POINT PRESSURE MEASUREMENTS ON MODEL CIRCULAR STORAGE BINS, SILOS AND TANKS

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Introduction

A number of failures of cylindrical structures, such as bins, silos and tanks, has highlighted the limited data, and lack of understanding on the wind loading of these structures (1). In terms of design, the Australian wind loading code AS1170 part 2 - 1983 provides no indication of the expected internal or external wind pressure distribution on such structures.

Recently a program of wind tunnel model tests was initiated to determine the wind loads on circular storage bins, silos and tanks. This paper reports results of point pressure measurements obtained in the first phase of the test program.

Experimental Set Up

(i) Wind tunnel Modelling

Results of the turbulent boundary layer simulation in the 7' x 5' Low Speed Aeronautical Wind Tunnel have been reported by Kwok and Macdonald (2) in this workshop. The boundary layer simulation was found to adequately represent a 1/100 scale model of flow over a category 2 open country terrain.

The silo model was made of perspex and constructed in tight-fitting segments. Nine different model configurations were tested which included models of three different aspect ratios (H/D = 0.5/1, 1/1, 2/1) each being tested with three roof configurations (no roof, flat roof and 25° pitch conical roof).

Test Reynolds numbers of between 2.5×10^5 and 3.4×10^5 were achieved. These exceeded the limiting value of 2×10^5 (with a turbulence intensity of greater than 4%) suggested by Cheung and Melbourne (3) for modelling of full scale configurations with circular features.

(ii) Pressure Measurements

One of the perspex segments was fitted with 50 pressure tappings spaced at 7.2° centres around the circumference. This segment was positioned to take pressure measuements at various heights on the model. The 25° pitched conical roof contained rows of 5 pressure tappings spaced at 36° centre.

A single Honeywell 163 pressure transducer was connected to the pressure tappings via a 48 port Scanivalve and 400 mm of PVC tubing. The tubing's pressure transmission response was damped by a single small bore restrictor achieving a flat frequency response up to approximately 130 Hz. The signal output from the transducer was low-pass filtered at 200 Hz before being digitized.

A microcomputer was used to digitally sample at a rate of 1000 Hz for 10 seconds, from which the mean, standard deviation, maximum and minimum coefficient of pressure were obtained and referenced to the dynamic wind pressure at

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silo wall height. Measurements were repeated four times for each tapping and the average calculated. For open topped silo models, internal pressures were also measured.

Results and comments

Figures 1 - 3 present the variation of mean pressure coefficient with the angle θ from the stagnation line, for the three different aspect ratios and the roof configurations. The pressure distributions over the 25° pitch conical roof are also presented, in the form of mean pressure coefficient contours.

Significant trends observed in the results include:-

1) The maximum positive pressure decreases as aspect ratio increases (1.0 to 0.8).
2) The maximum negative pressure increases as aspect ratio increases (-1.0 to -1.7).
3) The windward region of positive pressure extends to between 30° and 40° from the stagnation line, marginally decreasing as aspect ratio increases.
4) When the negative internal pressure of the open topped silo is considered the region of windward positive pressure increases to between 50° and 60°.
5) Flow separation occurs at approximately 130° after which $\bar{C}p$ remain relatively constant.

Pressure measurements taken on the 25° pitch conical roof showed a largely symmetrical pressure distribution. Relatively high negative pressures were recorded near the leading edge, believed to be caused by reattachement of the separated shear layers. High negative pressures were also recorded near the centre of the roof.

Peak maximum and minimum, and standard deviation pressure coefficients were recorded at each pressure tapping. Figure 4 is a typical graph for a flat roof silo with an aspect ratio 2:1. The graph shows the large variation in wind pressure at any one point and hence the need for a measurement program to determine the critical structural loading, in particular the critical buckling load.

In general there were good agreements with results by Sabransky (4) and others. Minor differences, such as the maximum negative pressure occurring at approximately 80°, rather than 90° and separation occurring at 140°, may be attributed to the different wind tunnel and the lower Reynolds Number used by Sabransky (4).

Conclusion

Results from the experimental program allowed the assessment of the wind tunnel simulation and other experimental technique to be made.

Results of $\bar{C}p$ showed a good agreement with previous work and extended data to include the dependence of the mean wind pressure distribution on aspect ratio and roof configuration. A family of curves to define $\bar{C}p$ as a function of aspect ratio, roof configuration and θ is being considered for inclusion in AS 1170 for general design purposes.

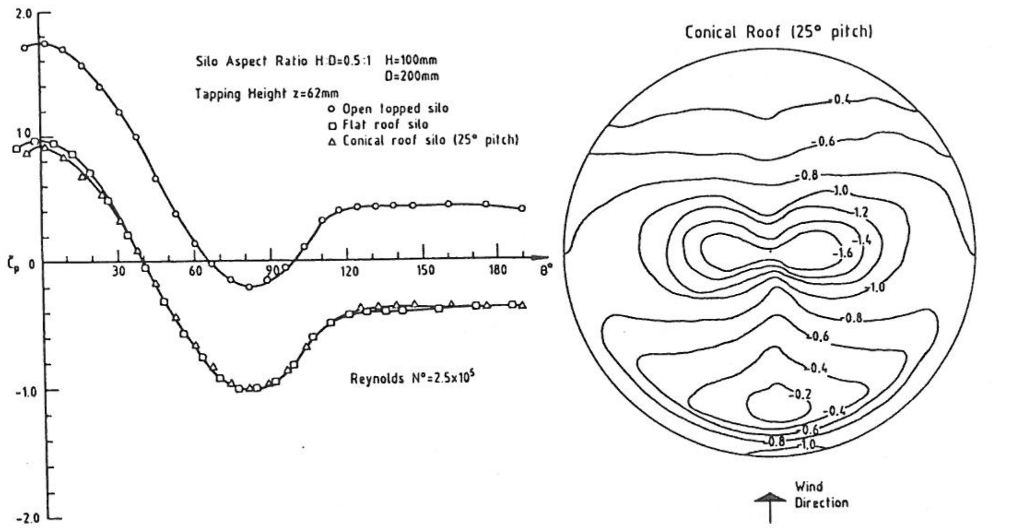

Fig. 1 - Mean Pressure Distributoons (h:d=0.5:1)

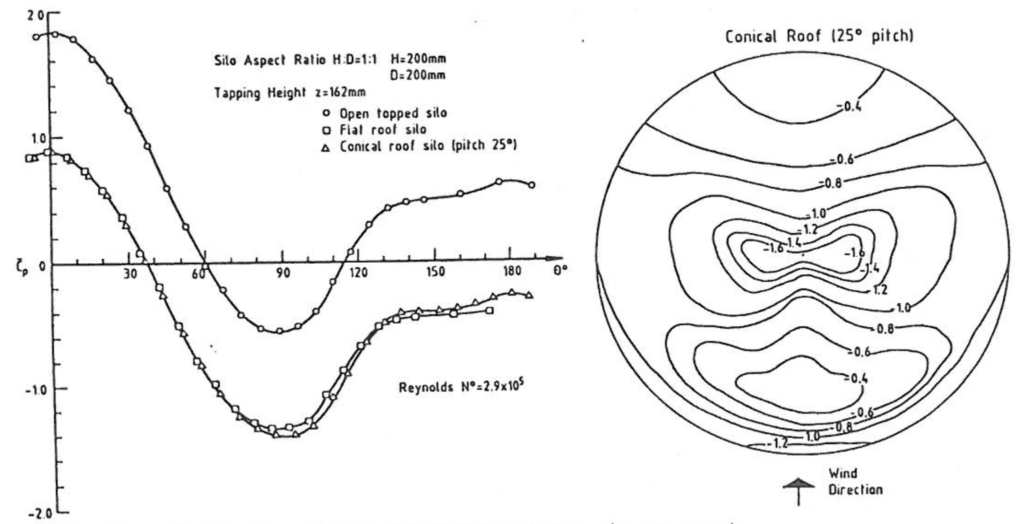

Fig. 2 - Mean Pressure Distributions (h:d=1:1)

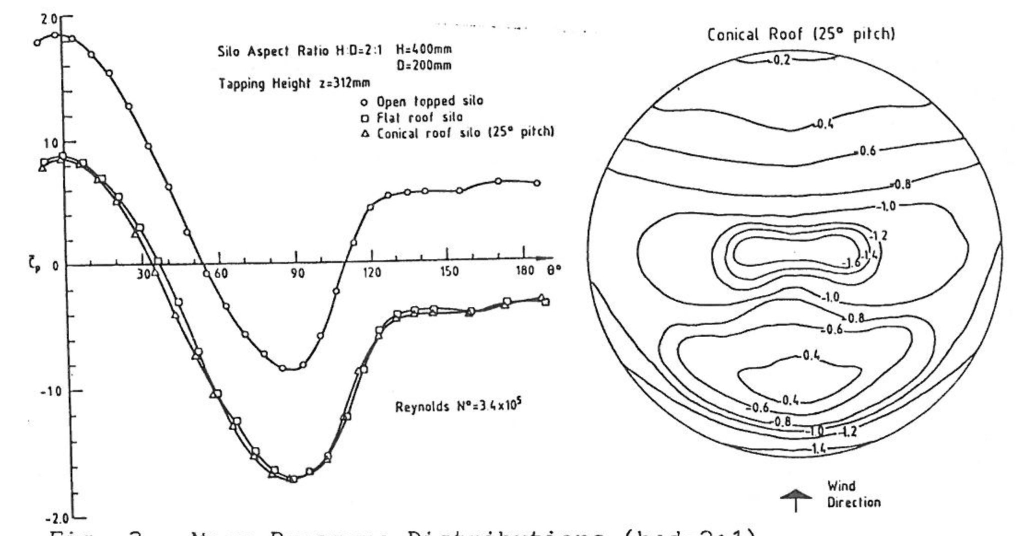

Fig. 3 - Mean Pressure Distributions (h:d=2:1)

References

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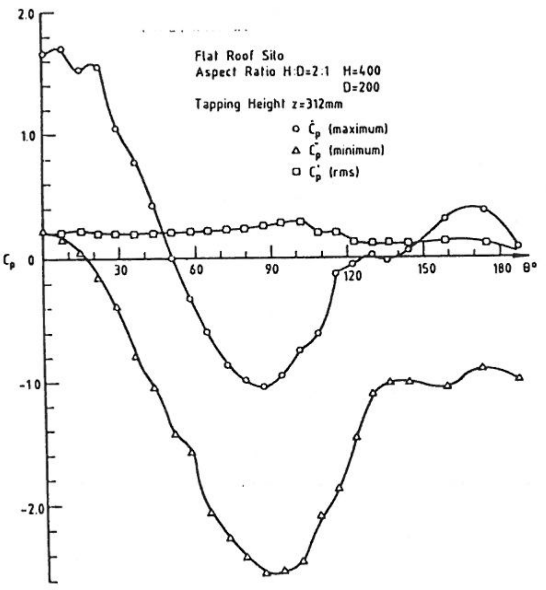

Fig. 4 - Maximum, minimum and standard deviation pressure coefficients (h:d=2:1)