (1.5m to 2m above ground), should closely match expected mean and gust wind speeds for the given terrain category.

5. Desktop assessment benchmark method

Predictions of the theoretical approach flow pedestrian height mean and gust wind speeds using the same method outlined above (extrapolating the mean boundary layer profile to pedestrian height and using an appropriate peak factor to determine peak gust wind speed) could also be used to benchmark results of desktop wind effects assessments.

Particularly where a subject building has little or no shielding for one or more wind directions (e.g. where a development significantly larger than the surrounding developments is proposed) and one would expect the form of the building to result in some localized shielding as well as some localized speed-up effects, then the values of approach flow pedestrian height mean and gust wind speeds could be used as a reference value about which various wind speed values in the vicinity of the subject building might straddle. That is, we might expect that pedestrian height wind speeds in leeward areas of the building to be lower than the approach flow values. We might also expect pedestrian height wind speeds in exposed upstream building corner areas to be higher than the approach flow values. How much higher could be estimated using empirical results such as those in Aynsley, Melbourne and Vickery (1977).

6. Conclusions

Benchmarking test or desktop results of pedestrian wind effects assessments is crucial for quality control. A simple and reliable benchmark that allows at least some of the results to be readily audited for quality would be good for maintaining industry standards and keeping a level playing field for all.

The benchmarking exercise outlined is a fairly simple and worthwhile exercise for the wind engineer to conduct to gauge the accuracy of a test set-up or the results of a desktop assessment.

The desktop benchmarking exercise outlined is being used as a review process by Moonee Valley City Council as a basis for assessing planning application submissions.

References

Standards Australia, (1989), "SAA Loading Code Part 2 Wind loads", Australian Standard, AS 1170.2 - 1989

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