Extreme Wind Speeds During Rainfall

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Introduction

In the design of building facade for weather resistance it is important to know both the wind and rain environment around the building. The amount of rain water falling onto walls of buildings is a function of rainfall intensity as well as wind velocity. The design of water seals and joint details requires knowledge on wind pressure and precipitation intensity. It is therefore important to know the characteristics of wind speed during rainfalls.

Data for the present study

In the present study, extreme wind speeds in Sydney are studied. There are four meteorological stations scattered around Sydney where both wind speed and rainfall intensity are regularly recorded. They are Mascot Airport, Sydney Observatory, Bankstown and Richmond stations. Record lengths for the four stations are different. Pluviograph for Sydney meteorology station dated back to 1913 whereas for Bankstown it only dated back to 1968. Anemographs dated back to 1930 for Mascot and 1968 for Bankstown. The wind records are hourly mean wind speeds recorded at 3 hour intervals averaged over the 10 minute before the hour. The rainfall records give the cumulative rainfall at variable time intervals (minimum of 1 hour) with more frequent data during rain storms. A data base for each station is constructed composed of pairs of simultaneous hourly mean wind speed and hourly rainfall intensity values. Extreme value analysis of the wind speed is carried out, first irrespective of rainfall (Normal). Then extreme value analysis is again carried out on the wind speed for winds occurring at a rainfall intensity of R mm/hr and higher. R is set equal to 10, 20, 30, 40 and 50 mm/hr for the present study.

Extreme wind analysis

Figure 1 shows the Mascot data where the lines are fitted for the Fisher Tippett type-1 distribution as given in equation 1.

$$P(V) = \exp(-e^{-a(V-b)}) \qquad 1$$

where V is the extreme mean wind speed, P() is the cumulative probability, and a, b are constants for the type-1 distribution.

Each line in figure 1 is individually fitted to the individual set of data. It can be observed that the slopes and intercepts for lines for extreme winds at different lines are different. This however creates a contradiction. Since the wind data used for the calculation of extreme winds regardless of rainfall would consists of all the wind data used for extreme winds for rainfall intensity of 10 mm/hr and higher. Thus the extreme wind speed regardless of rainfall must be greater than or equal to the extreme wind speed for rainfall intensity >= 10 mm/hr (at the same probability). And similarly the 10 mm/hr ones greater than or equal to the 20 mm/hr ones and so on. Now since the lines have differing slopes, they will cross one another resulting extreme wind speeds for the higher rainfall intensity greater than those of the lower intensities and those regardless of rainfall.

To over come this problem Murakam et al[1] suggested that all the lines should have the same slope. Least square fitting is used on all the data to produce a common slope but different intercepts for the different sets of data. The lines are plotted out in figure 2. It can be observed that the lines do not really fit the data points especially the 'Normal' extreme wind curve. Furthermore the shape of each set of data points seem to form a convex curve rather than a straight line. The same phenomenon can be observed in figure 3 for the Sydney data. The Bankstown and Richmond data also show similar trends.

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As the data suggests a curve and no a straight line, it seems the type-1 distribution is not satisfactory for modelling extreme wind during rainfalls. The data seems to be bounded by an upper bound which indicates the type-III distribution as given by equation 2.

$$P(V) = \exp\left(-\left(\frac{w-V}{w-c}\right)^k\right) \qquad 2$$

where V is the extreme mean wind speed, P() is the cumulative probability, w is the upper bound and c, k are constants for the type-III distribution.

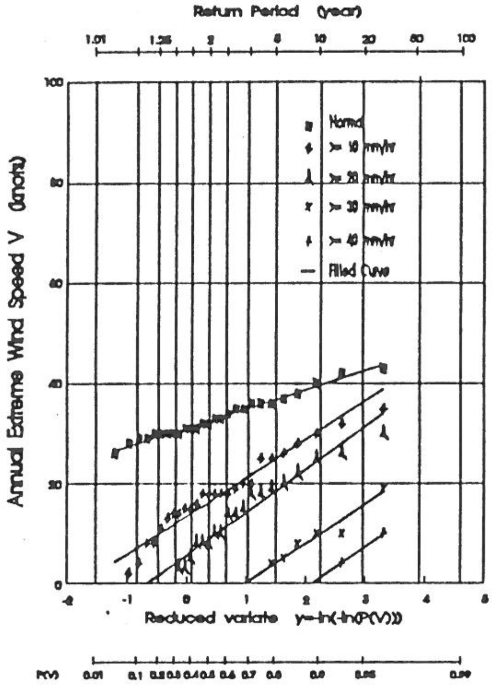

Figure 1 Mascot extreme wind for various rainfall intensities (Lines individually fitted)

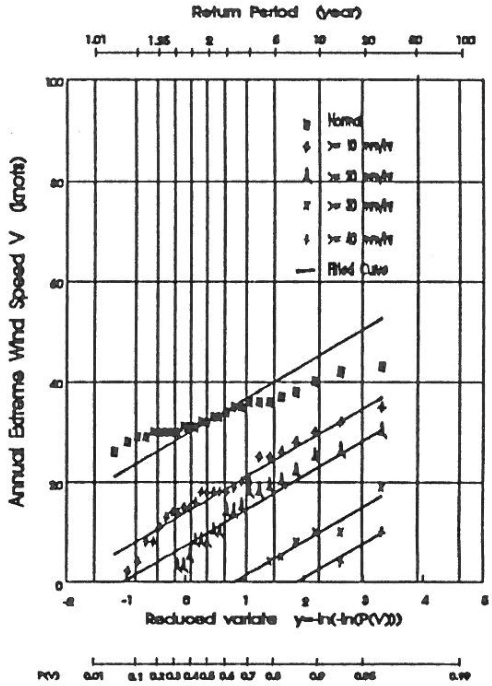

Figure 2 Mascot extreme wind for various rainfall intensities (Multiple lines fitted)

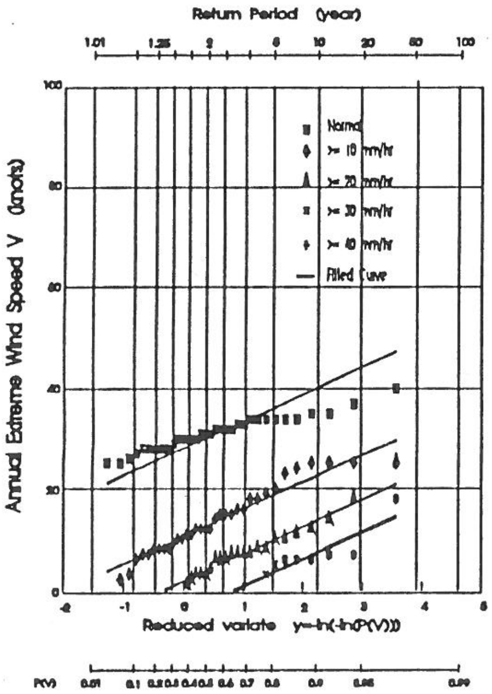

Figure 3 Sydney extreme wind for various rainfall intensities (Multiple lines fitted)

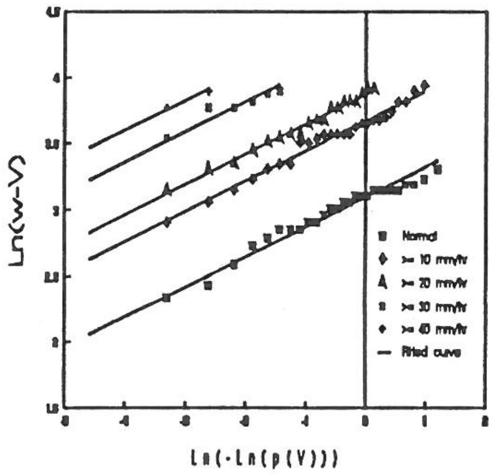

Figure 4 Type-III fitting for Mascot data

Curvi-linear curve fitting technique is used to solve for the constants w, c and k. In order to confirm that the type-III distribution is suitable, equation 2 is transformed to equation 3 where ln(-ln(P(V))) and ln(w-V) are linearly related. The mascot data and the fitted type-III curves are plotted in figure 4. It can be observed that the data points form more or less parallel straight lines which confirms the type-III distribution. Plots of the same data and the type-III curves on probability paper are shown in figure 5. The lines show much better fitting than those in figures 1 and 2.

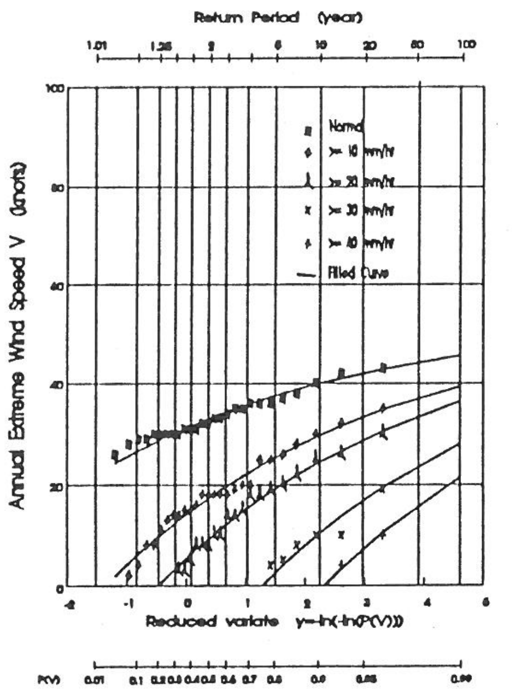

Figure 5 Mascot extreme wind for various rainfall intensities (Type-III fitting)

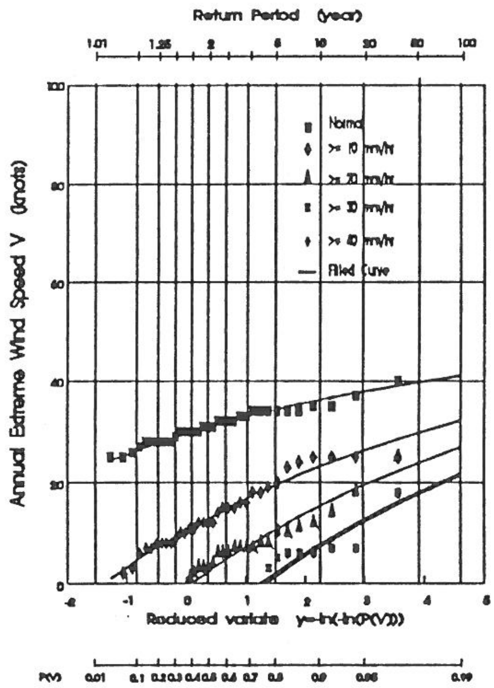

Figure 6 Sydney extreme wind for various rainfall intensities (Type-III fitting)

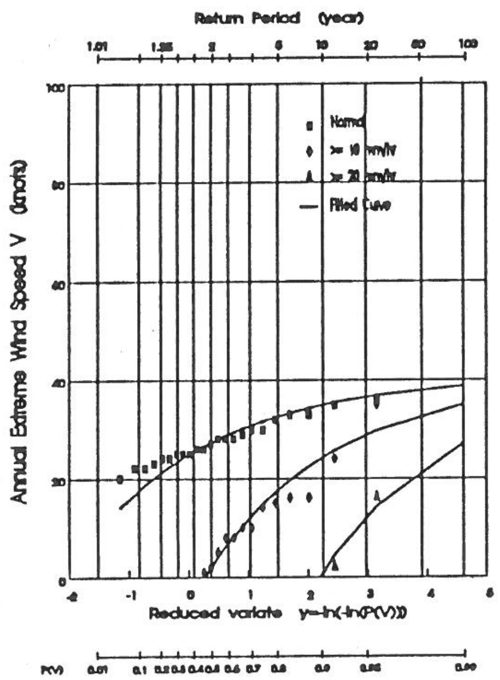

Figure 7 Bankstown extreme wind for various rainfall intensities (Type-III fitting)

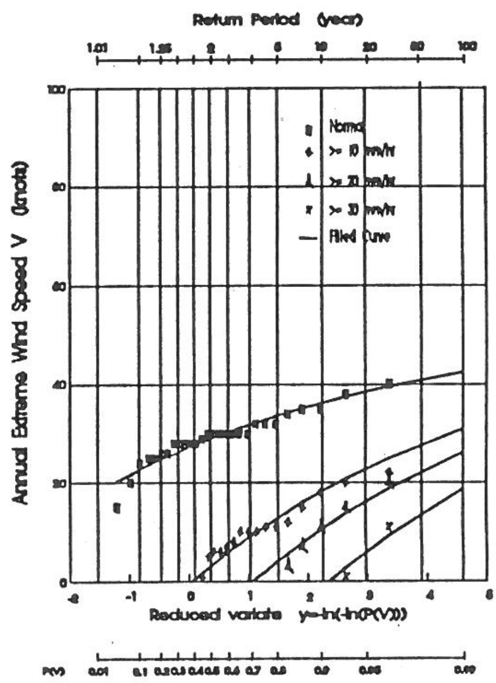

Figure 8 Richmond extreme wind for various rainfall intensities (Type-III fitting)

Similar analysis is carried out on the Sydney, Bankstown and Richmond records. The data together with the fitted type-III curves are shown in figures 6, 7 and 8 respectively. It can be seen that they have similar trends of variation as those described for the Mascot data.

The predicted extreme wind speed for return periods 10, 20, 50 and 100 years for the four stations at various rainfall intensities using the type-III fitting are given in table 1.

		Extreme wind speeds [knots (m/s)]				
Station	Return period (year)	Normal	Rainfall intensities (mm/hr)			
			10	20	30	40
Bankstown	100	38.8(20.0)	35.0(18.0)	27.1(14.0)	20.7(10.7)	
	50	38.0(19.6)	32.9(16.9)	22.0(11.3)	13.2(6.8)	
	20	36.6(18.8)	28.8(14.8)	12.1(6.2)		
	10	35.0(18.0)	24.2(12.5)	1.0(0.5)		
Mascot	100	45.5(23.4)	39.5(20.3)	36.4(18.7)	28.1(14.5)	21.4(11.0)
	50	44.2(22.8)	37.1(19.1)	33.5(17.2)	23.9(12.3)	16.0(8.2)
	20	42.0(21.6)	33.3(17.1)	28.8(14.8)	16.9(8.7)	7.2(3.7)
	10	40.0(20.6)	29.7(15.3)	24.5(12.6)	10.4(5.4)	
Richmond	100	42.5(21.9)	31.0(16.0)	26.2(13.5)	18.7(9.6)	7.0(3.6)
	50	41.0(21.1)	27.8(14.3)	22.3(11.5)	13.7(7.1)	0.4(0.2)
	20	38.6(19.9)	22.8(11.7)	16.2(8.3)	6.0(3.1)	
	10	46.4(23.9)	18.3(9.4)	10.8(5.6)		
Sydney	100	41.0(21.1)	32.3(16.6)	27.0(13.9)	21.9(11.3)	26.2(13.5)
	50	39.8(20.5)	30.0(15.4)	24.1(12.4)	18.3(9.4)	22.3(11.5)
	20	37.9(19.5)	26.4(13.6)	19.5(10.0)	12.8(6.6)	16.2(8.3)
	10	36.3(18.7)	23.3(12.0)	15.5(8.0)	7.9(4.1)	10.8(5.6)

Table 1 Extreme wind speed for various rainfall intensities for different return periods

Discussion and conclusion

It is important to point out here that the analysis carried out in the present study is on the raw data recorded by the anemometers. They are velocities at the height of the anemometer. No modifications have been made for height and terrain conversions. The anemometer heights are all 10 metre about ground level with the exception of that for Sydney Observatory which is 17 metre above ground. From table 1 it can be observed that the extreme wind speeds are very different for the four stations. Mascot being the most exposed and close to the coast should give the best estimate for unobstructed conditions. First looking at the variation of wind speed with return periods for the same rainfall intensity, wind speed increases with increase in return period. The rate of increase is faster at short return periods; as the return period gets longer the rate of increase flattens out. The rate of increase also depends on the rainfall intensity. The higher the rainfall intensity, the higher is also the rate of increase. Secondly for the same return period, the extreme wind speed decreases with increase in rainfall intensity. Higher rainfall intensities have lower extreme wind speeds. The rate of decrease in wind speed with increase in rainfall intensity is faster for shorter return periods.

Extreme wind study on winds during rain storms is carried out in the present paper. It is observed that the type-III distribution is much more suitable for describing the characteristics of extreme winds during rain storms. Magnitude of the extreme wind is also found to be highly dependent on rainfall intensity.

References

1. Murakami S, Iwasa Y, Morikawa Y, Chino N, 'Extreme wind speeds for various return periods during rainfall', J. of Wind Engg. and Industrial Aerodynamics, 26 (1987) 105-125.

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3. Pilgrim D H, 'Australian rainfall and runoff - A guide to flood estimation' The Institution of Engineers, Australia, 1987.