The effects of tropical cyclone Vance on Exmouth

by *Greg Reardon (Cyclone Testing Station, James Cook University, Townsville), Geoff Boughton (Curtin University of Technology, Perth), David Henderson and John Ginger (Cyclone Testing Station, JCU)*

Introduction

Cyclone Vance hit Exmouth on the morning of Monday 22nd March, 1999. Exmouth is a small coastal township some 1250 km north of Perth, and almost at the tip of Northwest Cape in Western Australia. It is located on the west side of the Exmouth Gulf and has a population of just under 3000. It was established in the early 1960s as the service centre for the Australian–United States Communication Station. Now its main industry is tourism.

The township extends over an area of about 4 km long by 2 km wide, and is about 1 km inland from the gulf waters. The overall housing stock is unusual insomuch as it mainly consists of six readily identifiable types. There are block houses built for the US services personnel, houses built by the (then) Western Australian Housing Commission, imported US kit houses, houses built for Defence Housing Authority, transportable houses and a group of newer houses built in the last ten years. The different types of housing are generally scattered throughout the township, but with newer development concentrated to the north.

The Australian Standard wind loading code (Standards Australia 1989) defines the 50 km wide coastal strip between latitudes 20°S and 25°S in Western Australia as Region D, the most severe region for tropical cyclones. For engineering design the code assigns Region D a basic ultimate limit state gust wind speed of 85 m/s (306 km/h). Exmouth is in the middle of this region.

The Bureau of Meteorology has developed a five point system for defining the severity of tropical cyclones. All cyclone warnings issued by the Bureau include a severity classification. A description of the classifications is included in the front section of all telephone books in cyclone regions, so that communities are familiar with the rating. *Table 1* shows the system, with the maximum gust speed expressed in both kilometres per hour (km/h) and metres per second (m/s).

The damage potential listed in *Table 1* for each category of cyclone has been based on likely performance of buildings in cyclone Region C, as defined in the wind loading code. It assumes a full cross section of new and old houses, including older ones in various states of neglect or disrepair. Because it was established in the mid 1960s, Exmouth does not have many of these older houses.

The design gust wind speed for Region C is 70 m/s, that is, about the middle of the range for category 4 cyclones. As already stated, Exmouth is located in Region D which has a design gust wind speed well above the minimum for category 5 cyclones. The effect of this is to move the damage potential listed in *Table 1* up one category relative to wind speed. Therefore a more accurate estimate of the damage potential for a category 5 cyclone in Region D is 'Significant roof and structural damage. Dangerous airborne debris', that is, the tabulated description for a category 4 event in Region C.

Category	Maximum Gust (km/h)	(m/s)	Damage potential for towns in Region C
1	<125	(<35)	Negligible house damage. Damage to crops and foliage.
2	125–170	(35–47)	Minor house damage. Significant damage to crops, signs and caravans.
3	170–225	(47–63)	Some roof and structural damage. Power failures likely.
4	225–280	(63–78)	Significant roof and structural damage. Dangerous airborne debris.
5	>280	(>78)	Extremely dangerous with widespread destruction.

Table 1: Tropical cyclone categories

Cyclone Vance

Vance formed in the Timor Sea and was declared a Category 1 cyclone by the Bureau of Meteorology on 18 March. It headed west then southwest as it intensified rapidly to become a Category 5 by 21 March. The following day it was travelling almost due south as it entered Exmouth Gulf. The Bureau's report states that the eye of the cyclone passed approximately 25 km to the east of Exmouth. They estimated the cyclone's eye to be about 20 km diameter, and its forward speed in the gulf to be 25–30 km/h.

Exmouth is serviced by the airport at Learmonth, some 35 km to the south. The Bureau has a Dines anemometer at the airport. The cyclone's eye wall was estimated to be about 20 km east of Learmonth at 11.45 am when the anemometer recorded the peak gust of 267 km/h. The Bureau has made copies of the anemograph readily available, and annotated it with the following statement: 'Peak wind: 103 knots (190 km/h) gusting to 144 knots (267 km/h) from SW at 11.45 am on Monday March 22, 1999, setting a new record for the highest surface wind speed ever recorded on mainland Australia'. *Table 2* lists wind speed and direction data for Learmonth taken from the anemograph. It can be seen that the wind came from about the south east and as the cyclone went past swung around to about west south west. The wind direction change was about 130°. Wind directions at Exmouth would have been similar to those at Learmonth.

Time 22/3/99	Mean wind speed km/h	m/s	Gust wind speed km/h	m/s	Mean wind direction from N degrees
0600	65	18	102	28	150
0900	102	28	157	44	155
1000	120	33	176	49	160
1100	157	44	222	62	170
1130	176	49	250	69	205
1145	191	53	267	74	215
1200	157	44	204	57	225
1230	111	31	167	46	255
1300	74	21	130	36	280

Table 2: Wind speed and direction at Learmonth

A nearby barometer recorded the minimum pressure as 938 hPa.

Although the 267 km/h gust wind speed is the highest recorded on mainland Australia, it would not have been the highest gust in Vance. Also, it is just below the threshold for Category 5 cyclones. There are two reasons why this recorded gust would not be the peak within the cyclone. Firstly, the eye passed about 20 km away from Learmonth, so there would be a reduction in wind speed because of that distance. Secondly, because Vance passed to the east of the Learmonth and Exmouth while heading in a southerly direction, its forward speed of 25–30 km/h would reduce the effect of the clockwise rotational wind speed at those locations. Wind gusts to the north, south and especially to the east of the eye would be significantly higher, well into the Category 5 classification.

As Vance's track was slightly closer to Learmonth than to Exmouth, the peak gust winds at Exmouth have been estimated as 250 km/h. Analysis of damaged structures indicate that the maximum winds would have been in the range 220–250 km/h (61–69 m/s) in the southern and exposed parts of town, and 200–230 km/h (55–64 m/s) in the northern and sheltered parts.

Performance of buildings

Most buildings in Exmouth were houses or industrial buildings, with a few offices and shops in the town centre. The industrial area was at the southern end of town, where the wind speed was greater.

In order to obtain a clear overview of the extent of the damage to housing, the authors undertook an extensive survey of the type of housing and the amount of damage to each house. The survey covered the entire town with the exception of the industrial section. The survey data was collected either by a person walking, or from a slow moving car. Therefore it is based on external features visible from the street. Special care was taken to prevent unintentional bias in collecting the data. Information was collected on 460 houses, which would represent about half of the total number in the town.

The damage classification system was based on one developed by Leicester and Reardon (1976) for Darwin after cyclone Tracy. It ranks the amount of visible structural damage to the house. The categories range from negligible or non-structural damage such as broken soffits or loss of flashing to loss of all walls, where the house was considered to be beyond repair. For Exmouth they were categorised and defined as follows:

1. Negligible/Non-structural

Includes no damage, or small amounts such as the loss of a small section of wall cladding material. It also includes damage to elements which are not part of the main structural framework, such as guttering, soffit lining, fascias, garage doors and the like.

Photo 1: The majority of newer houses successfully resisted the wind forces.

2. Impact

Where a house has obviously been impacted by flying debris, but which has not led to consequential damage. Examples would be a bent debris screen or indentations in external cladding.

3. Roofing

Loss of a significant amount of roofing only, but where battens and roof structure are left substantially intact. Roofing that had peeled back to the overbatten, but not beyond, was included in this category. This was so even if the edge batten was still attached to the roofing that had peeled back.

4. Roof battens

Failure caused by inadequate fixing of roof battens to rafters, so roofing and battens were blown off. The rest of the roof structure is in place.

5. Half roof

A significant portion of the roof structure has been blown away.

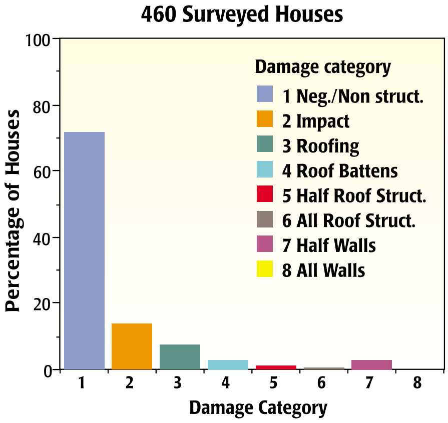

Figure 1 Distribution of damage–all houses

6. All roof

All of the roof structure would need to be replaced.

7. Half walls

Loss of most of the roof structure and loss of some walls.

8. All walls

Loss of most walls.

The damage categorisation system relates only to structural damage to housing visible from outside, and was usually restricted to the front and sides. It is likely that some lower level damage such as debris impact or even damaged roofing would have been missed. Therefore the survey results should be taken as being indicative of the damage.

Figure 1 shows a graph of the distribution of damage for all houses surveyed.

Figure 1 shows that about 70% of housing had only minor damage and a further 15% was damaged by debris. Thus only about 15% of houses had structural damage, including loss of roofing. These statistics were unexpected for a town that had been hit by winds of up to 250 km/h. After cyclone Tracy, a category 4 event, Darwin had much higher percentages of serious damage (Lester and Reardon, 1976). Even the damage potential listed in *Table 1* for category 4 wind speeds predicts greater damage than shown in *Figure 1*.

One of the reasons for the lower amount of damage was the excellent performance of the block houses built for the US Naval personnel when they were at Exmouth. They had reinforced blockwork walls, a reinforced concrete roof, small windows and debris screens. Eighty four were included in the survey. All were classified as having minimal damage i.e. damage Category 1. It is obvious by their description that they were designed to withstand very high wind forces. Presum-


Photo 2: Transportable houses put in the poorest performance of any housing group.

ably the criteria were set so that work at the naval base would not be disrupted by loss of staff housing in the event of a cyclone.

This excellent performance of the block houses was anticipated as many owners invited their neighbours from other types of houses to shelter in them. In this way the block houses were used as unofficial cyclone shelters.

Even if the block houses are considered to bias the data set and are removed, about 65% of the remaining houses are still in the minimal damage category. Obviously the percentages in the other categories increase, but they still remain relatively small.

Structural performance

The DHA houses also performed well, having virtually no major structural damage. The majority of the newer houses successfully resisted the wind forces (see *Photo 1*) although most had the advantage of being at the northern end of town where the wind speed is estimated to be slightly less.

The transportable houses put in the poorest performance of any of the groups. This type had generally been built in two sections in Perth, transported to the site and joined together. They lost roof structure and sometimes walls. Most of them were of older construction, with timber framed walls and timber or steel roof trusses. *Photo 2* shows one that had lost its roof and walls. At least one new steel framed transportable house on the southern outskirts of town lost its entire roof structure (*Photo 3*) due to inadequate fixing of the trusses.

The Housing Commission houses appeared to perform fairly well, despite their age, but there have been recent reports based on detailed inspections that indicate that there may be hidden damage. This includes roof battens partly separated from rafters. Four out of five blocks of flats lost their entire roof structure from the leeward slope in similar fashion. *Photo 4* shows one of the roof slopes. In each case the leeward slope peeled off in one piece, initiated by failure near the ridge. Failure was a classic case of inadequate tie down from roof to foundations. The plane of the roof structure had been well designed with robust members bolted together and an adequate bracing system. But the tie down to internal party walls was not sufficient.

The argument has already been made that the damage potential for houses in Region D as defined in the wind loading code could be taken as one level below those listed in *Table 1*, which would have been based on the lower design wind speeds of Region C. If the estimate of peak gust wind speed of 250 km/h is accurate, it can be argued that the damage potential listed in *Table 1* for a category 3 cyclone is more appropriate for these houses designed for Region D wind speeds. This was actually the case. The best definition from *Table 1* for damage to the houses at Exmouth is 'some roof and structural damage. Power failures likely'.

A number of non-structural elements failed due to wind pressure, which led to


Photo 3: This new transportable home lost its entire roof structure due to inadequate fixing of trusses.


Photo 4: On this block of flats, the leeward roof slope peeled off in one piece, initiated by failure near the ridge.

water entry and other damage. Doors on some of the US kit homes flew open when the striker plate tore out of the door jamb. This pressurised the interior of the houses and, in a number of instances, caused failure of the end wall. *Photo 5* shows such a failure.

Most of the industrial buildings were fairly new. They usually had open webbed steel trusses on posts spaced two to three metres apart. Most resisted the wind forces, but sometimes lost some flashing or one or two sheets of cladding. There was one spectacular exception, where the columns pulled out of the ground, the building became flying debris, hit two others and finally wrapped around a light pole (*Photo 6*). A couple of older industrial buildings were stripped of all roofing. There were reports of this cladding from the industrial area flying to the adjacent residential area and causing missile damage to housing.

Caravans and on-site cabins generally did not fare well. Although the proprietor at one caravan park chained the chasses securely to concrete pads there was still extensive damage. Older vans broke up leaving the chassis and floor still secured to the slab. On some newer vans, and on cabins, the turnbuckles used to tighten the chains yielded under the stress and the hook opened setting the chains loose and allowing the vans or cabins to roll.

Non-structural performance

Water entry was a significant problem. Some residents told of jets of water spurting from beneath windows and sliding doors. Others reported water getting into roof space through failed soffit linings or vented gable ends, usually resulting in collapse of the ceiling. Such collapse could lead to structural problems if the ceiling is relied upon to provide diaphragm action to link bracing walls. In any case, it effectively rendered the occupants homeless until replastering could be completed.

Because of the general improvement in the structural strength of housing in the past twenty years, future emphasis may need to be directed towards better design of non-structural elements to prevent entry of rainwater into houses during cyclones. This water entry is becoming more of a problem with the increasing number of electronic items which are regarded as necessary in a household. Roof spaces are often vented to allow air circulation and provide reduced indoor temperatures during summer months. The design of these features will need to be improved to prevent wind driven rain from penetrating the roof space.

Conclusions

Although cyclone Vance was a category 5 event, its path relative to the township of Exmouth meant that the wind speeds that hit the town were in the Category 4 range. They are estimated to be between 200 and 250 km/h, with the lower wind speeds in the northern part of town.

The overall structural damage to the housing stock was considerably less than was anticipated from a Category 5 (or even Category 4) cyclone. The majority of houses had minimal structural damage. This is partly because of the higher design wind speeds specified in the wind loading code for this Region D and partly because of the advances in cyclone resistant construction that have been introduced throughout Australia since cyclone Tracy hit Darwin in 1974.

The block houses built for the US Navy, with reinforced blockwork walls and concrete roof, came through the cyclone virtually undamaged. They were used as pseudo cyclone shelters. The DHA houses and the new houses also performed well.

The wind pressures did find weak links in the chain of tie-down from roof to ground. Transportable houses had the worst performance of the groups, with many losing their roof and some walls.

Despite being in the southern part of town where the wind gusts were the highest, industrial buildings generally performed well although loss of sheets of cladding was not uncommon. Conversely, many caravans broke up or rolled over because of inadequate tie down. Water entry through vents or damaged soffits caused ceilings to collapse and water damage of contents.

Photo 5: Failure of the end wall due to interior pressurisation.

Photo 6: This entire building became flying debris, coming to rest wrapped around a light pole.

References

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