THE INFLUENCE OF THUNDERSTORMS ON THE DYNAMIC RESPONSE OF BRISBANE AIRPORT TOWER AND DESIGN IMPLICATIONS

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Introduction

As has been widely documented previously (Denoon et al., 1999), Brisbane & Sydney Airport Control Towers have been instrumented with accelerometers and anemometers as part of a long term investigation of occupant response to wind-induced accelerations. This paper will examine the effects of thunderstorms on the wind-induced dynamic response of Brisbane Airport Tower and the implications for serviceability acceleration design will be discussed.

Anatomy of a Thunderstorm

The most extreme gust wind speed measured at Brisbane Airport Tower in over four years of measurements resulted from a thunderstorm. This thunderstorm is illustrated with time histories of wind speed, direction and tower accelerations in x and y directions in Fig.1. Fig. 1 was developed from two 15 minute data records plotted sequentially and the wind data was obtained from a propeller-vane anemometer mounted 9m above the centre of the tower roof on a mast.

The thunderstorm can be seen to last around 11-12 minutes within the 30 minutes of data presented. A significant change in wind direction can be seen at the end of the thunderstorm event, and this change in wind direction is preceded by a very short period of high wind speed. This short period of high wind speed produced the highest gust wind speed measured during the project of 37.6 ms^{-1}. However, it can be seen that this short period of very high wind speed is not sustained enough to allow a significant resonant response of the tower to develop. Earlier in the record, however, when wind speeds were sustained at around 30 ms^{-1}, a much larger resonant response did develop, and these were the some of the highest accelerations measured during the project.

Wind-induced response of Brisbane Airport Tower

The wind-induced response of Brisbane Airport Tower is illustrated in Figs. 2-4 which are graphs of peak acceleration v. maximum gust wind speed, peak acceleration v. mean wind speed and combined standard deviation acceleration v. mean wind speed.

Examining Fig. 2, it can be seen that the highest gust wind speed did not result in a particularly large dynamic response. This was shown in Fig. 1, where this wind speed was measured near the start of the second data record plotted. This, however, was an isolated example caused by the measurement system employed: a rolling 15 minute measurement would not have produced the same result. However, it can be seen that the overall degree of scatter in the data is much lower in Fig. 2 than in either Fig. 3 or Fig. 4. This reduced scatter is due to the non-stationarity of thunderstorm events. That is to say, during a 15 minute measurement period, only part of the typical thunderstorm (say 10-15 minutes in duration) will be captured in this data record. Hence, the gust factor within that 15 minutes will be artificially high, as the mean wind speed does not necessarily represent the mean wind speed within the thunderstorm which is causing large resonant response. This explains the scatter in

Fig. 3, where scatter is largest. In Fig. 4, where the scatter is still larger than in Fig. 2, there are a number of outliers where relatively large accelerations result from moderate mean wind speeds. Again, these can be seen to be the result of thunderstorm activity not being well represented by measures of standard deviation acceleration or mean wind speed.

Thus, it would appear that in regions susceptible to short duration extreme wind events such as thunderstorms, the most statistically reliable design parameters are peak acceleration and maximum gust wind speeds.

Return periods and acceptability of acceleration

Analysing all of the data from each 15 minute record over the course of the project, return periods of various peak accelerations were calculated and plotted (Fig. 5). Fig. 5 shows two distinct distributions. This is similar to the analyses of Holmes (2000) which show the influence of thunderstorms on the wind climate of several major Australian cities. In effect, the lower distribution is due to cyclonic winds, but the distribution encompassing the extreme acceleration events is due to thunderstorm activity. Calculating the expected 5 year return period using a Gumbel fit to this higher data, a figure of 13.3 milli-g is obtained which compares with Melbourne's (1988) five year return acceptable acceleration of 12.0 milli-g. The predicted value exceeds the design criteria but complaints are not regularly received. A similar analysis for data from Sydney Airport Tower, where thunderstorm effects did not dominate the data, predicts a 5 year return acceleration of 10.1 milli-g which compares with Melbourne & Cheung's acceptable acceleration of 9.9 milli-g. Yet, complaints are regularly received at Sydney Airport but not at Brisbane despite them appearing to perform similarly.

However, if a return period of 100 days is taken, the expected acceleration at Brisbane Airport is around 5 milli-g, but at Sydney is around 7.5 milli-g. Thus, the infrequent, but extreme, thunderstorm wind events do not give an accurate representation of the regular motion environment in the Brisbane tower. It is the regularity of smaller events at Sydney Airport which causes complaints but the infrequent large motion events at Brisbane do not generate serious dissatisfaction among the workers.

It is clear that serviceability acceleration criteria need to be based not only on infrequent, extreme wind events causing large accelerations but also on more regular wind events. The use of a much smaller return period than is currently in use is recommended to reflect wind environments at a given location.

Conclusions

The effects of thunderstorms on the wind-induced dynamic response of Brisbane Tower have been examined. Peak acceleration and maximum gust wind speed are recommended as the most appropriate serviceability acceleration design parameters. The use of shorter return periods in this design process is also recommended.

References

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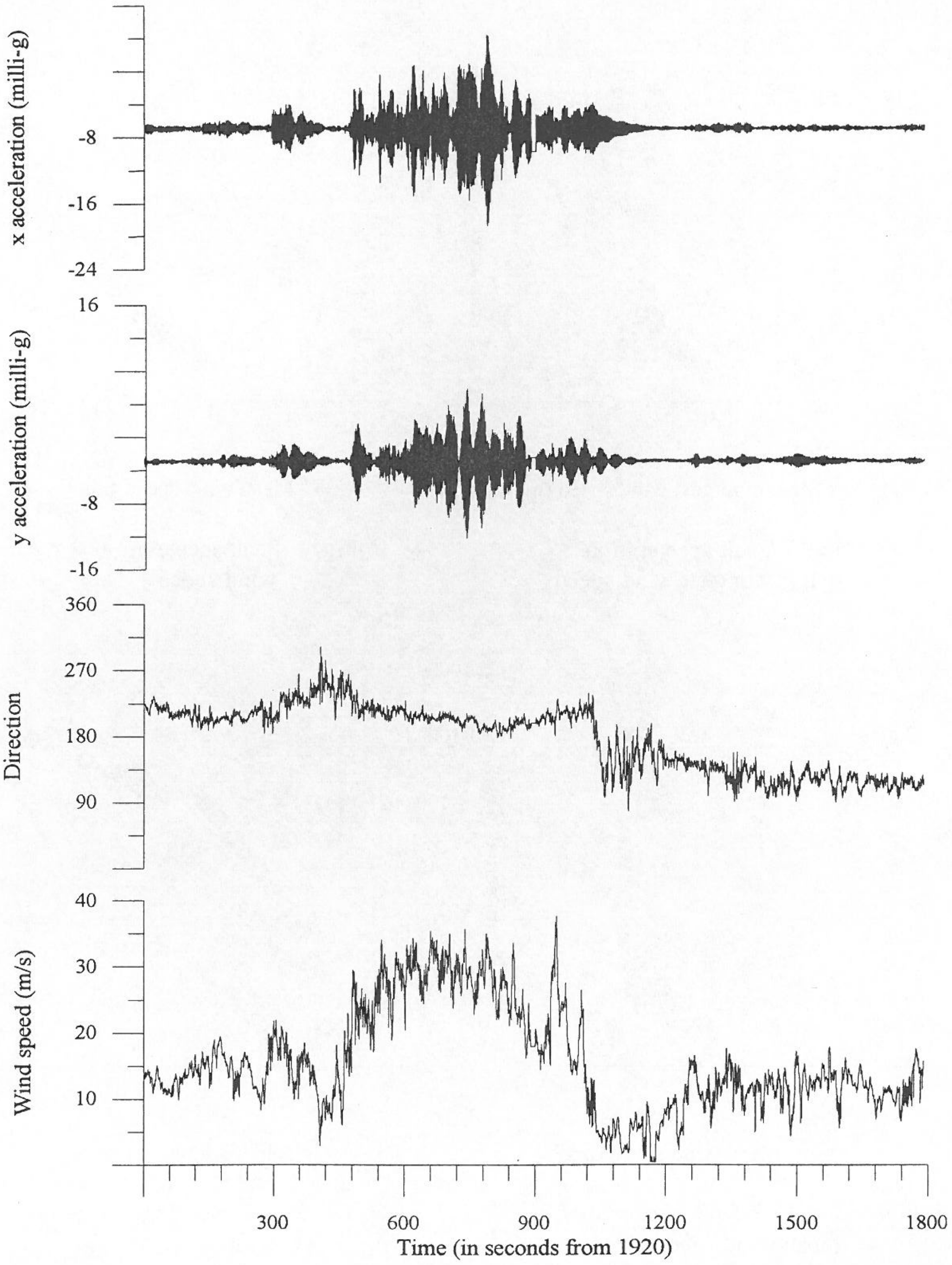

Fig. 1 Thunderstorm time history

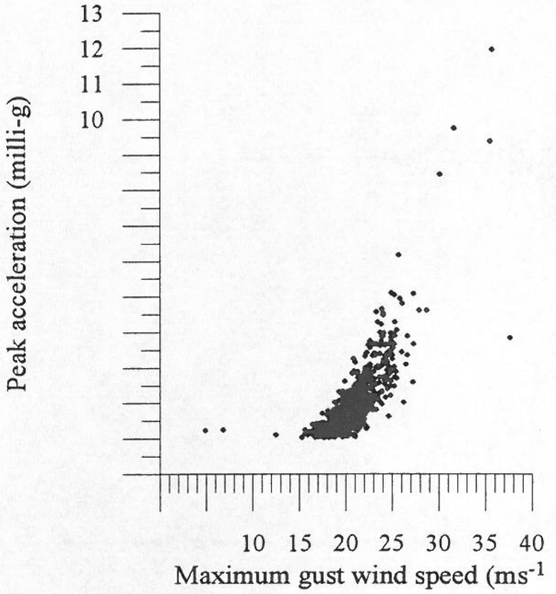

Fig.2 Peak acceleration v. maximum gust wind speed

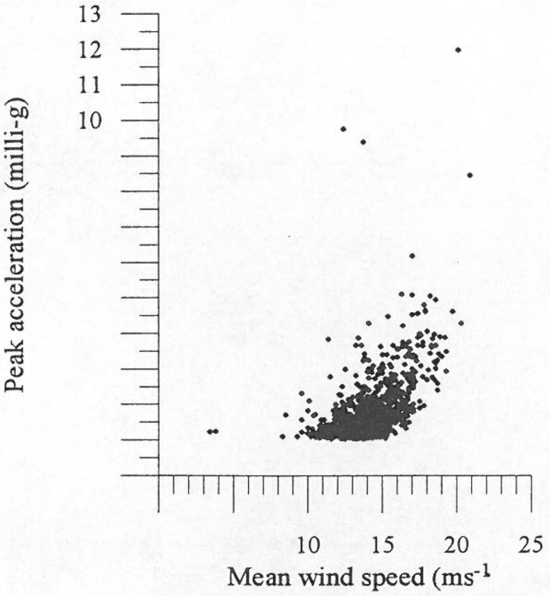

Fig. 3 Peak acceleration v. mean wind speed

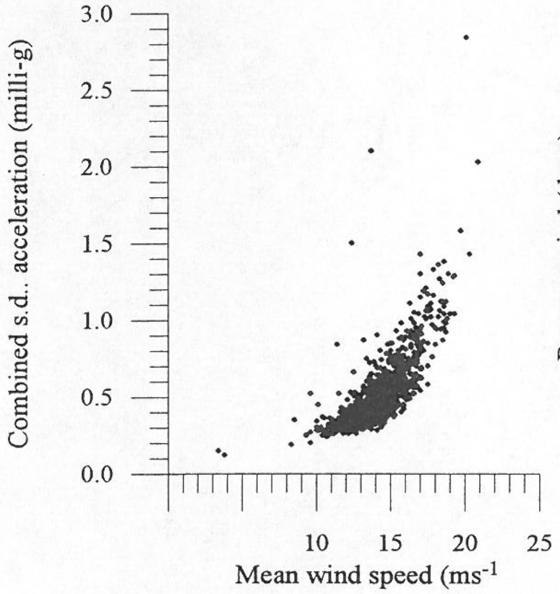

Fig. 4 Combined s.d. acceleration v. mean wind speed

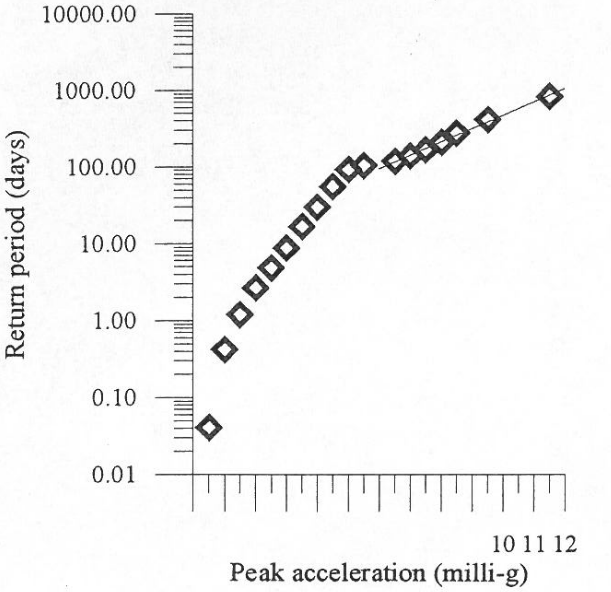

Fig. 5 Peak acceleration return periods