



**Investigation of housing and sheds in Proserpine, Midge Point
and Airlie Beach, following Tropical Cyclone Ului**

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**Investigation of housing and sheds in Proserpine, Midge Point and
Airlie Beach, following Tropical Cyclone Ului**

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Summary

Tropical Cyclone Ului crossed the coast in the early hours of 21 March 2010 with its eye passing over Proserpine. The cyclone path was across the islands of the Whitsunday group, including Hamilton Island. The Bureau of Meteorology classified the cyclone as a Category 3 as it made landfall.

A team from the Cyclone Testing Station carried out a survey immediately following Cyclone Ului in the Proserpine, Midge Point and Airlie Beach areas. This survey primarily investigated the damage to domestic houses and co-located sheds. Some inspections were conducted on commercial and light industrial properties. The damage investigation did not include infrastructure such as power, communications, strata-title buildings etc.

The damage survey found that;

- Peak gust wind speeds in the coastal regions surveyed were estimated to be in the order of 140 to 160 km/h.
- There was minimal structural damage as the peak gust wind speeds were estimated to be less than the design wind speed.
- In the few cases where structural failure did occur from wind loading, the damage was attributed to inadequate, missing or corroded structural components.
- Wide spread tree and vegetation damage (i.e. fallen trees) led to some structural damage
- There were many instances of failures of ancillary elements such as flashings, guttering, advertising signage, shade-cloth and vents.

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The CTS is very grateful to the residents who generously assisted this survey by volunteering information, answering questions and on occasions inviting the authors into their houses to inspect damage.

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2. Wind speeds

The intensity of cyclones is usually expressed in terms of the strongest gusts likely to be experienced, which is related to the central pressure, and structure of the storm system. The Bureau of Meteorology uses the five-category system shown in Table 2.1 for classifying tropical cyclone intensity in Australia.

Table 2.1: Australian tropical cyclone category scale

Cyclone Category	Gust Wind Speed at 10 m height in flat open terrain			Central Pressure hPa
	km/h	knots	m/s	
1	90 - 125	49 - 68	25 - 35	990
2	125 - 164	68 - 89	35 - 46	970 - 985
3	165 - 224	89 - 121	46 - 62	950 - 965
4	225 - 279	121 - 151	62 - 78	930 - 945
5	> 280	> 151	> 78	< 925

The impact wind speed on a structure is dependent on its position relative to the cyclone's path, diameter and forward speed. The structure's position relative to the path will also dictate the change in wind direction during the course of the event.

There will be an increase of wind speeds due to speed up over steep topography.

2.1 Measures of wind speed in the surveyed area

The Bureau of Meteorology operates an Automatic Weather Station (AWS) at Proserpine Airport located about 30 km inland. The gust and mean wind speed measured at 10 m height, and the corresponding approach wind directions (i.e., from the North is 0° and from the East is 90°), are given in Figure 2.1 and Figure 2.2, respectively. The AWS was located in open terrain with an unobstructed fetch in the direction of maximum winds. The maximum gust wind speed measured was 146 km/h (41 m/s) at approximately 2.00 am with the wind approaching from the South. This is followed by a rapid reduction in wind speed and a change in direction as the "eye" passed over the AWS. A lower peak gust wind speed from a Northerly direction was then observed at around 3.30 am. The minimum recorded barometric pressure was 980.5 hPa at 2:25 am.

The AWS at Mackay recorded a maximum gust of 106 km/h (30 m/s) from an Easterly direction.

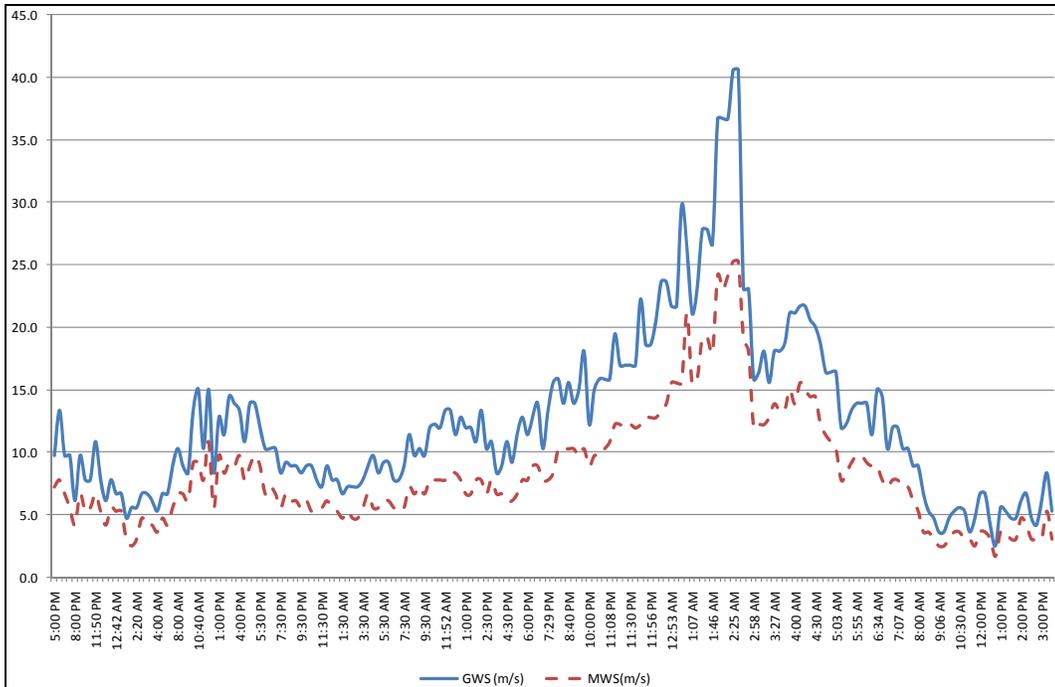


Figure 2.1: Gust and mean wind speeds measured at the AWS-Proserpine Airport
(Courtesy Bureau of Meteorology)

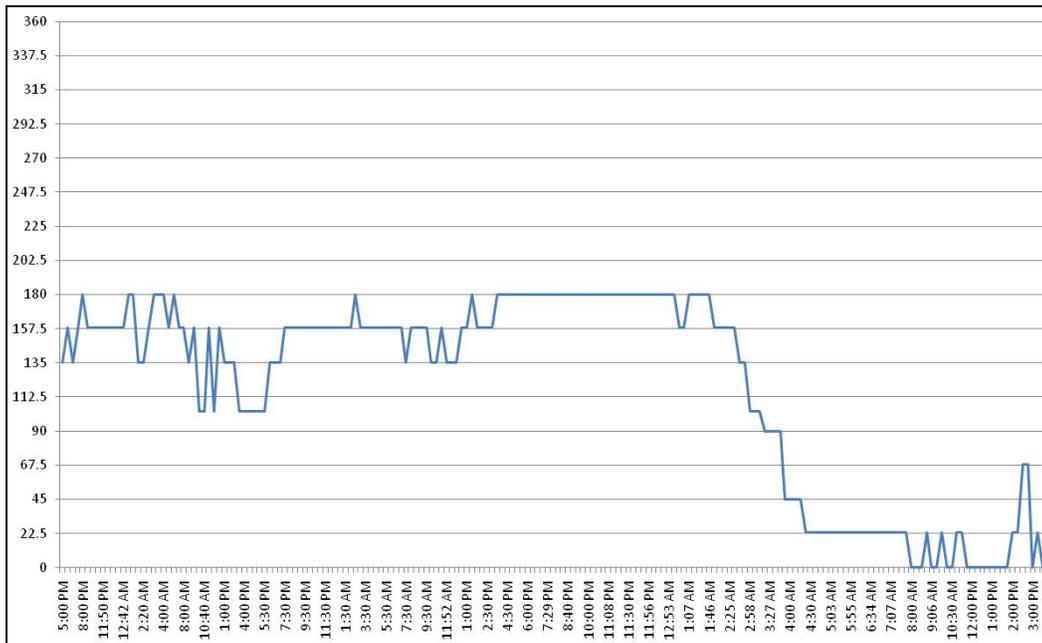


Figure 2.2: Wind directions measured at the AWS-Proserpine Airport
(Courtesy Bureau of Meteorology)

Midge point located on the coast, approximately 40 km to the SSE of Proserpine was estimated to be just outside the eye and likely experienced the largest wind speeds.

Residents in Proserpine reported that the eye of the cyclone passed over their homes, lasted about an hour and there was a complete change of wind direction.

A first hand detailed account from a Proserpine resident about the timeline for passage of the eye (he was in his home in Fuller St), is as follows;

- Before the eye, wind coming from the South (hand held anemometer with reading of 115 km/hour).
- Sunday 21 Mar, at 2:10AM, no wind at all.
- At 3:15AM, the wind came back, “very gusty”, blowing from the North.
- About 4:15AM wind even stronger and “more steady”
- About 6:30AM, very quiet, “No wind”

Cantilevered road signs provide a means of obtaining a measure of the spatial variation of gust wind speeds in the surveyed areas. These signs are generally flat plates that are attached to one or two cantilevered posts and located in exposed flat terrain adjacent to the road. The wind loads acting on these plates can be calculated and upper (U) and lower (L) bound wind speeds from signs that were bent-over, shown in Figure 2.3, and those that remained upright, as described in the CTS report on TC Larry (Henderson et al 2006, Ginger et al 2007).

Basic analysis of cantilevered road signs and qualitative assessment of damage, suggest gust wind speeds in the order of 140 k/hr in Proserpine and Airlie Beach to approximately 160 k/hr (45 m/s at 10m height in open terrain), in the vicinity of Midge Point, as shown in Figure 2.4. The Bureau of Meteorology states that the larger gust wind speeds measured at Hamilton Island resulted from the enhanced exposure of the site.



Figure 2.3: Bent road signs and measurement of pipe dimensions

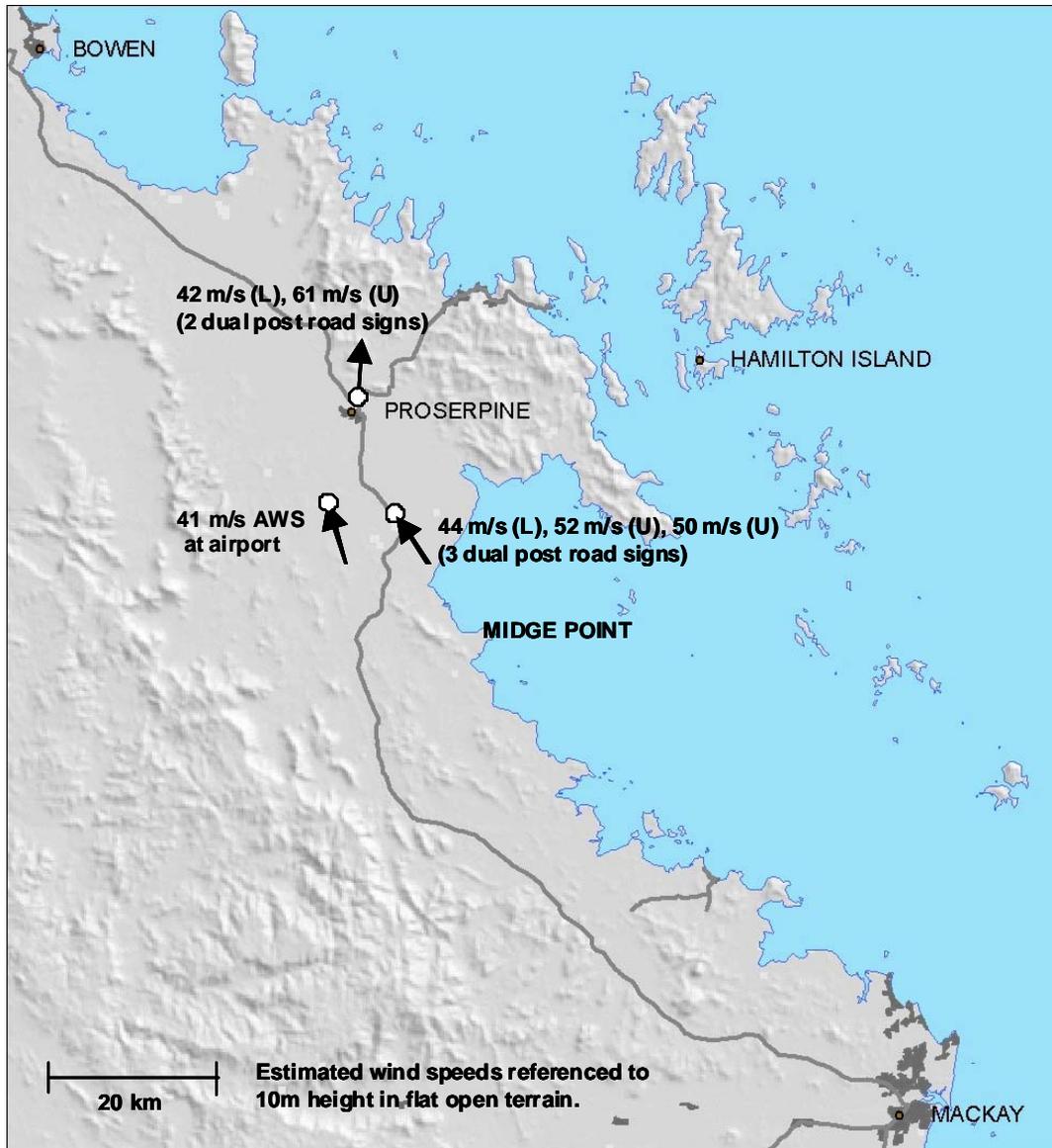


Figure 2.4: Estimate of wind speeds and direction

2.2 Design wind speeds

The Australian Building Codes Board (ABCB) publishes the Building Code of Australia (BCA 2009) which stipulates design parameters for the majority of buildings in Australia. These requirements are met by compliance with a range of Standards relating to building construction (e.g. AS/NZS1170.2 (Standards-Australia 2002)). Codes and standards have been used in the design and construction of engineered structures in Australia, for several decades.

Houses in Townsville and Darwin suffered significant damage during Cyclone Althea and Cyclone Tracy, respectively in the 1970s. This precipitated the development of the Home Building Code of Queensland (1975 - 1984) as an Appendix 4 to Standard Building by-laws,

which was in widespread use by the mid 1980s. This required homes to be categorised by site design wind speed at eaves height, and it contained deemed to satisfy detailing for the different categories.

The Whitsunday region is located in Cyclone Region C as defined in AS/NZS1170.2 (2002), where the ultimate limit state design wind speed (in flat open terrain) is 69 m/s. The design wind speed at the roof height of the building is factored to account for the terrain, height and the topography. This factored design wind speed impacting on the building can be related to the pressures exerted on its elements through a series of coefficients defined in the wind loading standard, AS/NZS1170.2 (2002).

3. Damage to domestic construction

The vast majority of housing and co-located sheds had little or no damage, as expected since the wind loads were well below the design levels for the region. There was a significant amount of vegetation and tree damage, with some cases of fallen trees causing structural damage to buildings.

A street survey of the houses located in the Midge Point area was conducted. A street survey provides an overview of types of damage observable from the street, that is, any damage to the rear of a structure is typically missed. However, the benefits of the street survey provide a measure of overall damage types and enable a comparison in structural performance of building types subjected to similar wind speeds.

Estimates of damage to the houses exterior were collated to give an estimate of damage types. Of the 80 houses surveyed, only six percent suffered structural damage due to the wind loads as opposed to damage caused by from fallen trees. The six percent were all built prior to the 1980s with loss of some roof cladding through to loss of complete roof structure. It was estimated that approximately 20% of the houses surveyed were constructed prior to the mid 1980s. In addition to the 6% with significant structural damage, approximately 10% of the houses had observed damage to ancillary elements such as guttering, flashings, awnings, etc.

Complementing the street survey data from Midge Point, areas of Proserpine, Cannonvale, Bloomsbury and Airlie Beach were traversed by the survey teams, gathering an overview on the damage to houses with details collected on wind damaged buildings where appropriate.

3.1 Current construction

Typically housing that was constructed in the past 30 years survived with minimal structural damage from the wind loads, as shown in Figure 3.1. There was observed damage from fallen trees.

There were examples of loss of guttering, TV antennas, window sun shades and awnings across the surveyed areas. A few roof ventilators (“Whirly Birds”) were missing with some others starting to flatten out (pancake) due to the centrifugal forces from the spinning.

There were many reports of water ingress via undamaged doors, sliding door/window tracks, and vents. It was reported by householders that the water was driven into the house typically in the order of 2 m. Discussions with residents provided anecdotal evidence that storm shutters over windows and doors prevented water ingress.



Figure 3.1: Houses splattered with vegetation but structurally resisted loads

3.2 Co-located sheds

A number of properties had co-located sheds near the houses (i.e. back yard sheds) and used as workshops or garages for boats and cars. These sheds were of recent construction, typically steel clad and built from cold-formed sections with two to three bays each fitted with a domestic roller door (i.e., a rolling curtain door with a continuous sheet rather than linked slats).

In the Midge Point area, several shed roller door failures were observed, with an example shown in Figure 3.2. However, several other shed doors of similar dimensions, construction and orientation were still intact. Conversations with the owners of the sheds with intact roller doors revealed that these doors had been strengthened by various means, such as temporarily installing taut steel wire ropes behind the doors (e.g., Figure 3.3), erecting internal timber struts, or even backing cars onto the door from the inside.



Figure 3.2: roller door failure

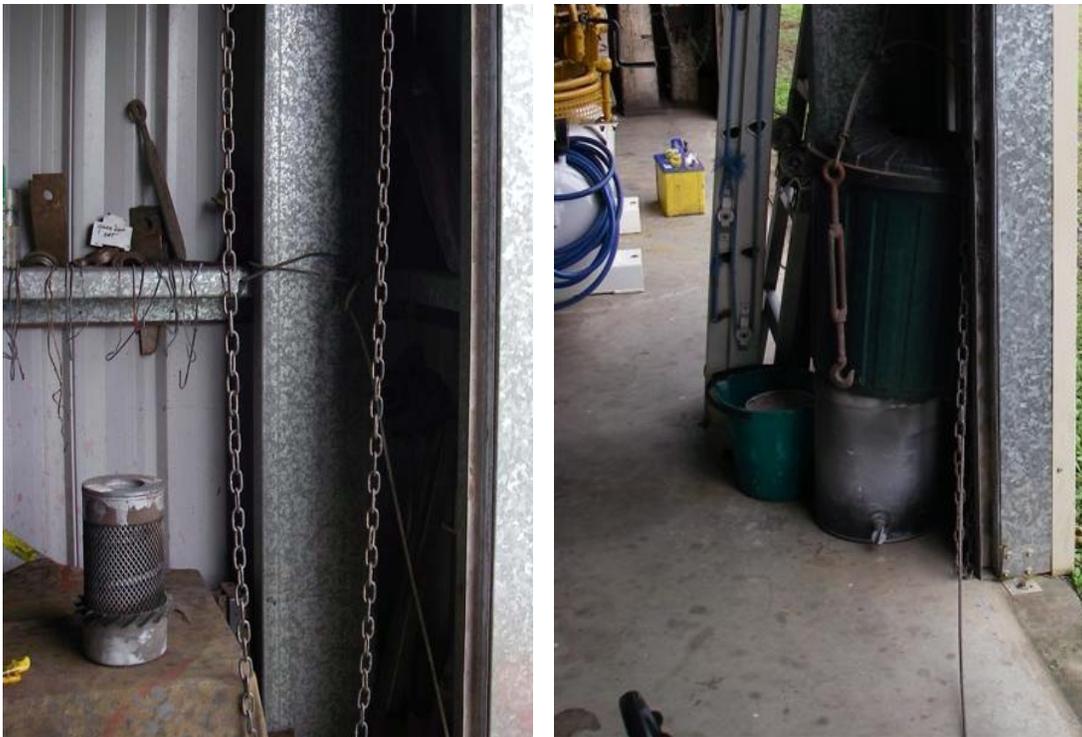


Figure 3.3: Steel wire rope and turnbuckle used to support roller doors

3.3 Older construction

Less than 10% of the surveyed older houses, that were built at least 40 years ago, suffered significant structural damage, due to the wind loads, typically the loss of roof cladding and roof structure.

In these few instances the failure typically originated at the batten to rafter connection with the nailed connections not having sufficient load carrying capacity. Figure 3.4 and Figure 3.5 show loss of roof structure (cladding and battens) caused by failure of batten to rafter nail connections. The battens were nailed to the trusses or rafters, with only one nail at some batten to rafter joints. Examples are shown in Figure 3.6 and Figure 3.7.

The current timber framing standard AS1684.3 (2006) details batten screws or galvanised straps for the batten to rafter connections for the edge zones of a metal clad roof. In some cases the roofing had been replaced without any strengthening or upgrading of the connections of the roof batten to rafter or rafter to top plate. Loss of the entire roof structure is shown in Figure 3.8, where the roofing had been replaced and screwed to existing battens. The rafter to top plate connections, which consisted of skew nails and some metal strapping, was not sufficient to resist the wind loads. Large elements of the roof had travelled approximately 200 m down wind. Figure 3.9 shows cladding torn over roofing screws at edge batten.

Corrosion of fixings and/or degradation of the timber framing elements contributed to the reduction in wind resilience of the house. In a few cases, the loss of cladding was due to corrosion of cladding and/or fixings. These types of failures were also observed in older houses in Innisfail following Tropical Cyclone Larry (Henderson et al 2006, Ginger et al 2007).

It should be noted that housing should be inspected for areas of potential hidden damage, for example partial withdrawal of batten nails into rafters where the roof structure seems “springy” to walk on. This partial loss of resilience has been observed following events such as Cyclone Larry (Ginger et al 2007) and Cyclone Vance (Boughton 1999).



Figure 3.4: Failure at batten to rafter connections on windward face of house



Figure 3.5: Roof leaf lifted from the side of house and laid on leeward face of roof, with hip flashing still attached.



Figure 3.6: Roofing screwed to battens but insufficient strength at batten to rafter connections



Figure 3.7: Insufficient capacity at batten to rafter joint



Figure 3.8: Loss of cladding, battens and rafters showing skew nails and strap at top plate



Figure 3.9: Failure of under strength batten connection followed by tearing of cladding over cladding screws spaced too far apart

4. Damage to commercial/industrial properties

Structurally the majority of engineered buildings performed well. Some industrial sheds and commercial buildings lost wall cladding and flashing elements due to inadequate fixings, as shown in Figure 4.1 and Figure 4.2 respectively. Failures of sidewalk awnings and covered areas were noted, with some elements being dislodged and adding to wind borne debris.



Figure 4.1: Loss of cladding



Figure 4.2: Loss of flashing on side wall (relative to wind direction)

The Proserpine Sugar Mill lost a significant portion of the roof to one of its older mill buildings, as shown in Figure 4.3. CTS inspectors spoke to staff from the mill, on the day after the cyclone struck and were allowed to take photographs of the failure from outside the building but not able to conduct a closer inspection as a safety clearance had yet to be completed on the damaged building. Figure 4.4 (a) is a view of the South facing wall (that is, the windward wall prior to the passage of the eye) and damaged roof.

Figure 4.4 (b) is a more detailed view of some of the remnants of the failed steel purlins and roof cladding still attached to the building. Some sections of roof panels (cladding and steel purlins) were completely missing, but it was not possible to determine a likely cause of this failure without a closer inspection.

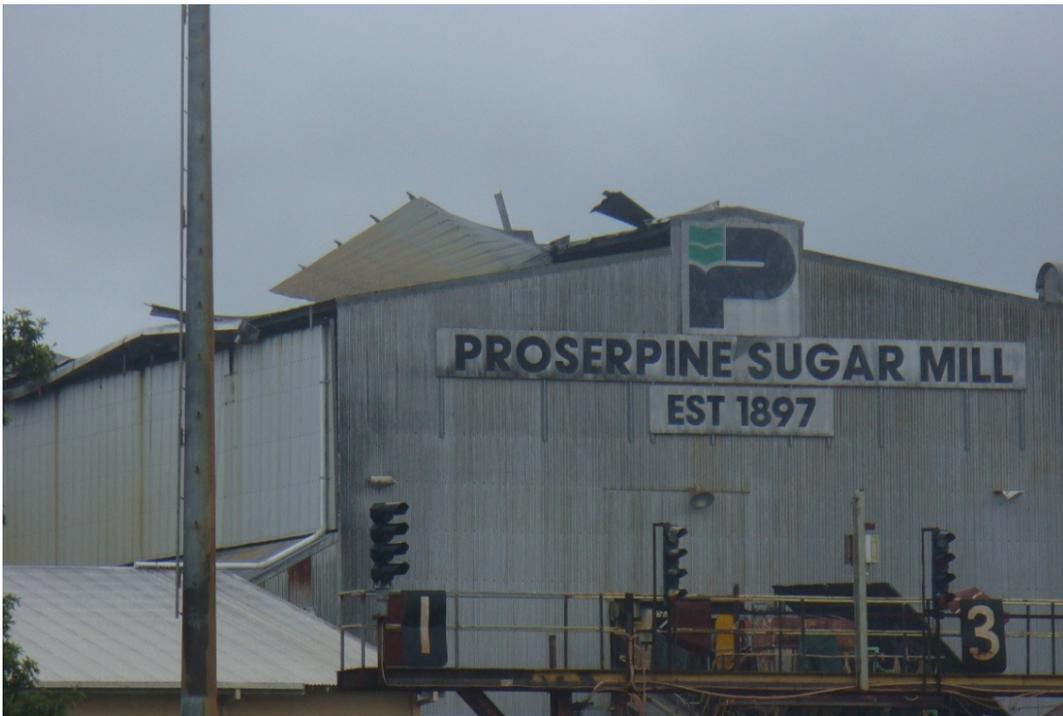


Figure 4.3 General View of Roof Failure to Proserpine Sugar Mill Building



(a) General view of South facing wall

(b) Detail of roof failure

Figure 4.4 Views of damaged roof from outside Mill building

Figure 4.5 shows failure of batten to rafter nailed connections in an old farm shed. The shed was located adjacent to housing.

**Figure 4.5: Failure of batten to rafter connections in old farm shed adjacent to housing**

A commercial shed suffered collapse of entire structure due to severe corrosion of major framing elements, as shown in Figure 4.6. The structure had an open south face towards the predominant wind direction. The intense Southerly winds generated large internal pressure causing the failure of the severely corroded base connection of the first frame (Figure 4.7), pulling out of the adjacent frame's 700mm deep footings.



Figure 4.6: Overall failure of shed



Figure 4.7: Failure of severely corroded portal frame near the base

There were a number of instances across the survey area where shade cloth, used as open canopy roofing, had failed due to wind loading, as shown in Figure 4.8 and Figure 4.9.



Figure 4.8: Shade cloth failure at a shopping centre car park



Figure 4.9: Damaged netting on commercial crop protection

It was observed that many of the commercial illuminated signage had not resisted the wind pressures, as shown in Figure 4.10. Damage to signage ranged from small hotel signs through to the large shopping centre signage. The “plastic” inserts had fractured or popped out of the frames exposing the lighting inside. In these instances the support structure stayed upright. These “inserts” do not appear to be designed and checked for structural adequacy for cyclonic regions, and are prone to failure in windstorms.



Figure 4.10: Examples of failure of signage elements

5. Other types of damage

5.1 Attachments and ancillary elements

Inadequate design and attachment of elements such as fascias, guttering and awnings can lead to damage to structure, increased water ingress and contribute to wind borne debris. Loss of gutters and down pipes was observed, as shown in Figure 5.1 and Figure 5.2. Figure 5.3 shows a failed solar hot water panel.



Figure 5.1: Loss of guttering and downpipes



Figure 5.2: Loss of guttering



Figure 5.3: Solar panel failure in Cannonvale

5.2 Damage from trees

The cyclone caused widespread tree damage with the exception of Cannonvale and Airlie Beach where the total number of fallen trees observed was considerably less.



Figure 5.4: Shed destroyed by fallen tree



Figure 5.5: Roof damage to newer house by fallen trees

5.3 Wind borne debris

Failed elements, such as roofing, awnings, guttering, flashings etc, were blown by the wind. In some cases the roofing elements travelled more than 200 m, highlighting the threat to life safety and potential for further damage to other structures.

Correct design and installation of materials is required.

Early preparation in the removal or securing potential objects and structures that could become wind borne debris was evident. These actions certainly played a part in minimizing the damage.

As the cyclone had a large eye diameter and decreasing intensity, this resulted in return winds (after the passage of the eye) of lower velocity than the first pass. Debris generated from the first pass was not able to be blown back again from the returning winds.



Figure 5.6: Failed roof cladding 60m downwind of shed



**Figure 5.7: Loss of majority of roof blown over 200m downwind
(From the house shown by arrow)**

There was considerable tree damage with broken off branches and fallen coconuts, etc, along the foreshore of Midge Point. However, there was surprisingly little damage to building envelopes by wind borne debris along the first row of houses, with only very few windows broken. Research by the CTS and other institutions, has shown that for debris to become airborne in windstorms a certain threshold wind velocity must be exceeded. This value is governed by relationships of available debris geometry and density. The lack of damage observed here suggests that although the wind velocities were large enough to break off tree branches and coconuts they were not sufficient to initiate and sustain flight.

Furthermore, where wind borne debris impacts occurred, the impact velocities were not sufficient to induce significant damage to the building envelopes, apart from a small number of broken windows. This observation is consistent with current research in the way that the resultant damage is a function of debris velocity, mass and impact area. It has been found that for brittle materials such as glass or fibre cement (most houses here were clad with fibre cement sheeting) there is no range of deformation damage, the damage threshold virtually divides the states of intact/undamaged and punctured/shattered.



Figure 5.8: Broken windows

5.4 Deterioration of components

Many of the failures observed were initiated from structural elements suffering severe deterioration (i.e. corrosion or rot). Structures require correct specification and installation of materials to suit the level of exposure, combined with ongoing maintenance. The ongoing maintenance is particularly important in cyclone regions as it may be many years until a severe cyclone impacts the building. Severe corrosion of cladding is shown in Figure 4.7, Figure 5.9 and Figure 5.10.



Figure 5.9: Corrosion in cladding adjacent to screw



Figure 5.10: Severe corrosion of cladding

6. Conclusions

Overall, there was minimal structural damage caused by wind loads. Where failures caused by wind forces (not falling trees) were observed they were associated with older construction, deterioration (corrosion or rot) of fixings and members, or inappropriate products or incorrect construction practice on newer structures.

The main conclusions from this survey of damage caused by Cyclone Ului are:

- The estimated peak gust wind speed in the surveyed areas was about 140 to 160 km/h
- The vast majority of houses resisted the wind forces. However this should be expected as the estimated peak gust wind speeds were significantly less than the design wind speed.
- Some failures attributed to inadequate, missing or corroded structural components.
- There was widespread tree & vegetation damage

7. Recommendations

It is recommended that the following issues be considered:

- Reconstruction and repairs should be carried out in accordance with relevant Standards.
- For the rebuilding or upgrading of older housing, the complete load path from roofing to foundations, and not just from roof cladding to battens, needs to be considered. This may not always be feasible so at the very least (pragmatic approach for partial solution) upgrade from roofing to top plates of walls. This includes the rafter to top plate connection and strapping from rafters and ridge plates to ceiling joists and tops of internal walls. Reference should be made to documents such as the Standards Australia handbook for the upgrading of older housing HB132.2 (1999)
- Specify and use appropriate materials suitable for the site exposure conditions.
- Ensure that illuminated signage is designed and constructed so that it can support specified wind loading
- Domestic and commercial roller doors including mullions etc. be designed and installed so that they can support design wind loading.
- Shade cloth either be designed for 500 year return period wind speed or taken down during cyclone preparation stage.
- Regular inspection of structural elements (including in the roof space) to look for signs of deterioration (e.g. corrosion, rot, etc).

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