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Characterisation of a new blockage tolerance wind tunnel

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ABSTRACT

An existing open jet atmospheric boundary layer wind tunnel has been reconfigured to include a blockage tolerant test section. Blockage tolerant test sections allow for wind tunnels to test models with blockage ratios higher than typically recommended with negligible impact on the measured pressures, whilst maintaining the flow speed within the tunnel. Models based on the Wind Engineering Research Field Laboratory (Texas Tech University) full scale building as well as a two dimensional prism at different scales were tested in the wind tunnel. A comparison of the full-scale results with measured pressures demonstrates that the wind tunnel and the pressure acquisition system is capable of accurately reproducing and recording roof corner pressures. The results presented also show that the blockage tolerant wind tunnel configuration is able to maintain consistent results (within 10%) with a blockage of up to 13% in the case of cladding pressures and up to 21% in the case of overall drag loads.

1. Introduction

To ensure reliable results from wind tunnel tests of buildings it is important to ensure that the wind tunnel models do not overly reduce the effective cross section of atmospheric boundary layer wind tunnel test sections. The "blockage ratio" is typically defined as the largest cross-sectional area of the model divided by the cross-sectional area of the wind tunnel. The AWES QAM (2019) specifies that the blockage ratio should not exceed 10%.

For blockage ratios greater than this theoretical correction factors may be applied however they are not suited to all measurement parameters (ie overall drag vs fluctuating pressures) and there are difficulties in applying them in highly fluctuating or separating flows. These corrections also differ between closed and open jet wind tunnels (Barlow *et al*, 1999).

To overcome this a blockage tolerant section can be included within a wind tunnel. Typically, these sections consist of a plenum located on the wall or roof of the wind tunnel which is separated from the main working section by spaced aero-foil shaped slats (Figure 1). Similar blockage tolerant sections in open jet atmospheric boundary layer wind tunnels have been described by several other authors for example Parkinson and Cook (1992), Glanville and Kwok (1997) and Aurelius and Rofail (2001).

2. Blockage Tolerant Atmospheric Boundary Layer Wind Tunnel Design

An existing open jet wind tunnel was modified to include a blockage tolerant section. The new working section of the wind tunnel is 3m wide and 1.5m high. The blockage tolerant plenum is 0.5m high. The new design also includes a permeant contraction section to increase the flow speed (Figure 2, Figure 3). The aerofoil blades are 150mm wide and the solidity ratio is 58%.

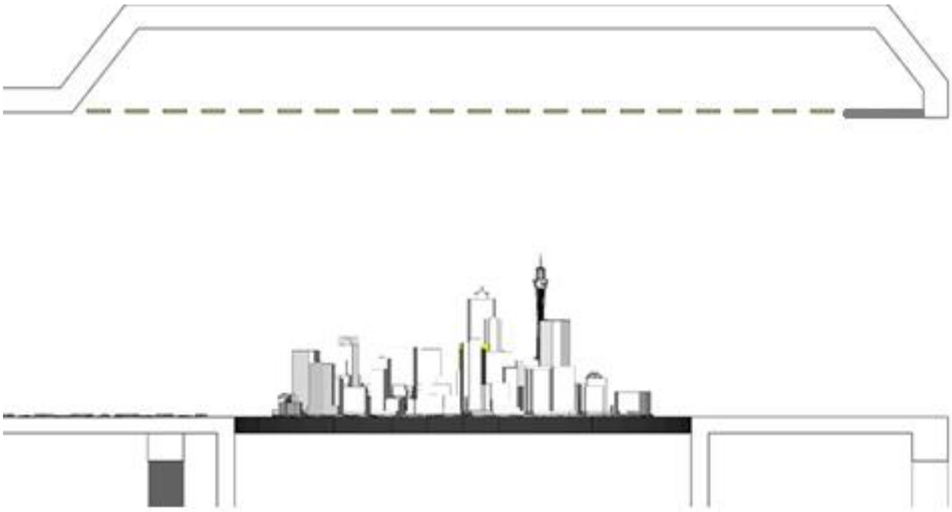

Figure 1. Example of a Roof Mounted blockage tolerant plenum

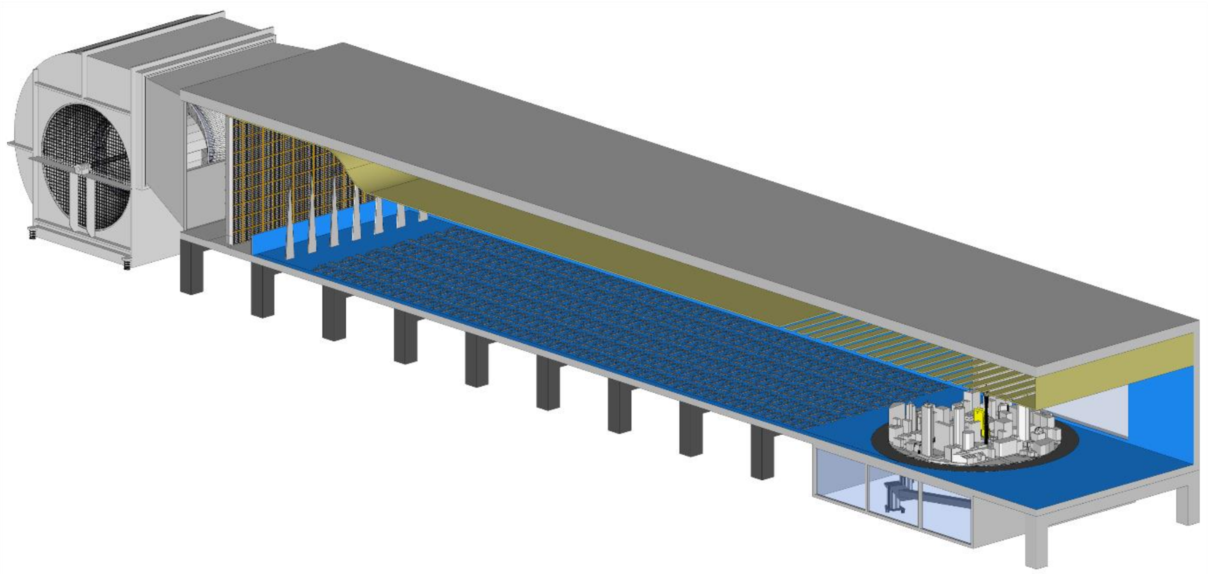

Figure 2. Blockage Tolerant Atmospheric Boundary Layer Wind Tunnel Design

Figure 3. Photo of Blockage Tolerant Atmospheric Boundary Layer Wind Tunnel

3. Test Setup

To test the performance of the modified wind tunnel, scale models based on the well-known Wind Engineering Research Field Laboratory (WERFL) full scale building at Lubbock Texas on the campus of Texas Tech University (TTU) were used (Levitan and Mehta, 1992). To achieve the required blockage levels at reasonable model scales, the building was extended to create a two-dimensional rectangular blockage. For the extended cases where there were significant gaps between the model and the wall, end plates were fitted to remove end effects and ensure that the flow remained two-dimensional.

Table 1: Model Dimensions

Scale	**1:1 (TTU)**	**1:20**	**1:50**	**1:20**	**1:12**	**1:12**
Extended Width		No	Yes	Yes	Yes	Yes
Height (m)	4.0	0.20	0.08	0.20	0.33	0.33
Width (m)	13.7	0.69	2.95	2.91	2.3	2.8
Depth (m)	9.2	0.46	0.18	0.46	0.76	0.76
Blockage		3%	5%	13%	17%	21%

The buildings were all tested with in an open terrain profile (Terrain category 2). The sensor locations are shown in Figure 4.

Pressure measurements were made with a combination of a custom-made pressure sensor system combined with National Instruments data acquisition hardware and software.

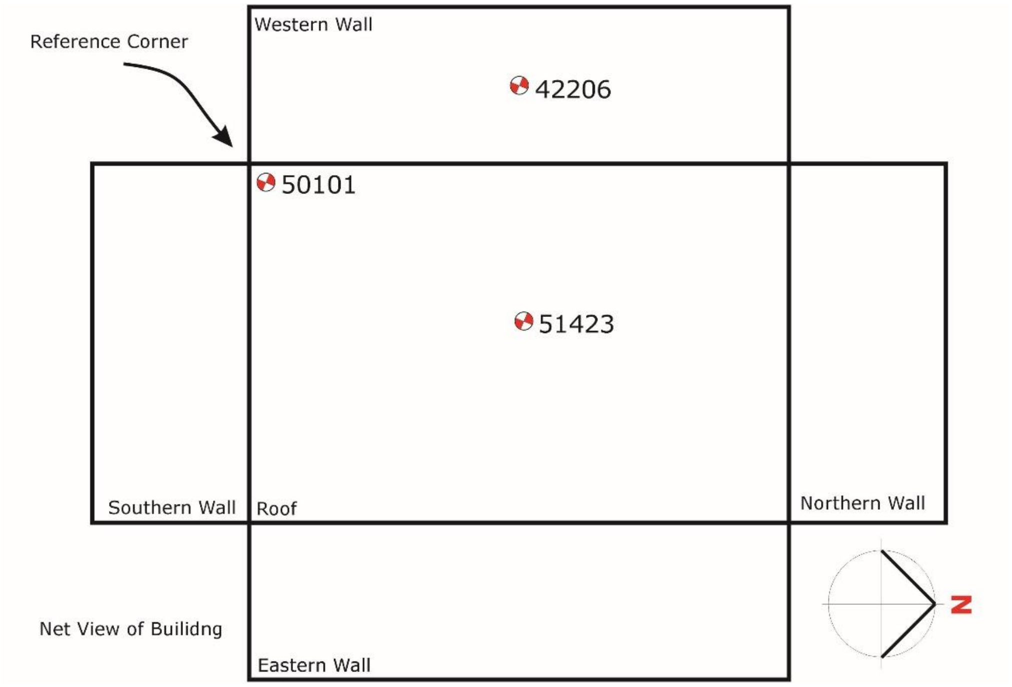

Figure 4. Sensor Locations for the TTU building

4. Comparison with WERFL TTU full scale data

To assess the performance of the wind tunnel and pressure measurement system, the pressure measurements from a 1:20 scale model of the WERFL TTU building were compared with field data from the full scale WERFL TTU building (Levitan and Mehta, 1992).

Pressure results for one corner roof pressure sensor (A50101) and one wall pressure sensor (A42206) are presented in Figure 5. The wind tunnel results for the roof pressure sensor demonstrate that the combination of the wind tunnel and the pressure acquisition system is capable of accurately reproducing and recording roof corner pressures. For the wall pressure sensor there is a good comparison for the peak positive windward pressures (270 degrees). When the sensor is orientated in the leeward position (90 degrees) there were fewer field pressure measurements to make a comparison with. However, the side wall pressures are reproduced well (180 degrees).

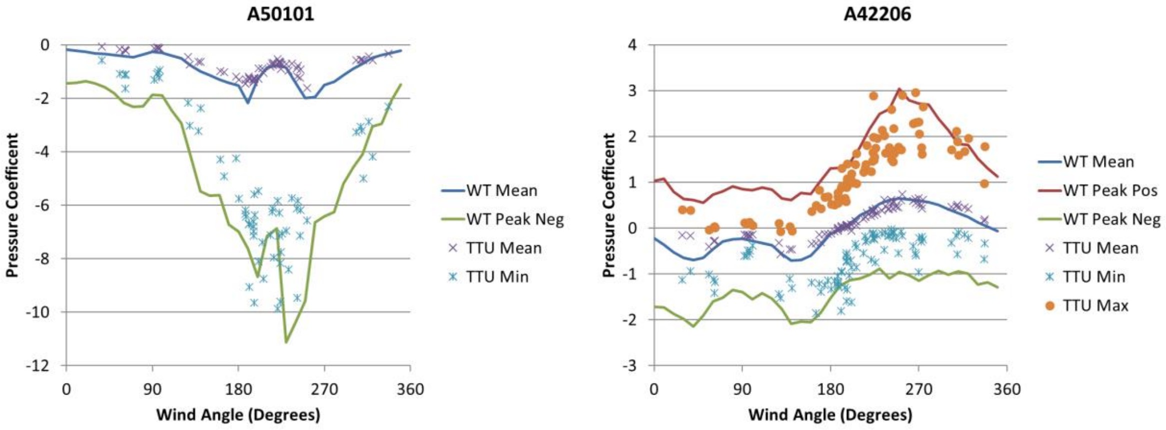

Figure 5. TTU Corner Roof and Mid Wall Pressure Comparison

5. Comparison for varying blockage ratios

To assess the impact of blockage on the performance of the wind tunnel scale models of the basic WERFL TTU buildings were built and then extended in their longest axis such that they almost spanned the full width of the wind tunnel. Measurements from roof and wall sensors were consider. Following Parkinson and Cook (1992) the pseudo-drag which was defined as the windward pressure minus the leeward pressure was also calculated. In all cases measurements have been taken for when the wind occurs perpendicular to the extended building.

Figure 6 presents results for the windward and the leeward sensors. From these cases the impact of the increase in blockage is evident on the measured pressures.

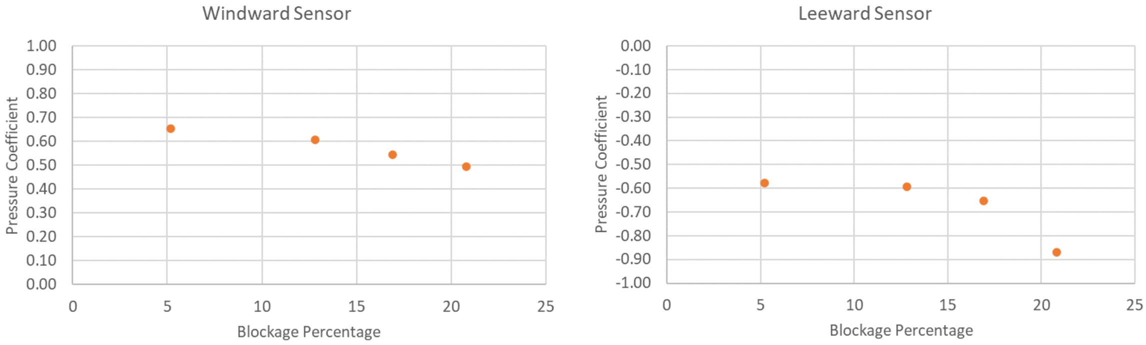

Figure 6. Leeward and Windward Pressure Comparison for Varying Blockage

Figure 7 presents results for the roof sensor and pseudo-drag. From these cases there is less evidence of the impact of the increase in blockage on the measured pressures.

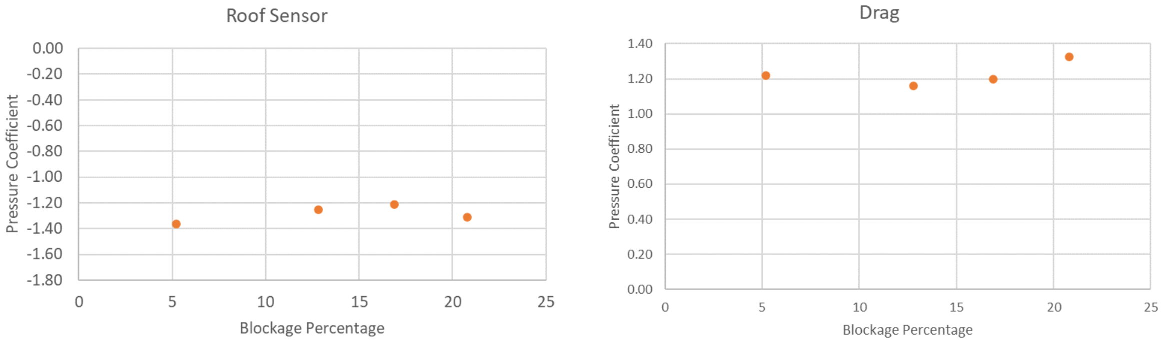

Figure 7. Roof and Overall Drag Comparison for Varying Blockage

The results presented in Figure 6 and Figure 7 show that the blockage tolerant wind tunnel configuration is able to maintain consistent results (within 10%) with a blockage of up to 13% in the case of cladding pressures and up to 21% in the case of overall drag loads.

6. Conclusions

A comparison was made between measured wind tunnel pressures and those taken in full scale fielder measurements and it was demonstrated that the wind tunnel and the pressure acquisition system is capable of accurately reproducing and recording roof corner pressures. There was also good comparison for the windward and sidewall pressures. The results presented also show that the blockage tolerant wind tunnel configuration is able to maintain consistent results (within 10%) with a blockage of up to 13% in the case of cladding pressures and up to 21% in the case of overall drag loads.

References

Aurelius, L.J. and Rofail, A.W. (2001), Performance of Windtech's slatted roof blockage tolerant boundary layer wind tunnel in 3D flow, 9th AWES Workshop, Townsville

Barlow, J.B., Rae, W.H. and Pope, A. (1999), "Low Speed Wind Tunnel Testing", 3rd Edition, John Wiley and Sons, Inc, New York, USA

Glanville, M.J. and Kwok, K.C.S (1997). Further investigation of the blockage tolerant windtunnel technique. Journal of Wind Engineering and Industrial Aerodynamics, 69-71, 987-995

Levitan, M.L. and Mehta, K.C. (1992). Teaxs Tech field experiments for loads. Journal of Wind Engineering and Industrial Aerodynamics, 43, 1565-1588

Parkinson, G.V. and Cook, N.J. (1992), Blockage tolerance of a boundary layer wind tunnel. Journal of Wind Engineering and Industrial Aerodynamics, 41-44, 873-884