MEASURES TO REDUCE WIND LOADING AT THE LEADING ENDS OF FREE STANDING WALLS

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1. INTRODUCTION

Wind load studies on free standing walls in turbulent boundary layers by Letchford[1] and Holmes[2] and combined publication in Letchford & Holmes[3] found significantly increased wind loads on panels adjacent to free ends of such walls. These loads have now been codified for design in [4] & [5]. Apparant doubt over the magnitude, and confusion over the application, [6] of these much increased wind loads amongst other matters, including height effects, has led to a study at Silsoe to monitor full scale wind loads on walls [7]. This paper aims to compare some full scale and wind tunnel measurements of wall wind loads in the vicinity of free ends and report on measures to reduce these high loads.

2. EXPERIMENT

As is quite often the case the full scale measurements and the earlier model scale tests had limited overlapping configurations of panels size and location within walls of different aspect ratio(length/height, L/h) and wind direction (alpha). To overcome this deficiency additional wind tunnel tests were conducted in the Oxford University Low Speed Wind Tunnel, using the same simulation and model as in the earlier study [1]. The tunnel is 4m wide and 2m high and has approximately 14m for boundary layer development. The simulation employed here was nominally a 1:75 scale rural/suburban flow with z_o = 0.1m. Mean wind speed and turbulence intensity at wall height level were approximately 5m/s and 20% respectively.

The wind tunnel model wall employed here and in the earlier study [1], was 67mm high and 7mm thick and had 15 tappings, in three rows of five, pneumatically averaged over the front and back faces and analogued differenced to give net pressure or force. Coefficients(C_f) were obtained by dividing by the mean dynamic pressure at wall height. Blockage corrections identical to [3] have been employed. The area averaged panel had a width to height ratio of b/h = 1, and wind direction is defined as 0° normal to the wall.

The full scale arrangement is described in [7] and data presented here is mean net pressure or force coefficients over the same panel dimensions (b/h = 1). The approach flow is across open grassland with z_o and turbulence levels similar to the wind tunnel study.

3. RESULTS & DISCUSSION

Figure 1 compares the mean force coefficient (C_f) on the leading or end panel for the earlier studies [1,2], the present wind tunnel study and the full scale tests at Silsoe[7] for the case of wind approaching from 45°. The wall aspect ratio (L/h) ranges from 1 to ~45. The agreement across space and time is excellent for all experiments and it would seem the question raised in [7] concerning whether the leading wall panel load continues to increase with aspect ratio is answered with a limit, $C_f \sim 3$, being reached in the vicinity of the longest wall measured at full scale L/h = 13. Figure 2 shows the results for the same panel for wind normal to the wall. This time the full scale results are somewhat less than the three independent wind tunnel tests, particularly over wall aspect ratios 3 to 10. No satisfactory explanation has yet been advanced for this discrepancy.

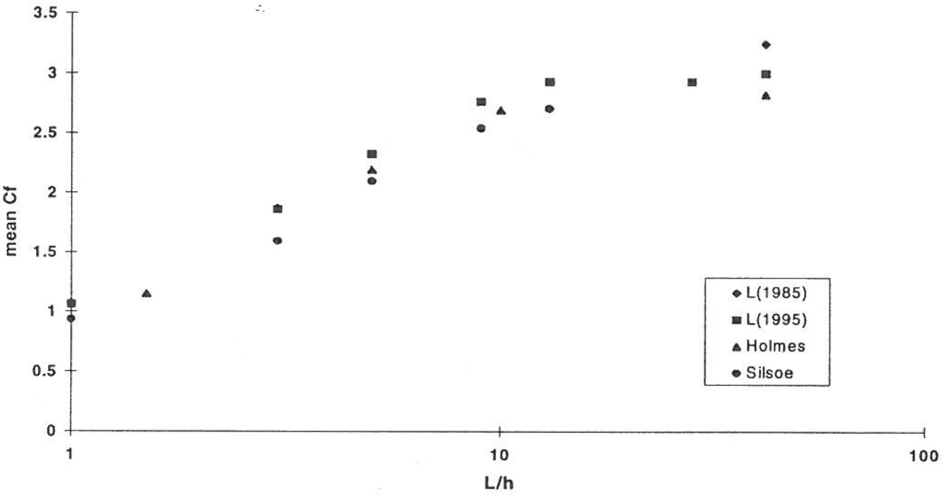

Figure 1. Comparison of end panel mean force coefficients from various sources for wind direction of 45°.

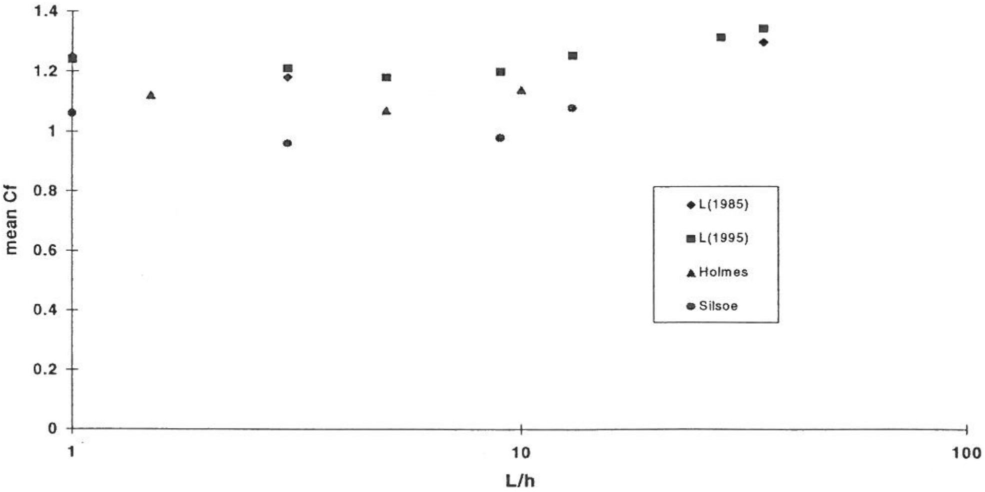

Figure 2. Comparison of end panel mean force coefficients from various sources for wind direction of 0°.

Figure 3 shows results from the present wind tunnel study to determine the wind direction producing the worst loading on the leading panel. Typically up to L/h=9, 45° leads to the worst loading. However, as the wall gets longer, the worst loading is produced by a smaller angle of attack ~ 35° to 40°. The full scale results[7] show identical trends.

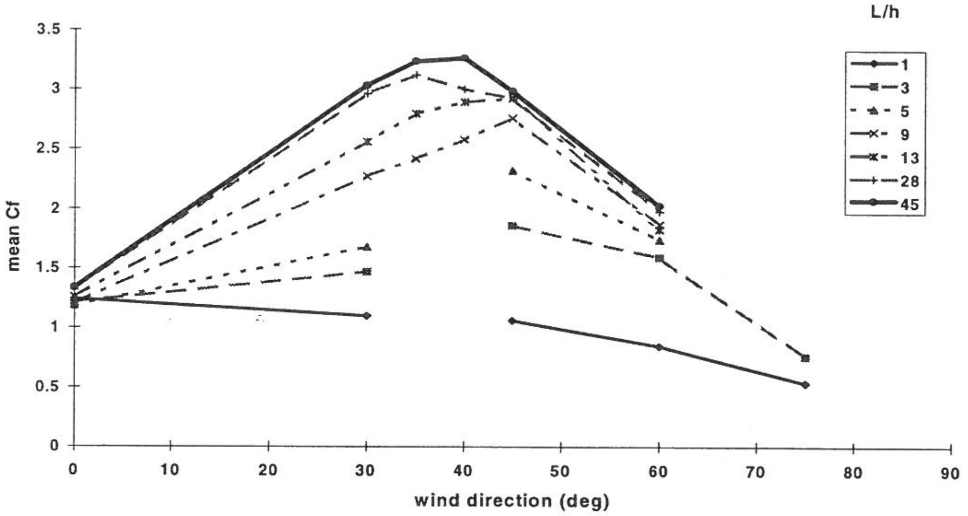

Figure 3. Mean end panel force coefficients as a function of wind direction and aspect ratio (L/h).

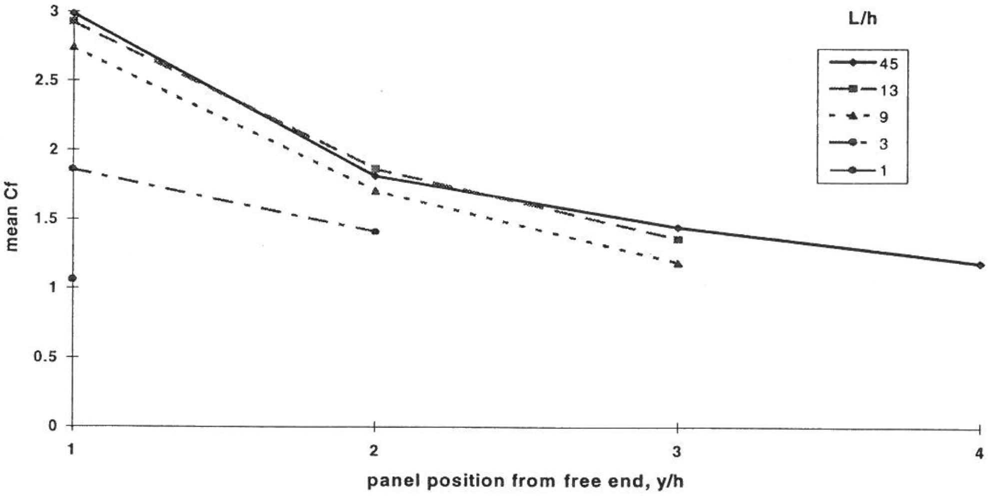

Figure 4. Mean force coefficient for wall panel (b/h = 1) as a function of proximity to free end for wind direction of 45° and for various wall aspect ratios.

Figure 4 shows the results from the present wind tunnel study for the reduction in wind loading as the sensing panel is moved away from the free end. After about three panels from the free end, irrespective of wall aspect ratio, the wind loading is reduced to that of a panel within a very long wall for a wind normal to the wall - ie., the minimum design load case.

In Table 1, the effect on the end panel load due to a short return wall set perpendicular to a semi-infinite wall for two wind directions is shown. Once again the sensing panel has a b/h = 1, which makes direct comparison with codes [5] difficult. However, it is seen that return lengths of less than 0.5h do not significantly reduce the load on the leading panel as suggected in [5].

wind direction return length (R/h)	30°	45°
0	3.07	2.98
.5	2.75	2.67
1	2.33	2.12
2	1.92	1.63

Table 1. Mean force coefficients on the end panel of a semi-infinite wall (L/h = 45) as a function of perpendicular return wall length.

In the present study the effect of different end wall configurations on a semi-infinite wall (L/h = 45) were examined for a wind direction of 45°. For a solid first panel the force coefficient on the second panel, as shown in Figure 4, is 1.81. If the first panel is replaced by a panel of 75% solidity (100% represents a solid wall), the C_f increases to 2.20, while if the first panel is replaced by panel of only half height the C_f is further increased to 2.34. Finally if the first panel is displaced to leave a gap in the wall of half-height , the load on the adjacent or 'second' panel is 2.51. These forms of end treatment have been proposed to alleviate the wind load at the free end of a wall and it is seen from these studies that most are ineffective except perhaps for a return wall greater than 1h in length.

Surface oil flow visualization has shown the presence of a very strong vortex centered about .3h downstream of the leading edge and .3h away from the wall for a semi-infinite wall at 45°. On the ground plane this vortex is fed from the flow around the end of the wall and smoke flow visualization shows that the vortex core bends in the vertical plane to be fed from the shear layer separating from the top of the wall. It is seen that different end treatments, eg., venting with gaps and porous panels, has only limited effect on this vortex and thoughts of similarities with venting separation bubbles to reduce loads are quite erroneous.

4. REFERENCES

1. C.W. Letchford, Wind loads on free standing walls, OUEL Report 1599/85, Department of Engineering Science, Oxford University, Oxford, 1985.
2. J.D. Holmes, Wind loading on free standing walls, Internal report 85/13, CSIRO Division of Building Research, Melbourne, 1985.
3. C.W. Letchford & J.D. Holmes, Wind loads on free-standing walls in turbulent boundary layers, JWEIA 51, 1-27, 1994.
4. Standards Association of Australia, SAA Loading code: Part 2: Wind Loads, AS1170.2, Asutralian Standards, North Sydney, NSW, 1989.
5. British Standards Institution, BS6399: Loading for buildings: Part 2: Code of practice for wind loading, BSI, London, 1995.
6. A.P Robertson, R.P. Hoxey and P.J. Richards, Design code, full-scale and numerical data for wind loads on free standing walls, JWEIA 57, 203-214, 1995.
7. A.P. Robertson, R.P. Hoxey, J.L. Short, W.A. Ferguson & S. Osmond, Wind loads on boundary walls: full-scale studies, abstract accepted for BBAAIII, 1996.