Weak links let down strong buildings

Photo: AFP PHOTO / Shelly Alsop

On 13 March, one of the strongest tropical cyclones ever recorded made landfall in Vanuatu, crippling the country's infrastructure. Many buildings were severely damaged, with media reports of 90% damage in some areas.

According to James Cook University Cyclone Testing Station (CTS) director David Henderson, that event is a strong reminder of the need to remain vigilant in ensuring Australian buildings are designed and built to withstand such extreme weather events.

Queensland communities recently braced as Tropical Cyclone (TC) *Marcia* approached the coast as a Category 5 event. Fortunately, it crossed the coast at the sparsely populated Shoalwater Bay and rapidly dissipated as it moved south.

"Bureau of Meteorology measurements showed that by the time it had reached Yeppoon, the peak gusts were about 155 km/h or Category 2 and at Rockhampton they were about 115 km/h or Category 1," Henderson said.

However, there is a perception among some members of the community that the region had survived a Category 5 cyclone. Henderson is concerned this may result in complacency in the building industry.

"If a community thinks that they have experienced a Category 4 or 5 cyclone when it has actually experienced Category 1 or 2, there is a real risk of complacency in future events. This can place communities at risk," Henderson said.

"There are some important points that need to be understood. The wind speeds in Yeppoon would have resulted in pressures less than 55% of the design pressure and as such, the large number of failures is an indication of unacceptable building performance, whether due to design or construction issues or deterioration of materials."

In the aftermath of TC *Marcia*, Henderson joined forces with the immediate past chair of Engineers Australia's Structural College Board, Rob Heywood, to study the engineering implications. Heywood is an Urban Search and Rescue (USAR) engineer who was deployed with a USAR team to the region impacted by *Marcia*. Fortunately, rescue operations were not required, so the attention turned to damage assessments in the area. The CTS's damage assessments have been a key part of improvements to building codes and standards since Cyclone Tracy devastated Darwin in 1974.

What they discovered was at once encouraging and disturbing, given that most structures were not damaged in the cyclone but a significant number did experience failures well below design wind strength.

"As with previous cyclones, most of the damage in Cyclone *Marcia* arose from issues with the way structures were tied together", Heywood said. "If there is any weak

link in the load path, the wind will invariably find it and often unzip the structure."

According to the pair, common problems for older buildings were inadequate fixing of battens, rafters and top plates, as well as corroded connectors and the absence of tie-down. Failed windows and garage doors also led to pressurisation of structures and water ingress.

Another significant issue was the failure of roofs that had been replaced on older buildings. There were numerous examples of new roof cladding still with battens and rafters attached, essentially intact, being blown off the house leaving the walls still standing and the contents of the house open to the elements.

Heywood said "There is something inherently wrong when owners make an investment in a new roof, only to see it blown away because the next link in the tie-down chain was not upgraded at the same time. When roofing is replaced, the complete load path from roofing to foundations needs to be considered, and not just from roof cladding to battens".

A more concerning issue identified is that the damage was not constrained to older structures. There were numerous examples of substantial damage inflicted to new medium rise and industrial buildings. In these cases, the damage was primarily to "secondary" elements such as roller doors, flashings, fascias and the linings of eaves, along with air-conditioning plant, antennae and parapets being blown from buildings into the streets below.

"This should not have occurred at the wind speeds experienced, which were less than the serviceability limit state wind speed and hence below the nominal damage threshold. One can only imagine the level of damage that would have resulted from an event approaching the ultimate design wind speed," Heywood said.

"This issue is not restricted to cyclonic areas as the damage that occurred at Rockhampton did so for wind speeds less than the damage threshold wind speed for all regions of Australia, although the duration of cyclonic wind events are generally much longer."

The failure of these "secondary" elements, and the consequent water damage, has resulted in significant cost to owners, tenants and insurers.

"The engineering profession is in a position to manage these risks by ensuring the engineering design of these secondary elements does not slip through the gaps between the responsibilities of multi-disciplinary design teams," Heywood said.

Areas for improvement include ensuring these "secondary" elements are actively considered in the wind engineering design, according to Heywood. *Marcia* has demonstrated that simply screwing exposed air-conditioning equipment into the roof sheeting is inadequate, he said. Substantial flashings also require wind engineering design, if they are to remain intact in edge zones where the wind pressures are highest. Likewise, vent covers need to have demonstrated compliance for wind loads and ultra violet exposure.

Flashings, fascias and eave linings from new buildings sometimes ended up on the street.

Inattention to load paths left what was a newly installed roof, essentially intact upside down among the trees.

Heywood also said that flashings, fascias and soffits are part of the envelope of the building and need to be designed to withstand wind loads. Marcia had demonstrated that compromising these elements leads to water ingress and changes in internal pressure in the building with potentially damaging consequences to ceilings, walls and roofs, he said.

"Many structures in Yeppoon and Rockhampton suffered damage that was disproportionate to the intensity of the cyclone and so did not meet the requirement for structural robustness prescribed in the general principles section of AS 1170.0 Structural design actions," Heywood said.

"As engineers we can take simple steps to improve the situation by ensuring all elements exposed to the wind

Structural damage to houses left them open to the elements, causing a high insurance bill.

Rob Heywood (L) and David Henderson inspecting a damaged road sign in order to provide a lower bound estimate of wind speed.

are engineered and have redundancy, so that a progressive collapse is not a consequence of the failure of one element. It is also important that the durability of critical tie-down components is consistent with the life of the structure, especially in coastal areas and where maintenance access is limited."

There have been significant improvements in the design of buildings in recent decades, thanks in no small part to the work of the engineering community. However, it is clear that there is still work to be done to rectify the issues Heywood and Henderson have identified.

As well as Vanuatu's *Pam* and *Marcia* discussed here, Australia has recently been impacted by cyclones *Lam* (NT), *Olwyn* (WA) and *Nathan* (Qld, NT, WA). In these events, as in many previous cyclones,

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contemporary buildings have generally performed well. However, Henderson said it has been shown that overlooking what may seem like small details can have much greater consequences.

"We have seen significant failures of building components and unacceptable consequences at wind speeds much less than the design wind speed," Henderson said.

"We have to look at the full picture and get the detailing right so that buildings perform to expectation. This is important because our houses are where most of us seek shelter in a cyclone. Not only is adequate performance critical for the reputation of engineers and the building industry, but also the safety of our families and our communities depends upon it." ●