FROM A CIRCULAR STRUCTURE TO CONSULTING SERVICES IN WIND ENGINEERING

John C. K. Cheung
Department of Mechanical Engineering, Monash University
Clayton 3168, AUSTRALIA

Abstract

This paper outlines the author's work, supervised by Professor Melbourne at Monash University, from the PhD study [1] of wind effects on a circular structure to the broader aspects of consulting services in Wind Engineering. Despite of many previous findings of the effect of turbulence on the aerodynamics and response of a circular structure in wind flow, it emphasizes the lack of data on blockage and Reynolds number effects for either rough or three-dimensional circular cylinders. It then leads onto the consulting services and highlights some results from different aspects of commercial wind tunnel testing. Finally, an example is illustrated by a recent wind tunnel study of wind break fence/planting near reservoirs to produce vorticity generator effect to promote mixing in the water to prevent algal growth.

1.INTRODUCTION

Being one of Professor Melbourne's ex-PhD students, the author studied the effect of turbulence on the aerodynamic characteristics and vortex-induced response of a circular cylinder with particular reference to enabling wind tunnel experimental data, together with full scale measurements, to be used as input parameters in the prediction theory for the response of circular structures in atmospheric wind flows. During the course of study, very significant increase in fluctuating lift force was measured with an increase in surface roughness of the circular cylinder. After the PhD study, wind tunnel tests have been conducted under Professor Melbourne's supervision for over 250 consulting projects. The objective of this paper is to highlight some results of these wind tunnel testings.

2.CIRCULAR STRUCTURE RESEARCH

While the increase of wind tunnel blockage or turbulence intensity level was shown to have an effect of increasing the Reynolds number in the flow, the surface of the cylinders can also be roughened to develop separated regions and pressure distributions corresponding to a higher equivalent Reynolds number on a smooth cylinder. However, this simulation of high Reynolds number transcritical behaviour using surface roughness to provoke premature boundary layer transition seems not really exact. Many recent measurements showed that influence due to surface roughness still exists at very large Reynolds numbers.

The experimental arrangements for the present data include nine circular cylinders varying in size from 51 mm to 250 mm diameter and in relative roughness from 2.1×10^{-5} to 2.3×10^{-3} which were tested in the wind tunnel working sections of 1.5×1 m and 2×1 m. All experimental data were corrected to zero blockage in the wind tunnel.

The fluctuating lift force measurements with the rough cylinders have the same trend as the smooth cylinder, except that the transition in the critical regime appears to occur earlier at a lower Reynolds number. The swinging of the wake is apparent in the presence of turbulence for rough cylinders. For constant turbulence intensity, the increase in fluctuating lift is also observed with increase in roughness. This increase in fluctuating lift becomes more significant at high Reynolds number for the very rough cylinder. In terms of the roughness Reynolds number based on the roughness height, there is a drop in fluctuating lift at low roughness Reynolds number as shown in Figure 1. Data obtained by Szechenyi [2] are also shown for comparison. This increase in fluctuating lift may be caused by localised effects on each roughness element on the surface of the cylinder. Data obtained for the very high roughness Reynolds numbers were measured from the rough cylinders only. Therefore whether there is such an equivalent increase in fluctuating lift for a smooth cylinder in the transcritical flow regime at that high roughness Reynolds number is still not known.

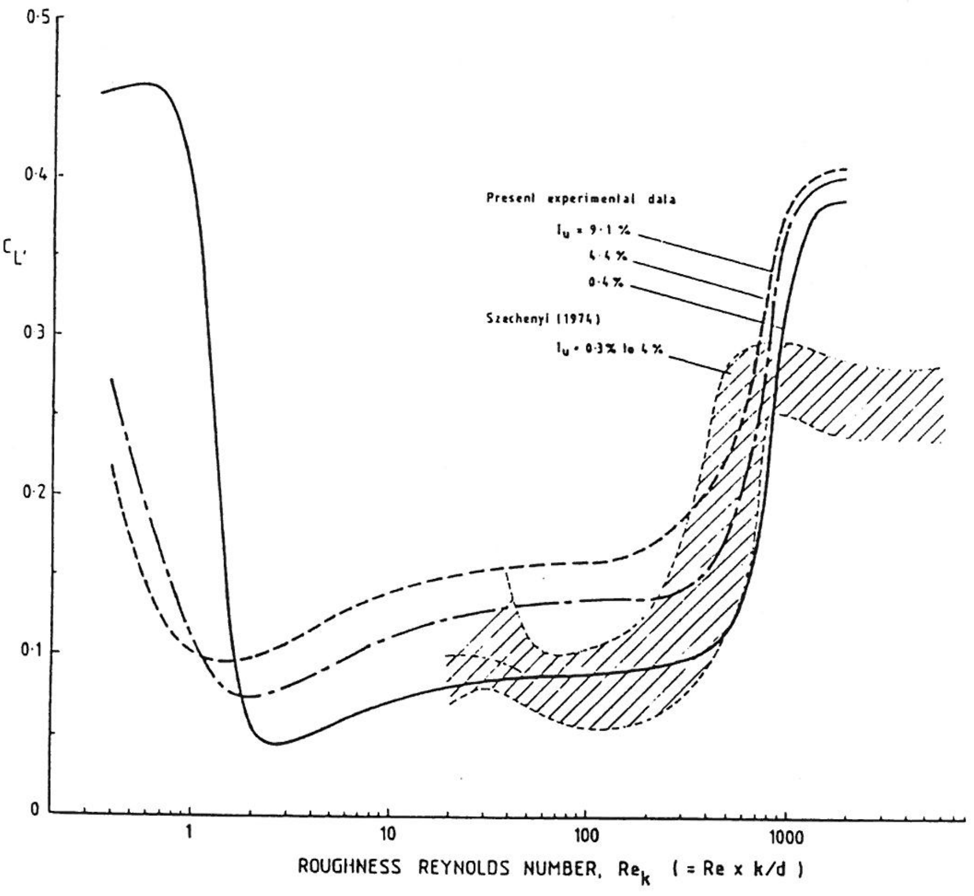

Fig. 1 Fluctuating lift coefficient as a function of roughness Reynolds number for different turbulence intensities.

3. WIND TUNNEL TESTING FOR CONSULTING SERVICES

Wind tunnel tests for wind engineering consulting services can generally be classified into two types. The first is concerned with the determination of wind loading effects by pressure or aeroelastic force measurements. The other is concerned with the flow induced around the structure as for environmental wind speed studies and dispersion studies of exhaust from a chimney stack.

Recent studies have shown that a circular or an aerodynamically circular planform of a tower has considerably reduced the overall response and lowered the range of wind speeds over which the cross-wind response peaks, which further lowered the response at the higher structural design wind speeds. Peak pressure coefficients as low as -1.8 have been measured on a building model without edge discontinuities but with balcony roughness, edge columns and re-entrant corners, as compared with a record high negative pressure coefficient of -8.5 measured on a model building facade near the edge above the colonade. The concentration of an exhaust has been reduced by almost ten times when the stack height is increased from 10 m to 20 m. Also, the wind dynamic pressure or squared wind velocity around the corner at the base of a tall building has been reduced by more than 50% with a combination of wind break fences and corner cut-off.

However, not all consulting projects require a reduction of wind effects. One of our recent wind studies is to specifically require an increase of wind speeds over the reservoirs to promote mixing in the water to prevent algal blooms. To bring the higher velocity air to water level requires the use of vortex generators which create axial vortices to enhance vertical momentum transfer. This technique has been commonly used to prevent boundary layer separation by re-energising the base of the boundary layer and has been described in detail by Schubauer and Spangenberg [3].

A range of flat plate vorticity generators and one of the triangular plow type, varying height, length, angle and arrangement have been used to optimise the increase of surface wind speed in an atmospheric boundary layer of open country terrain roughness. Initial measurements of mean and peak wind speeds, as shown in Figures 2 and 3 respectively, have shown that the trapezoidal type seems to be most effective. Further flow visualisation and measurements to investigate the effect of increasing porosity of the vorticity generators to simulate tree planting are being conducted. These results and conclusions will be discussed during the presentation of this paper.

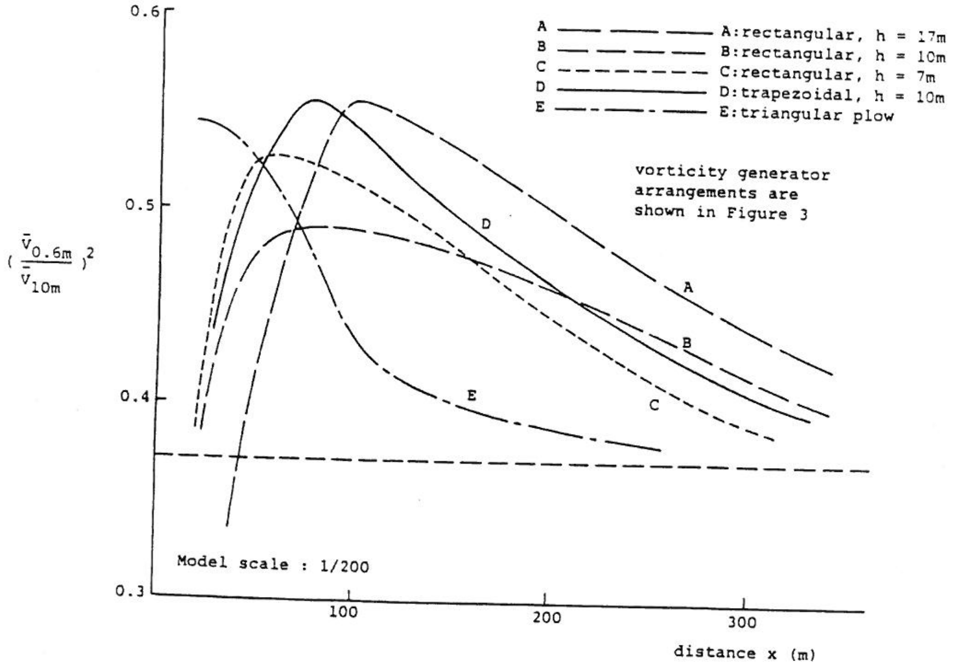

FIG.2 **Mean velocity squared ratio as a function of distance downstream for different type of vorticity generators.**

4.REFERENCE

[1] Cheung, C.K. (1983) "Effect of turbulence on the aerodynamics and response of a circular structure in wind flow", PhD thesis, Monash University.
[2] Szchenyi, E. (1974) "Simulation of high Reynolds numbers on a cylinder in wind tunnel tests", Rech. Aerosp. No. 1974-3, Mai-Juin, pp155-164.
[3] Schubauer, G.B. and Spangenberg, W.G. (1960) "Forced mixing in boundary layers", Journal of Fluid Mechanics, Vol. 8, Part 1, pp.10-31.

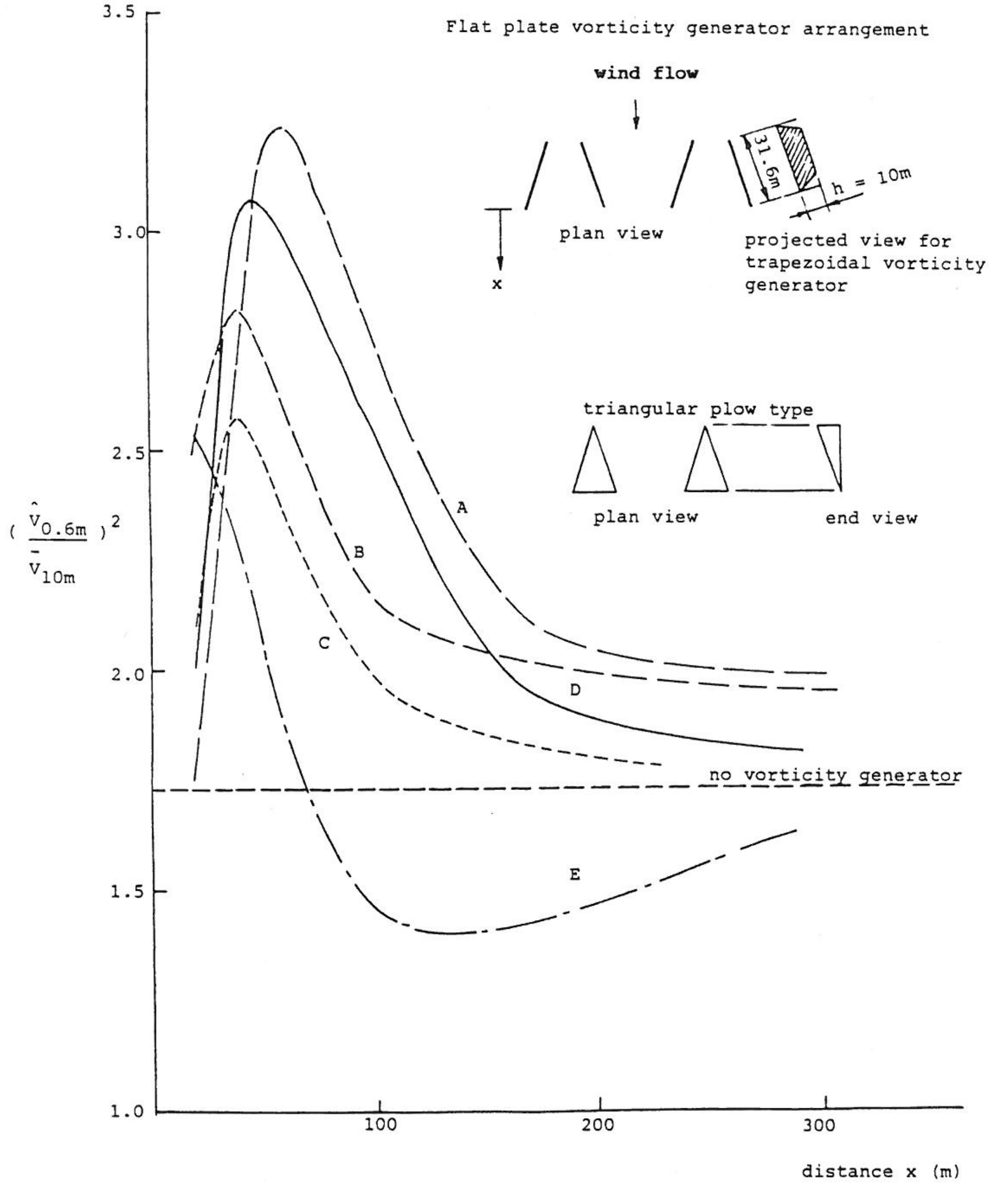

FIG.3 **Peak velocity squared ratio as a function of distance downstream for different type of vorticity generators.**