Wind Pressures on a 1:50 Scale model of Texas Tech University Experimental Building

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1. Introduction

The majority of structures built all over the world are classified as low-rise buildings. Roof and other cladding failures for this type of buildings are common occurrences in strong winds. The Texas Tech University (TTU) experimental building was designed and built more than ten years ago to study wind effects on low-rise buildings. Since then, many wind tunnel scale model studies of the TTU experimental building have been conducted to verify pressure data from scale model tests by comparisons with field data, particularly those large negative peak pressures at the roof corners. A summary of some of these studies is presented in Table 1. In general, all the wind tunnel results, including mean, standard deviation, positive peak and negative peak pressures agree well with the field data, except those close to the roof edges and roof corners where the discrepancies are 20% or higher. Factors that may improve these discrepancies have been investigated, and these include model scale, Reynolds number, turbulence intensities (particularly lateral turbulence) and scale, and frequency response of the pressure measurement system. The potential effects of mismatches in the pressure tap diameter, geometrical details and full-scale non-stationary effects were also noted.

An experimental study of wind pressures acting on a 1:50 scale model of the TTU experimental building was conducted in the CLP Power Wind/Wave Tunnel Facility at the Hong Kong University of Science & Technology (HKUST). This paper presents some of the test results and comparisons with the field data.

2. Experimental Arrangement

A combination of floor roughness elements, plain and saw-tooth fences were used to simulate the TTU wind profiles. The mean wind speed profile, longitudinal turbulence intensity profile and longitudinal turbulence spectrum are shown in Figures 1 and 2.

A 1:50 scale model of the TTU experimental building was fitted with 114 pressure taps at positions corresponding to those used in the field experiment. The computer software DROPtubes was used to design the tubing arrangement for connection to a high-speed electronic pressure scanning system. The tubing system consisted of a 100mm long restrictor tubing of 0.5mm ID in between 50mm and 200mm long tubing of 1.5mm ID. This tubing system provided a flat frequency response (to within ±20%) for frequencies up to 300Hz. A low-pass cutoff frequency of 200Hz was used for all measurements.

The model was tested for 15 wind directions: 0°, 45°, 90° and 315° degrees, and 180° to 270° at 10° intervals. At each direction, pressures at all the taps were sampled at a frequency of 800Hz for 20 seconds, which corresponds to approximately 15 minutes in full-scale. The measurements were repeated 10 times.

3. Result and Discussions

All pressure results are expressed as pressure coefficients referenced to the mean dynamic pressure at the top of the model (80mm in model scale). The reference static pressure was measured by a Pitot-static tube located upstream of the model.

Selected measured pressure coefficients at Tap 50501 at the roof edge, Tap 50101 at the roof corner, and Tap 42206 at the sidewall central position are shown in Figures 3 to 8. For mean and standard deviation pressure coefficients, the averages of 10 samples are presented. For peak pressure coefficients, the peak values for each of the 10 samples are presented. Field data for each of those taps were also included in the figures for comparisons.

At Tap 50501 at the roof edge, the 10 sample average mean pressure coefficients agree well with the field data, as shown in Figure 4. The largest negative peak pressure coefficient recorded in the wind tunnel is approximately –12 at 210°, which is very similar in magnitude to that measured in the field, as shown in Figure 3. Within the wind angles of 180° to 270°, the 10 sample average peak values are up to 25% smaller than the largest field data measured at similar wind angles.

At Tap 50101 at the roof corner, the 10 sample average standard deviation pressure coefficients agree well with the field data, as shown in Figure 6. The largest negative peak pressure coefficient recorded in the wind tunnel is approximately –10 at 220°, which is also very similar in magnitude to that measured in the field, as shown in Figure 5. Within the wind angles of 180° to 270°, the 10 sample average peak values are 10% to 15% smaller than the largest field data measured at similar wind angles.

At Tap 42260 at the sidewall central position, the 10 sample average mean pressure and positive peak pressure coefficients are in good agreement (generally within approximately 5%) with field data, as shown in Figures 7 and 8. The largest positive peak pressure coefficient recorded in the wind tunnel is approximately 3 at 260°, which is also very similar in magnitude to that measured in the field.

4. Concluding remarks

The results obtained from the HKUST wind tunnel experiment using a 1:50 scale model of TTU experimental building are consistent with the results obtained by others using a similar size model. In general, there are good agreements with the field data for mean, standard deviation, positive peak and negative peak pressure coefficients, except at locations close to the roof edges and roof corners. At these locations, the 10 sample average negative peak pressure coefficients are up to 25% smaller than the largest field data, but the largest peak values for the 10 samples, for both positive and negative peaks, are very similar in magnitude to those observed in the field.

Table 1 A summary of previous works

Authors	Univ./Lab	Scale	Test wind speed (m/s)	Roofline turb. int. (%)	Freq. Resp. (Hz) [Actual]	Equiv. Sample time (min)	Extreme value analysis	Comments
Levitan & Mehta, 1992	TTU	Full Scale	8.9	20	[8~10]	15	Actual peak	- Different acquisition modes used for different data sets
Cochran & Cermak, 1992	CSU	1:50 & 1:100	8.5-9.5	22 & 25	5 & 2.5 [250]	30	Mean of four extrema	- "Delta wing" corner vortex and separated shear layer effects - Size effect associated with lower turbulence intensity - Importance of lateral turbulence
Okada & Ha, 1992	BRI, Japan	1:65, 1:100 & 1:150	5.0~5.6	15	0.48 to 2.93 [50 &100]	>30	Actual peak	- Low turbulence intensity in model flow - Low frequency response of tubing systems - Almost no size effect
Lin et al., 1995	UWO	1:50	Re up to 1.5×10^5	20	1.7 [100]	30	Actual peak	- Mismatches in tap diameter, turbulence properties, scale effects, and geometrical details - Full-scale non-stationary effects
Cheung et al., 1997	Monash	1:10	9	22	3 [30]	16.7	Actual peak	- Large test Reynolds no. = 2.5×10^5 - Largest negative peak pressures ~20% less than the field value
Tieleman et al., 1997	Clemson	1:50	N/A	20	N/A	15	Mean and dispersion for 5, 8 or 18 samples	- 2 lateral turbulence intensity levels: <20% and >20% - Increased u-v-w small-scale turbulence
Ham et al., 1998	CSU	1:50	10.6	19.5	4 [200]	15	Mean of 10 samples	- A relatively high frequency response pressure system
Current study	HKUST	1:50	10.5	23	3.4 [200]	20	Mean of 10 samples and actual peak	- A relatively high frequency response pressure system

5. References

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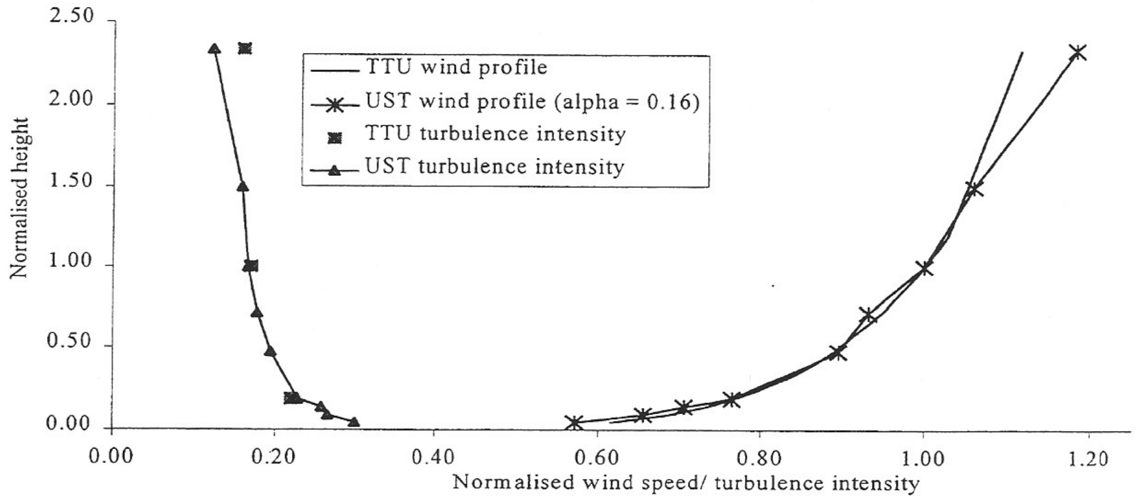

Figure 1 Mean wind speed and longitudinal turbulence intensity profiles

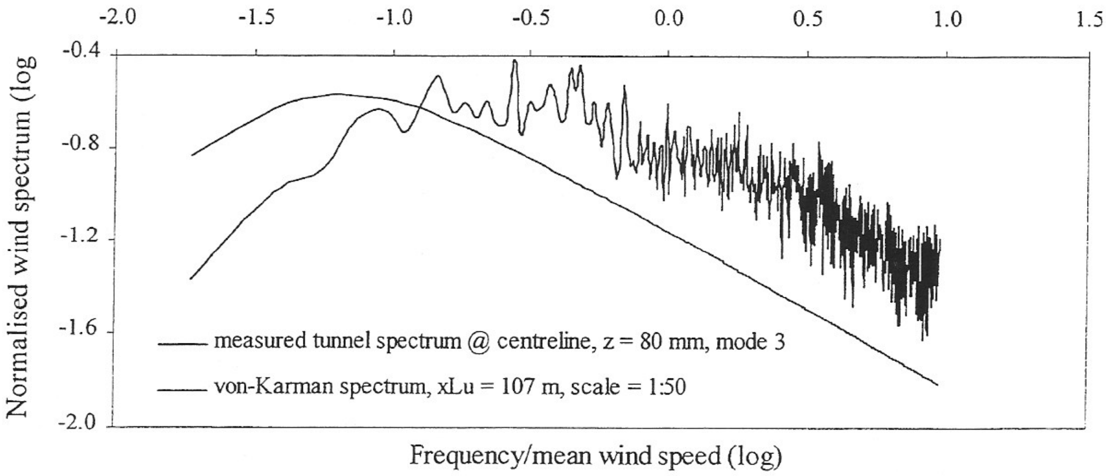

Figure 2 Longitudinal turbulence spectra

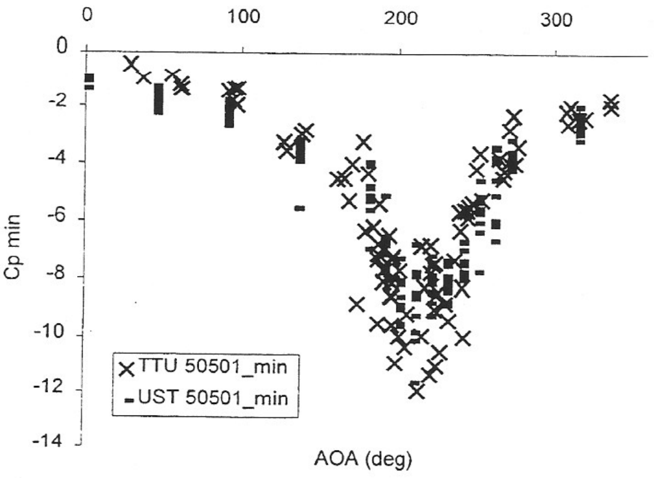

Figure 3 Tap 50501, $C_{p\,min}$

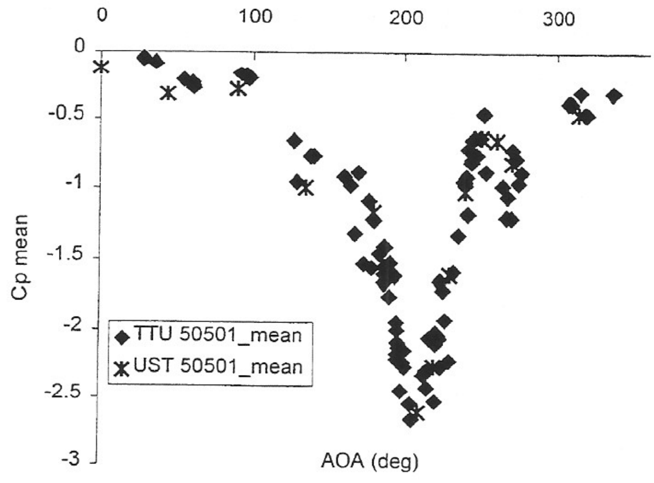

Figure 4 Tap 50501, $C_{p\,mean}$

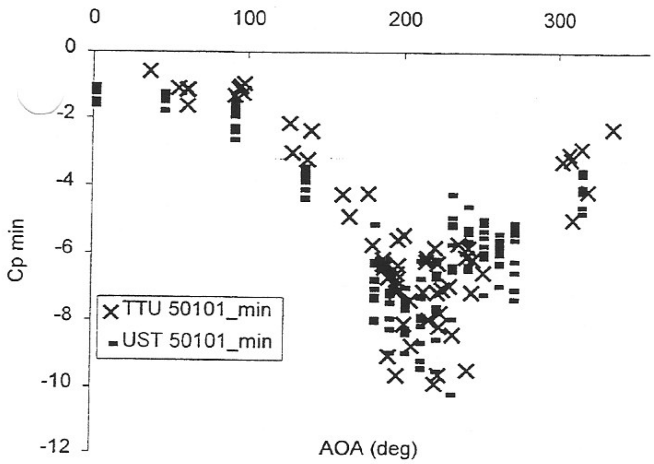

Figure 5 Tap 50101, $C_{p\,min}$

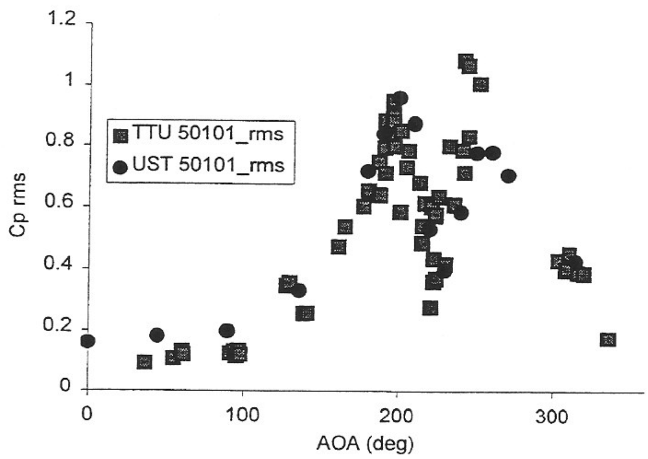

Figure 6 Tap 50101, $C_{p\,standard\ deviation}$

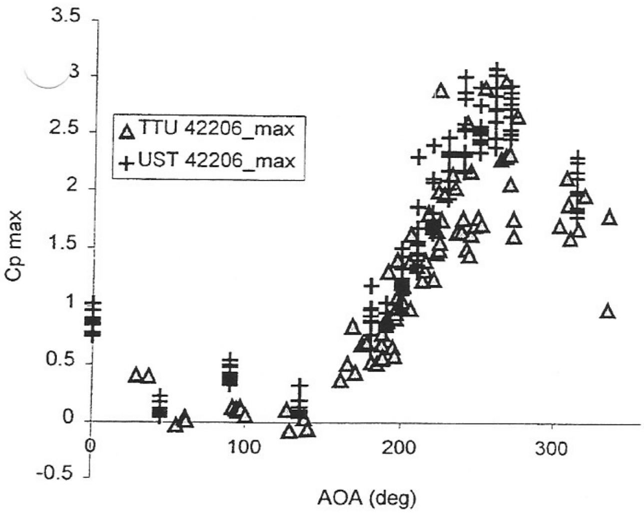

Figure 7 Tap 42206, $C_{p\,max}$

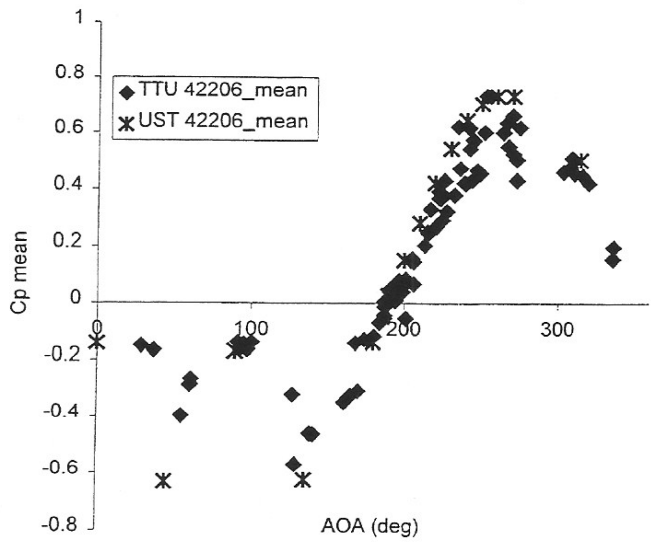

Figure 8 Tap 42206, $C_{p\,mean}$