Wind Loads on Coarse Ore Stockpile Covers

Blake S. Peoples

INTRODUCTION

Coarse ore stockpile covers are a relatively new innovation used mainly at bulk storage terminals and ports. Due to the conical shapes of the structures, there is currently no data available to engineers for design. In order to obtain this data, boundary layer wind tunnel model testing is required. A previously built ore cover was used as the basis for the model testing, and various configurations of ore within the structure were tested to determine the effect that the amount of ore has on the pressure distribution of the structure.

The aim of this thesis was to provide a set of pressure coefficients which will demonstrate the effect of wind loads on a segmented conical-shaped ore cover. The net wind pressure distribution was found to enable the design of structural systems and cladding for the structure. Recommendations were made to AS/NZS1170.2 (2012) with regards to the values of pressure coefficients used in the design of similar structures. This study also attempted to provide a basis for similar future studies and help provide information for wind load standard updates.

There were a number of topics which had to be investigated and understood before testing could begin. These included: The Atmospheric Boundary Layer, Determination of Design Wind Loads, Wind Flow around Structures, Drag Forces on Basic Shapes and Modelling Requirements. A review of similar previous studies was also undertaken. Some of these studies included those by Natalini et al. (2013) and Letchford and Ginger (1992), who examined mean loads on vaulted canopy roofs and fluctuating pressures on planar canopy roofs, respectively.

METHODOLOGY

The ore cover being studied consists of a conically shaped roof which is supported on 14 metre high columns and is comprise of 24 equal segments supported by ring beams. A 3.188m diameter hole is located at the apex of the structure through which the ore is deposited. The overall structure has a peak roof height of 32m. The basic dimension of the structure can be seen in Figure 1.

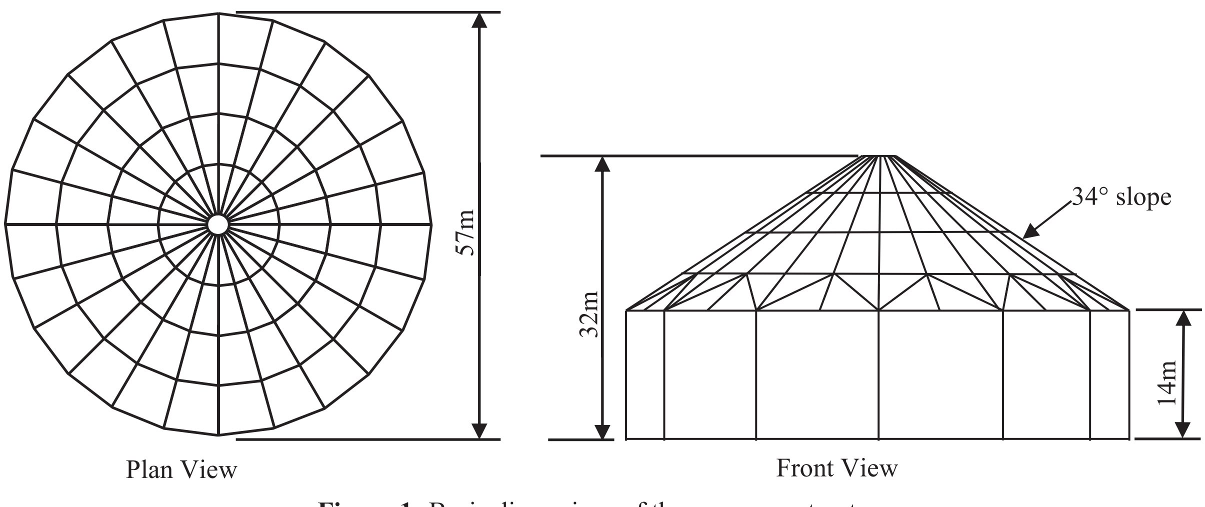


Figure 1: Basic dimensions of the ore cover structure

A wind tunnel study of this model was conducted in the 2 x 2.5 x 22 m Boundary Layer Wind Tunnel at the School of Engineering and Physical Sciences, James Cook University.

Atmospheric Boundary Layer Simulation
An approach terrain representative of terrain category 2 for a length scale L_r = 1:100 was simulated using carpet and 40mm cubic blocks as floor linings in the wind tunnel. The mean velocity and turbulence intensity profiles of this approach flow and the corresponding AS/NZS1170.2 (2012) profiles for Terrain Category 2 are shown in Figures 2 and 3, respectively.

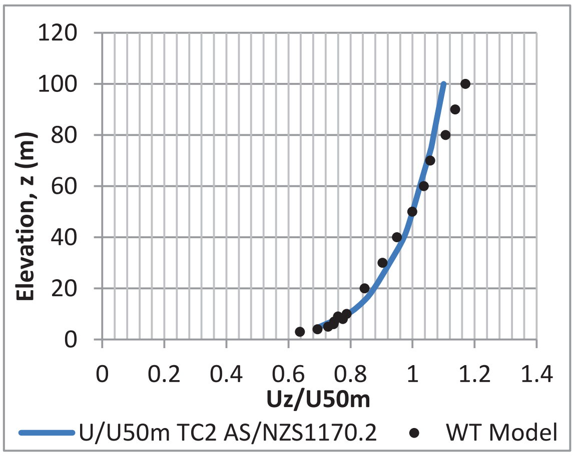


Figure 2: Mean Velocity Profile for TC2

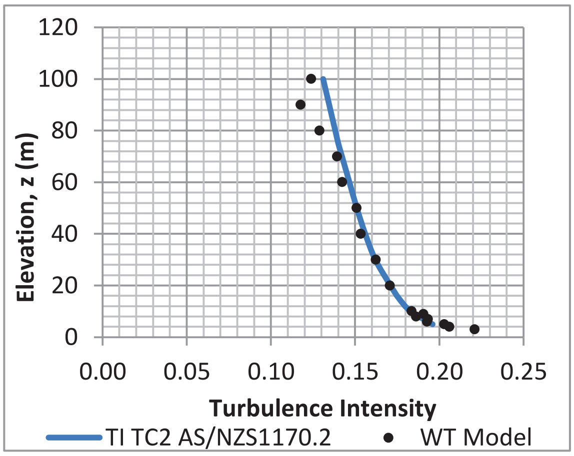
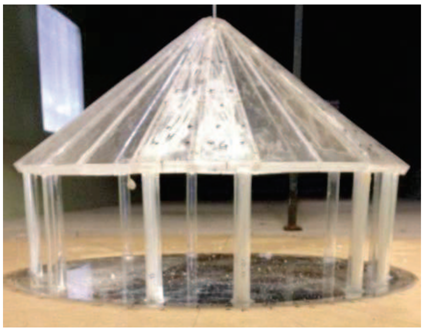


Figure 3: Turbulence Intensity Profile for TC2

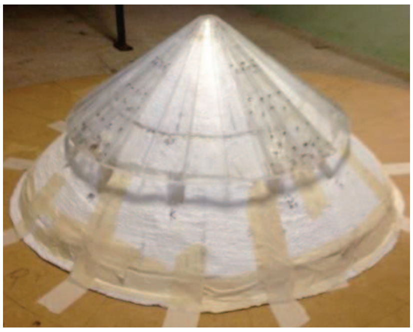
Ore Cover Model
A model of the structure was constructed from Perspex at a scale of 1:100 as shown in Figure 3.5. Pressure taps were installed in eight segments on the external and internal surfaces as detailed in Appendix A. External and internal pressures are measured on 6 panels (60 taps) simultaneously. These taps are used obtain the external, internal and net (i.e. external – internal) pressures on the ore cover and to determine the load effects on the beams, rafters and connections. The pressure tapped segments were rotated with respect to the approach wind direction (θ) so that the pressure distribution (external and internal) on the whole surface was obtained.

Tests were carried out for 3 ore configurations as shown in Figures 4a, 4b and 4c:
1) Empty
2) 50% of capacity
3) 100% of capacity



a) Case 1: Empty

b) Case 2: 50% Capacity



c) Case 3: 100% Capacity

Figure 4: Various ore configurations used for testing.

RESULTS AND DISCUSSION
The mean, maximum and minimum C_p's on the external and internal surface of the ore cover structure for the 3 ore configurations trialled are presented here. In addition, the mean net C_p are also presented and the overall lift and drag coefficients are obtained. Due to faulty pressure taps several of the nodes on the pressure distribution layouts are missing values, however as the structure is symmetrical these

values can be estimated from surrounding taps and the opposite side if required. The pressure coefficient distributions were all presented as shown in Figure 4.

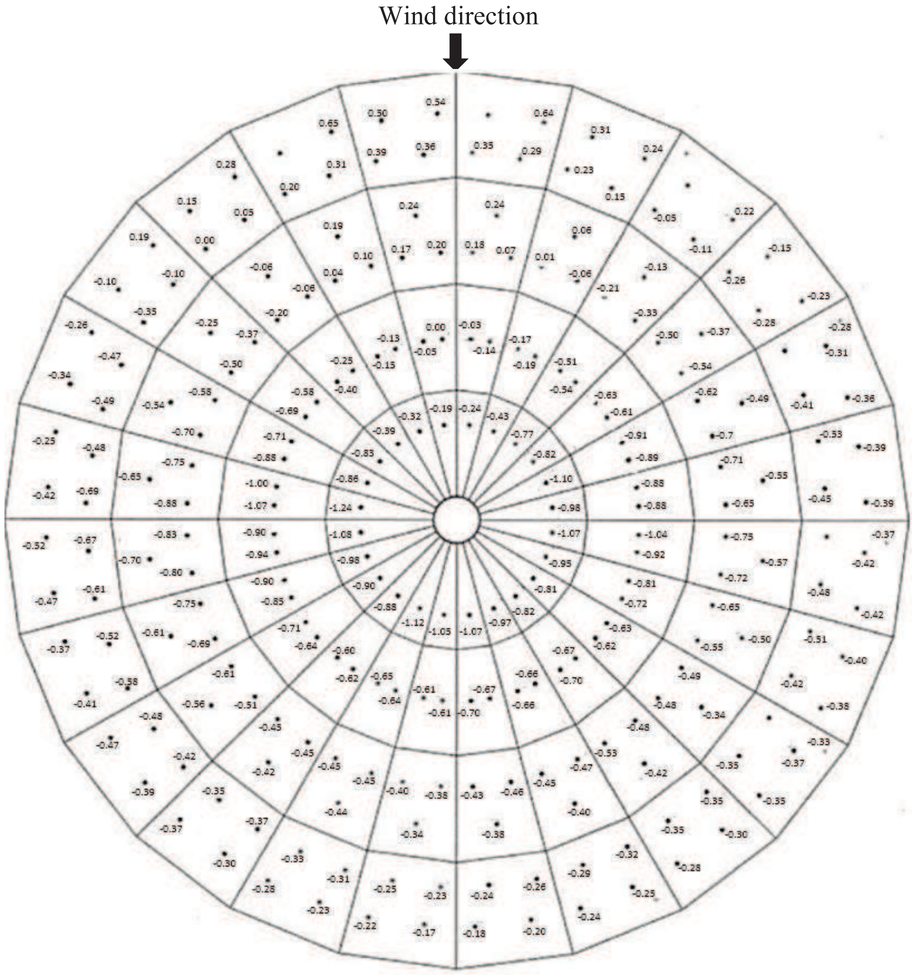


Figure 5: Case 1- Mean External Pressure Coefficient Distribution

As the ore increased, it was found that:

- Externally, positive pressures on the windward edge decreased and negative pressures on the leeward edge increased.
- Internally, pressure on the windward edge increased, and a positive to negative pressure change on the leeward edge occurred.
- No major changes to pressures occurred around the side edges of the structure for both external and internal.

From the pressure coefficients, the overall lift and drag coefficients for the entire structure were determined, as shown in Table 1. The coefficients follow the same sign convention external and internal pressure coefficients, as indicated in Figure 6.

Table 1: Mean Lift and Drag coefficient values for the overall structure

	External		Internal		Net	
Case	Lift	Drag	Lift	Drag	Lift	Drag
1	-0.381	0.176	-0.125	-0.133	-0.256	0.309
2	-0.431	0.156	-0.071	-0.106	-0.360	0.262
3	-0.460	0.118	-0.138	-0.101	-0.322	0.219

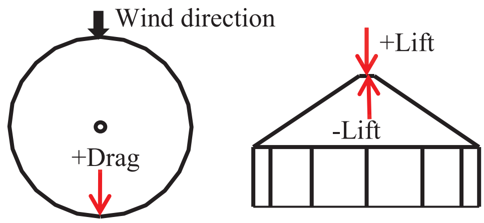


Figure 6: Sign convention for lift and drag

From the lift and drag coefficients calculated, the following was found:

- Largest net drag was produced by Case 1 (0.309)
- Largest net lift was produced by Case 2 (-0.360).
- When compared to other similar shapes and structures in AS/NZS1170.2 (2012) such as silo roofs (-0.5 to -0.8), the values obtained were generally smaller.

CONCLUSIONS

A review of the wind load standard AS/NZS1170.2 (2012) found that there is no design data for structures of this shape. Therefore the following recommendations have been made:

Design data for the lift and drag for structures of this type should be included in the standard. This could include overall lift and drag coefficients for the entire structure, as well as zone-specific averaged coefficients for external and internal C_p distributions. Recommended values for these in each case are shown in Figures 7a – c below.

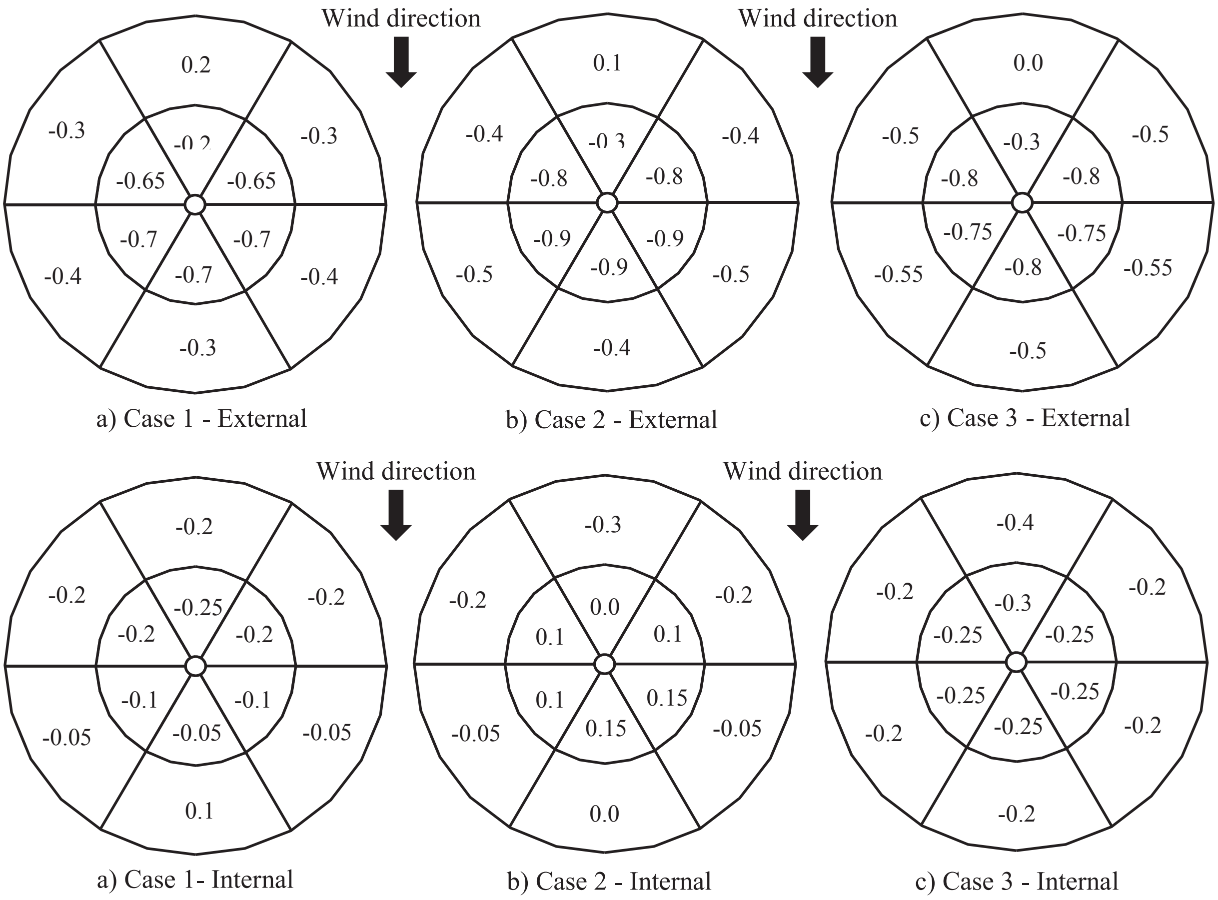


Figure 7: Recommended pressure coefficient values

REFERENCES

Letchford, C. W. and Ginger, J.D. (1992). Wind loads on planar canopy roofs — Part 1: Mean pressure distributions. *Journal of Wind Engineering and Industrial Aerodynamics,* ***45*****(1)**, 25-45.

Natalini, M.B, Morel, C., and Natalini, B. (2013), Mean loads on vaulted canopy roofs. *Journal of Wind Engineering and Industrial Aerodynamics,* **119**, 102-113.

Standards Australia. (2012). AS/NZS1170.2 *Structural design actions - Wind actions*. Sydney, NSW 2001: Standards Australia International Ltd.