ATMOSPHERIC BOUNDARY LAYER SIMULATION IN TWO WIND TUNNELS

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Introduction

In the past 12 months, attempts were made to simulate in the Boundary Layer Wind Tunnel (BLWT) and the 7 ft x 5 ft Low Speed Aeronautical Wind Tunnel (Aero WT) suitable 1/100 model of wind flow over category 2 open country terrain. These wind models are used in the study of wind loads on low to medium rise structures such as the Aylesbury house and circular storage bins, silo and tanks. This paper describes the simulation technique used and the turbulent boundary layer flow characteristics, and discusses the limitations of the simulated wind models.

Wind tunnel arrangements

The conventional augmented growth method was used in the BLWT. It consisted of a 0.3 m high fence and carpeted tunnel floor. Hot wire measurements were taken at 15 m downstream of the fence and at 3 lateral positions.

In the Aero WT, 4 triangular spires 0.9 m high and 0.12 m at the base, and carpeted floor were used. Measurements were taken at 2.25 m downstream from the spires and at 3 lateral positions.

Results and comments

Since there are only minor differences between measurements taken at the three lateral positions, only the results obtained at the centre-line of both wind tunnels are presented and discussed here. The mean wind speed profile, longitudinal, lateral and vertical turbulence intensity profiles, normalised Reynolds stress profile, and longitudinal turbulence spectrum in the BLWT are presented in Figure 1, and those in the Aero WT are presented in Figure 2.

In the BLWT, the mean wind speed profile follows closely the logarithmic profile and the power law profile (with an exponent $\alpha = 0.15$) for flow over a category 2 open country terrain, up to a height of 1 m. The logarithmic profile is based on a roughness length z_o of 0.02 m (full scale) as suggested by Melbourne (1981) for a category 2 open country terrain. In the Aero WT, reasonably good agreement with the logarithmic and power law profiles was obtained in the lower part of the boundary layer, up to about 0.3 - 0.4 m.

The turbulence intensity profiles can be compared with the code model (AS 1170, Part 2, 1983), the more accurate Deaves and Harris model (Deaves and Harris, 1978), and values suggested in ESDU 74031. In the BLWT, slightly lower values were recorded in the longitudinal turbulence intensity profile. At a height of 0.1 m (10 m in full scale), the lateral turbulence intensity is about 85% of the longitudinal value, and the vertical turbulence intensity, about 55%. These values are consistent with those suggested in ESDU 74031. In the Aero WT, there is quite a good agreement in the longitudinal turbulence intensity profile up to a height of about 0.3 - 0.4 m. At a height of 0.1 m (10 m in full scale), the lateral turbulence intensity is about 80% of the longitudinal value, and the vertical turbulence intensity, about 65%. It is noted that there is a noticeable peak in the vertical turbulence intensity profile at a height of

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about 0.2 m. This is believed to be introduced by the simulation method used and it may have a significant effect on roof loads for low-rise structures.

In the atmospheric boundary layer, the Reynolds stress or turbulent shear stress normally remains constant with height, or decreases slowly with an increase in height. In the BLWT, the Reynolds stress profile is nearly constant with height up to about 0.6 m. The concentrated Reynolds stress contained in the shear layer originating from the 0.3 m high fence has largely disappeared at 15 m downstream of the fence. In the Aero WT, the Reynolds stress profile exhibits a very prominent peak at a height of about 0.2 m which has a value of approximately twice the value close to the floor. The raised Reynolds stress level is thought to have some influence on the flow separation process, in particular separation and reattachment on roofs.

A geometric length scale ratio can be established by comparing the longitudinal turbulence spectrum with the Harris-Von Karman spectrum. Two length constants, L (10 m) = 800 m (ESDU 74031) and 1500 m (Counihan, 1975), were used in the Harris-Von Karman equation. In the BLWT, a geometric length scale of 1/100 is quite appropriate. The integral length scale at a height of 0.1 m was about 0.55 m or 55 m at 1/100 scale. This corresponds closely to the value of about 70 m suggested in ESDU 74031.

In the Aero WT, there is a significant mismatch in the longitudinal turbulence spectrum (if a 1/100 scale is adopted), by a factor of about 3. It has been suggested (e.g. Surry, 1982) that for the measurement of unsteady loads on low to medium rise structures, relaxation of model scale by a factor of up to 2 to 3 appears justifiable. Nevertheless, it should be noted that there is significantly more high frequency small scale turbulence which, as suggested by Melbourne (1980), may have a significant effect on the rate of shear layer growth and reattachment, and on the local unsteady loads on roofs of low-rise structures. The integral length scale at a height of 0.1 m was about 0.18 m or 18 m at 1/100 scale. This is considerably smaller, by a factor of about 4, than the value of 70 m suggested in ESDU 74031. The turbulence scale in the low frequency range is important in the determination of overall or large-area loads. However, the effect of a distorted length scale is believed not to be significant provided that the integral length scale is as large as and preferably larger than the typical model dimension.

Conclusions

Results of extensive boundary layer measurements in the Boundary Layer Wind Tunnel showed that a 0.3 m fence and 15 m carpeted fetch can be used to generate a satisfactory 1/100 scale wind model of flow over a category 2 open country terrain.

In the 7 ft x 5 ft Low Speed Aeronautical Wind Tunnel, the use of spires and a short 2.25 m carpeted fetch provided satisfactory simulation of the wind speed profile and turbulence intensity profiles. However, the simulation of the Reynolds stress profile and the matching of the turbulence length scales were less satisfactory. Nevertheless, the wind model should be adequate for the measurement of mean and unsteady wind loads on low to medium rise structures such as circular storage bins, silos and tanks.

References

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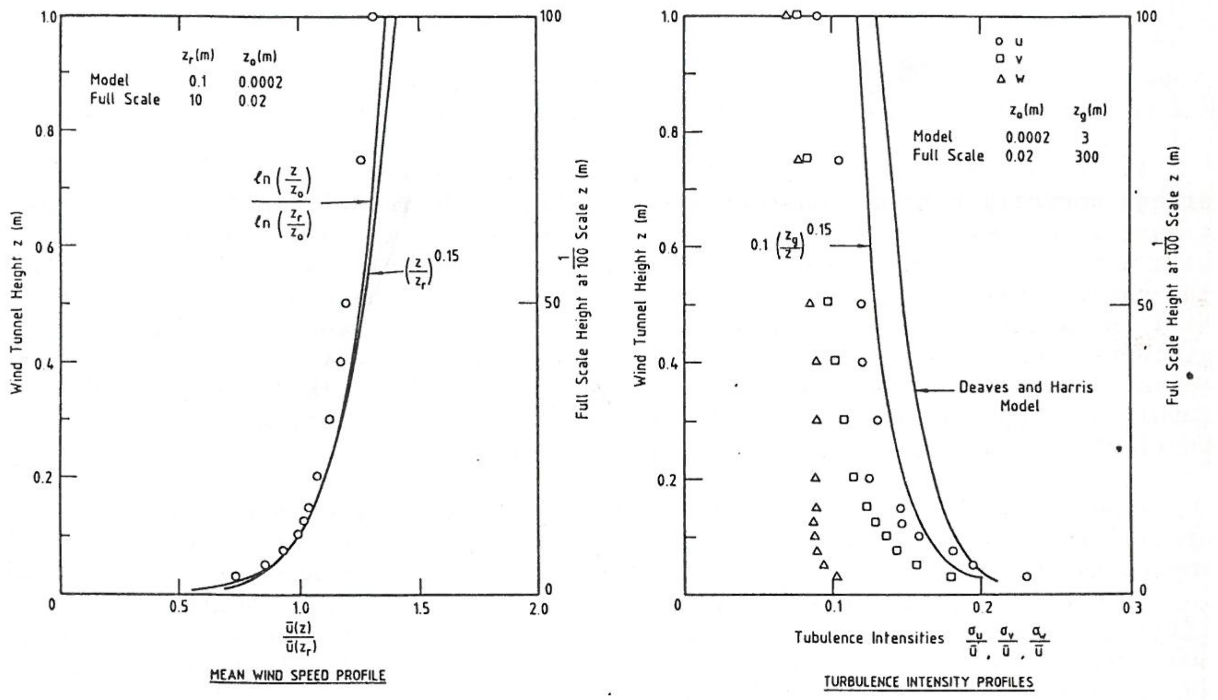
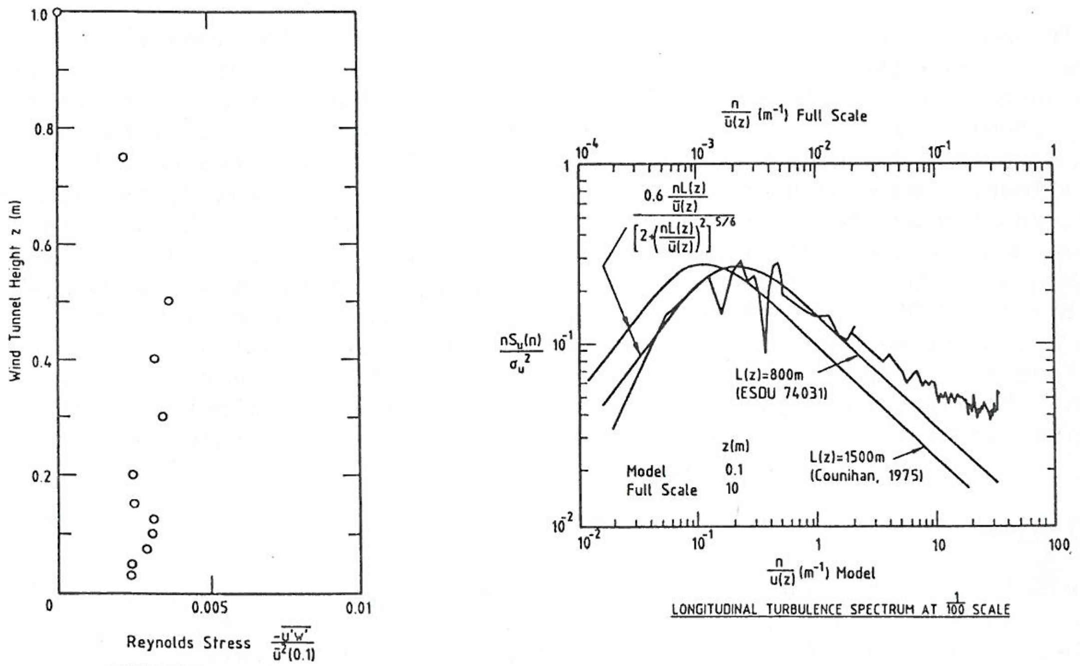


MEAN WIND SPEED PROFILE

TURBULENCE INTENSITY PROFILES



PROFILE OF REYNOLDS STRESS

LONGITUDINAL TURBULENCE SPECTRUM AT $\frac{1}{100}$ SCALE

Fig.1 - Boundary layer flow characteristics, Boundary Layer Wind Tunnel

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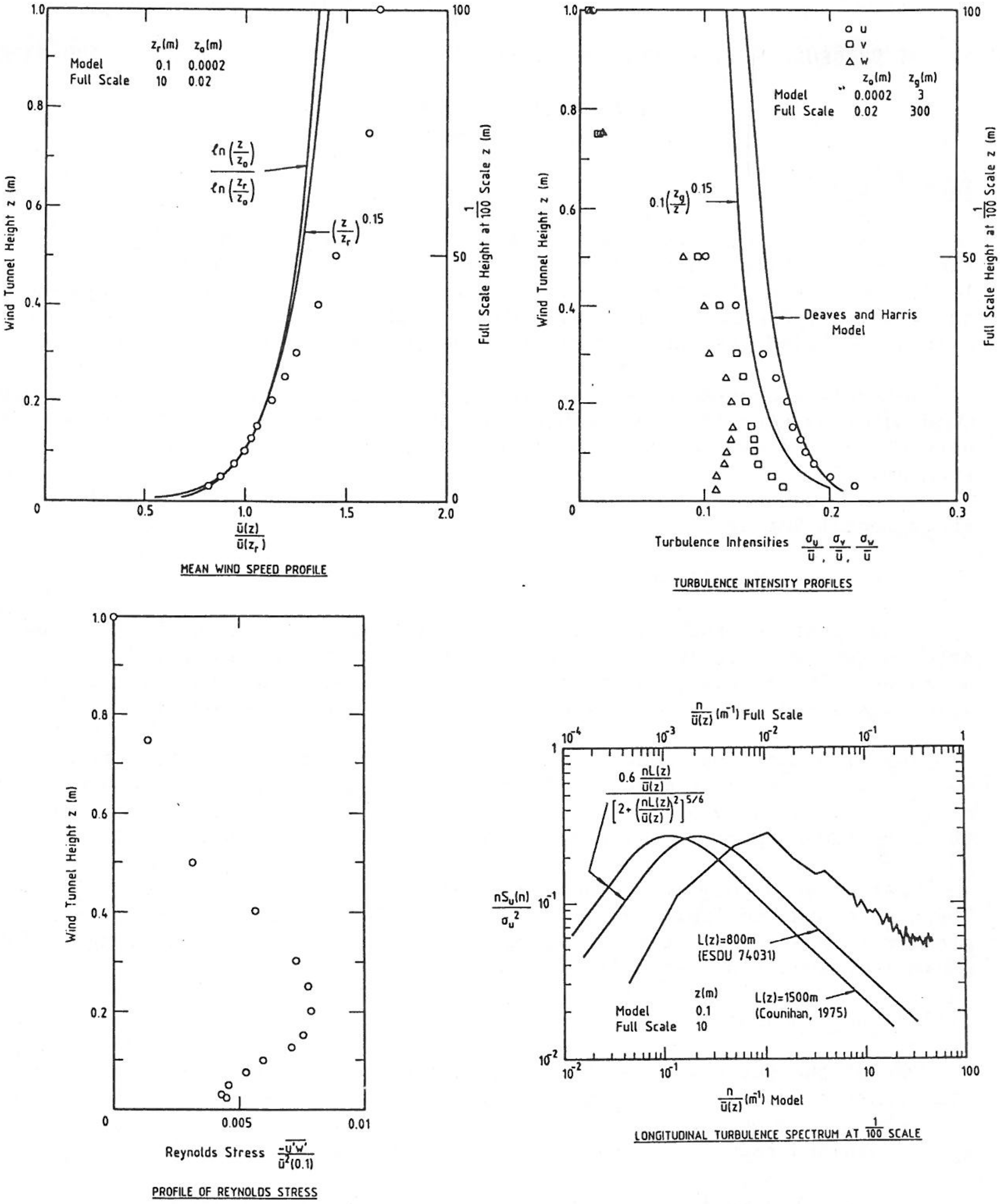

MEAN WIND SPEED PROFILE

TURBULENCE INTENSITY PROFILES

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LONGITUDINAL TURBULENCE SPECTRUM AT 1/100 SCALE

Fig.2 - Boundary layer flow characteristics, 7ft x 5ft Low Speed Aeronautical Wind Tunnel

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