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The maximum gusts in Cyclone 'Olivia' – April 10, 1996

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Abstract

This paper reviews the evidence for the maximum gust recorded on Barrow Island during the passage of Cyclone 'Olivia' in 1996. On the basis of this evidence, and an assessment of the strength of the supporting mast, it is considered likely that the recorded gust values were in error, and that the correct maximum 0.2 second gust was about 72 m/s, and the maximum 3-second gust was about 67 m/s.

Introduction

Tropical Cyclone 'Olivia' passed over Barrow Island, Western Australia on April 10th, 1996. 5-minute average wind speeds, 3-second average gusts, wind direction, relative humidity, and barometric pressure were recorded by an automatic weather station close to the centre of the island (Courtney, *et al.*, 2012). Based on this data, a maximum 3-second gust of 113 m/s has been claimed which, if correct, would be a world record. This is equivalent to a 0.2-second gust, in Terrain Category 2, of about 109 m/s – a value which has an average recurrence interval, R, of about 60,000 years, according to the probability distribution given in AS/NZS 1170.2 (Standards Australia, 2012 for Region D (V_R = 156 – 142 $R^{-0.1}$), and clearly a wind gust of that magnitude would justify a serious re-assessment of the design wind speeds for Barrow Island.

This paper reviews the evidence presented by Courtney *et al*., 2012, and presents a structural assessment of the strength of the guyed mast supporting the anemometer.

Track of Cyclone 'Olivia'

The track of Cyclone 'Olivia' (Figure 1) shows that the centre of the storm passed to the east of Barrow Island, suggesting that the at the time of maximum winds, the wind due to vortex rotation would have been opposed by the forward movement of the storm at that location. Hence, presumably even stronger winds would have occurred on the left hand side of the cyclone (facing in the direction of movement – i.e. well to the east of Barrow Island.

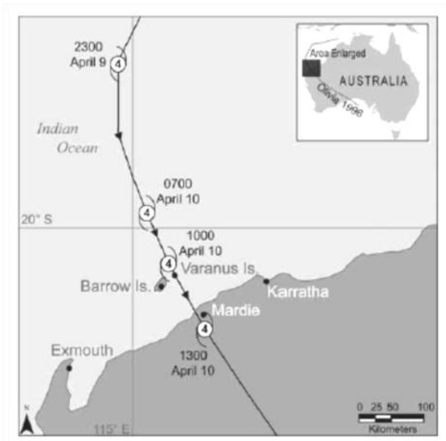

Figure 1. Track of Cyclone 'Olivia' (from Courtney *et al*., 2012)

Courtney *et al*. stated that the times shown on Figure 1 are local times (Western Australian Standard Time). However, if this were true the maximum winds at Barrow Island (around 1100 UTC, or 1900 local time) would have occurred well after the cyclone had made landfall. Hence, the times shown on Figure 1 are probably UTC.

Recorded data on wind speed and direction

Figure 2 shows the recorded and plotted time histories of the major atmospheric variables from 0600 to 1500 (UTC), obtained from a height of 10 metres at the location of the automatic weather station (co-ordinates: 115.39^o E, 20.82^{o}S). The surrounding terrain was virtually free of vegetation (i.e. equivalent to Terrain Category 1 in AS/NZS 1170.2), and although the site was on a hill, the approaching slope was quite shallow.

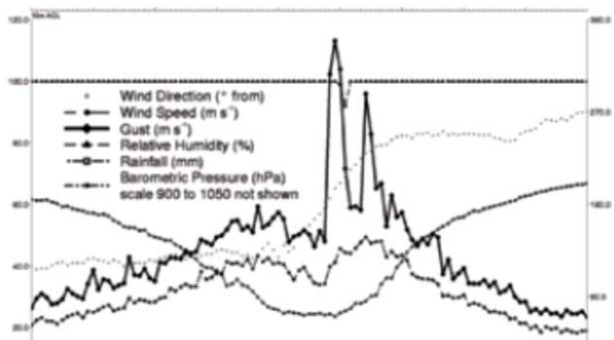

Figure 2. Recorded time histories of wind speed, direction, barometric pressure (from Courtney *et al*., 2012)

It is clearly noticeable that five values of 3-second gusts – i.e. those occurring at 10.50, 10.55, 11.00, and at 11.25 and 11.30 - lie well outside the general trend of variation in the gusts. However, those anomalous values are not reflected in unusual values of any of the 5-minute mean wind speeds, the wind direction, or the barometric pressure. The explanation for the extreme gusts, given by Courtney *et al*., of an embedded meso-vortex, does not correlate well with the generally well-behaved variations in these other quantities shown in Figure 2, particularly the wind direction and barometric pressure.

It should be noted that each of the 3-second gust values shown in Figure 2, was obtained by digital averaging of six values of instantaneous wind speeds sampled at 2 Hertz. Presumably one or more instantaneous gust values, apparently even higher than 113 m/s, were sampled, producing that value as an average of six.

Structural assessment of the anemometer mast

An important point raised by a number of people (e.g. Harper, 2012) was that no check had previously been made of the ability of the guyed mast, supporting the anemometer, to resist the extreme wind forces associated with a 3-second gust of 113 m/s.

Such an assessment has therefore been carried out by the second author, to check whether it is a reasonable assumption that the masts could have withstood a short duration gust of the order of 120 m/s. Fortunately, the necessary information on the dimensions and construction details of the supporting mast have been supplied by Courtney *et al*.

Drag Coefficients

The drag coefficients for the supporting pole, the guys, the cross-arms and the anemometer itself are obviously important inputs to calculations of the wind forces on the structure. Generally AS/NZS 1170.2 was used for these coefficients with input from other sources (e.g. Holmes, Burton and Fricke, 2012) as appropriate.

The Aanderaa 2772 ten-metre tower consisted of sections of anodised aluminium alloy tube of 50 mm outside diameter. For the tubular mast, assuming a velocity of 80 m/s and a roughness height for the anodized surface of 30×10^{-6} m (similar to 'painted metal' in AS/NZS 1170.2), gives a Reynolds Number, based on the diameter, of 2.8×10^5. For this roughness height/diameter ratio, the minimum Reynolds Number for super-critical flow is 2.6×10^5 (Holmes, Burton and Fricke, 2012). Then application of the equation for drag coefficient in AS/NZS 1170.2 (Note 2 below Table E6), gives a drag coefficient of 0.75.

For the guys, a drag coefficient of 1.2 was assumed, with inclination factors (K_i) of 0.74 and 0.42, for the upper and lower guys respectively. The cup anemometer was the Synchrotac 706 Heavy Duty Type, with a cup diameter of 127 mm (McVan Instruments, 2005). Assuming one cup is normal to the flow with a drag coefficient of 1.4, and that the other arms of the other two are at 120 degrees with a drag coefficient of 0.73, gives an effective $C_d.A$ of $0.036m^2$. Finally, based on the specifications for a similar Aanderaa mast (Aanderaa Data Instruments, 2006), the cross arm was estimated to have average dimensions normal to the wind flow of 0.025m by 0.5m and a drag coefficient of 2.0.

Structural Model

An equivalent structural model was created in the proprietary software SPACEGASS (Figure 3). A nonlinear static analysis was performed. In addition, buckling analysis was carried out to determine the capacity of the aluminium-alloy mast against the applied wind loads, determined using the drag coefficients outlined above. The minimum buckling factor to start failure of the mast is 1.059. The wind speed producing the wind forces were increased until failure of the aluminium-alloy mast was just reached, under the combined actions of bending, axial compression and shear. The gust wind speed was varied with height on the mast using values of terrain-height multiplier from Table 4.1 in AS/NZS 1170.2 for Terrain Category 1, normalized to 1.0 at 10 metres height.

Results

The short-duration gust wind speed at the top of the mast to just produce buckling failure, using the approach discussed in the previous section, was found to be **77 metres per second**. There is some uncertainty in the dimensions of the mast components and in the drag coefficients. When the combined products of $C_d.A$ for all the components are varied by plus and minus 10%, the failure wind speed becomes 73 m/s and 80 m/s respectively. For the frontal area of this structure, the duration of the effective gust is quite short – a reasonable assumption is that it is the same as the gust duration used in AS/NZS 1170.2 – i.e. 0.2 seconds.

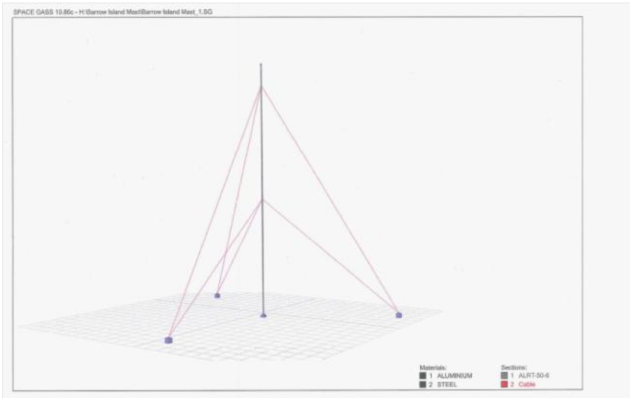

Figure 3. SPACEGASS structural model of the anemometer mast at Barrow Island

Gust factors and likely maximum gusts

Courtney *et al*. give gust factors (i.e. ratios of the maximum 3-second gusts to the corresponding 5-minute average wind speeds) calculated from the Barrow Island data. For the period of strong winds from 10.00 to 12.00 UTC, but ignoring the five anomalous values that produced very high gust factors, the average gust factor is 1.356. Assuming a value of *peak* factor for the 3-second gusts of 3.0 (e.g. Holmes and Allsop, 2012, 2013), this implies a turbulence intensity of about 0.12 (i.e. 0.356/3.0). The appropriate peak factor for a 0.2 second gust, as used in AS/NZS 1170.2 is 3.8. The corresponding gust factor for a 0.12 second gust is then: $1 + (3.8)(0.12) = 1.46$.

The maximum 5-minute average wind speed during Cyclone 'Olivia' was 49.4 m/s recorded at 11.25 UTC. Based on this value and the above gust factors, the expected 0.2 second gust is **72 m/s**, and the maximum 3-second gust would be **67 m/s**.

The above values are consistent with the best estimate of the predicted buckling wind speed for the mast of 77 m/s, and just under the range of predictions for buckling of 73 to 80 m/s (0.2 second gust).

Conclusions

A re-assessment of the maximum wind gust that occurred during the passage of Cyclone 'Olivia' close to Barrow Island, Western Australia, on April 10th 1996, has been carried out. In particular, a structural assessment of the supporting mast for the anemometer indicates that it would have buckled at a wind speed well below the claimed gust speed of 113 m/s.

Based on the recorded maximum 5-minute average wind speed, the best assessment of the maximum 0.2 gust speed at Barrow Island during Olivia is **72 m/s**, with a maximum 3-second gust speed of **67 m/s**. These values are consistent with the calculated gust speed range, for buckling failure of the mast, of 73 to 80 m/s.

The question remains as to what produced the apparent high gust values, including the 113m/s reading, reported by Courtney *et al*. Serious speculation about this is beyond the scope of this paper; however, since a pulse counter was used to process the cup anemometer readings, it is possible that lightning strikes (known to be prolific in the eye walls of tropical cyclones) may have generated numerous additional pulses that may have been interpreted by the electronics as rotations of the cups.

Acknowledgments

Mr. Arwin Salih (URS Corporation) is acknowledged for carrying out the structural assessment of the anemometer mast. Useful comments from Dr. Bruce Harper (GHD) and Dr. Graeme Wood (CPP) are also acknowledged by the authors.

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