AIRCURRENTS

IN THE AFTERMATH OF CYCLONE YASI: AIR DAMAGE SURVEY OBSERVATIONS

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EDITOR'S NOTE: In the days following Yasi's landfall, AIR's post-disaster survey team visited areas in Queensland affected by the storm. This article presents their findings.

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INTRODUCTION

Severe Cyclone Yasi began as a westward-moving depression off Fiji that rapidly developed into a tropical storm before dawn on January 30, 2011. Hours later, Yasi blew across the northern islands of Vanuatu, continuing to grow in intensity and size and prompting the evacuation of more than 30,000 residents in Queensland, Australia. By February 2 (local time), the storm had achieved Category 5 status on the Australian cyclone scale (a strong Category 4 on the Saffir-Simpson scale). At its greatest extent, the storm spanned 650 kilometers.

By the next day, it became clear that Yasi would spare central Queensland, which had been devastated by heavy flooding in December. But there was little else in the way of good news. Yasi made landfall on the northeast coast of Queensland on February 3 between Innisfail and Cardwell with recorded gusts of 185 km/h. Satellite-derived sustained wind speeds of 200 km/h were estimated near the center (Figure 1), indicating that gusts over 250 km/h had likely occurred.

In addition to the intense winds, Yasi brought 200-300 millimeters of precipitation in a 24 hour period and a storm surge as high as five meters near Mission Beach.

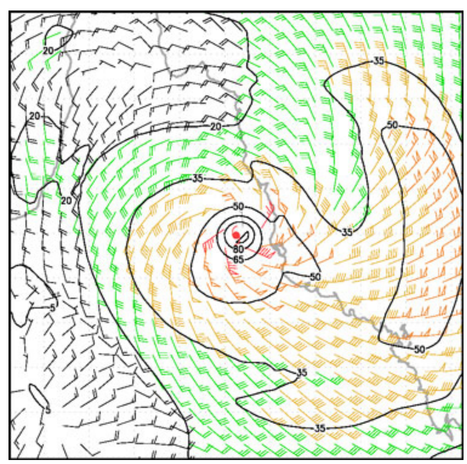


Figure 1. Satellite-derived 10-minute sustained wind speeds in knots just after Cyclone Yasi made landfall. Maximum winds to the left of center translate to 1-minute sustained winds of 200 km/hr. Source: NOAA-NESDIS-RAMMB

Those buildings that sustained the most significant damage were residential wood-frame structures with metal roofs, particularly older structures that predated the most recent building code. Newer commercial buildings sustained only minor structural damage. However, nonstructural damage—such as damage to windows and cladding and debris from trees—was more widespread. Other than property damage, Yasi also caused significant damage to Queensland's agriculture; in its March commodities outlook, the Australian Bureau of Agricultural and Resource Economics and Sciences estimated that Cyclone Yasi wiped out about AUD $300 million in production in the banana and sugar sectors.

Within hours after landfall, AIR estimated that insured losses to onshore properties, including business interruption, would be between AUD 355 million (USD 359 million) and AUD 1.5 billion (USD 1.5 billion). A week later, AIR's post-disaster survey team was on the ground, visiting affected areas in Queensland.

The damage left in the wake of Cyclone Yasi generated significant attention because it was the first time that newer, robust building standards were subjected to Category 5 wind speeds since 1974's Cyclone Tracy. Consistent with AIR's expectations, the team observed a higher incidence of damage to older buildings—generally those built before 1980—than newer ones, serving as a reminder that even regions with stringent building codes still have a mix of newer, code-compliant buildings and older, more vulnerable buildings. Yasi serves as a reminder, too, of the importance of bringing older structures in line with modern standards and to encourage, through appropriate incentives, homeowners and builders to adopt effective wind resistant standards.

CYCLONE TRACY AND AUSTRALIA'S BUILDING CODE HISTORY

Australia's first set of design rules for wind loads on engineered structures was established in 1952; these provisions were modified in 1971 to incorporate a contoured map of regional wind speeds in Australia and included wind speed modifiers based on terrain type and height above ground.

In 1974, Cyclone Tracy struck the northern coast of Australia near Darwin, killing 71 people, destroying or severely damaging the majority of the city's buildings and causing an estimated AUD $800 million of damage (1974 dollars). In Tracy's aftermath, the government conducted an investigation of building failures and developed new, more stringent wind loading requirements (AS 1170.2) and a revised wind speed map—including specific zones for cyclone regions along the coast. For the next several years, the loading provisions were periodically modified and in 1989, a major revision was implemented that incorporated changes in wind load standards and simplified the approach to determining wind loads for residential structures.

Salient features of the post-Tracy building codes included recognition of the impact of windborne debris, the effect of increased internal pressures due to openings created by window and door failures, and the importance of fatigue failure of cladding fastening systems. Indeed, one of the most important legacies from Tracy was the recognition that housing needs to be structurally engineered to properly resist wind loads. During the 1990s, the Insurance Council of Australia sponsored the development of guidelines for upgrading the wind resistance of old houses in coastal areas of Queensland, which were subsequently published by Standards Australia. Indeed, the AIR Tropical Cyclone Model for Australia has incorporated many of the engineering lessons from Tracy, particularly the effects of wind duration.

In 2002, the wind loading standards of Australia and New Zealand merged into a single publication in an effort to better ensure consistency across the countries. While building code enforcement is generally stringent across Australia, each state and territory is responsible for enforcing its own building and construction standards.

THE AIR SURVEY ROUTE

AIR's survey team landed in Cairns and traveled south, stopping at several tourist gateways to the Great Barrier Reef, including Cairns, Townsville, Cardwell, and Tully. The team captured information on broad damage patterns, as well as the response of individual structures and the factors that impact vulnerability, such as age, construction, roof type. What follows is a summary of their findings.

Figure 2. The AIR team started in Cairns, about 120 km north of the landfall point, and travelled as far south as Townsville. (Source: AIR)

CAIRNS: A FORTUNATE MISS

As Yasi approached the Queensland coast, the real fear was that it would make a direct hit on Cairns, a city with a population estimated at 160,000. In contrast to preliminary forecasts, however, Cairns narrowly escaped the storm's strongest winds. Most of the visible damage from the storm was observed along the Cairns Esplanade, a popular recreational area parallel to the shoreline. The storm surge of more than two meters above normal tide was reported, which was consistent with damage observations. Most notably, the storm surge had eroded the beaches and inundated the wooden boardwalk, causing a subsidence of soil beneath. Concrete barriers had been pushed inland about two meters.

Apartment buildings within the Cairns central business district, which are generally of newer high-rise reinforced concrete construction with significant glass exposure, escaped unharmed. Damage to commercial construction, which generally consists of one- to two- story masonry or steel framed structures with flat or metal roofing, was minimal and was largely restricted to signage or cladding on the canopies above pedestrian sidewalks (Figure 3).

Figure 3. Damage to signage along a shopping plaza in Cairns (Source: AIR)

TULLY (TULLY HEADS AND MISSION BEACH)

Tully and Mission Beach bore the brunt of Cyclone Yasi's powerful winds, and access to the worst affected areas was still restricted when the survey team arrived. They did, however, observe significant structural damage to many buildings along the perimeter of the restricted area. Damage to farm structures— mainly light metal storage buildings—was widespread. Figure 4 shows the deformation of the frame around the doorway and the door of a light metal shed. Typically, doors of light metal construction can be forced open by wind pressure or the impact of flying debris, with subsequent damage leading to more significant failures of the overall structure.

Figure 4. Metal sheds suffered deformation to doors and frames. (Source: AIR)

In downtown Tully, the majority of commercial construction is comprised of one-to three story buildings from the 1920s and 1930s, which are composed of a mix of wood, brick and masonry construction with sheet metal roofs. Figure 5 shows various degrees of cladding damage. While the wind speeds were certainly a factor, the team observed some inadequate fastenings and anchorage where the siding had been ripped off. Given the age of the structures in the area, deterioration of fasteners and connections may have hastened the failure of roofing and cladding components.

Figure 5. Buildings in downtown Tully with damage to exterior surfaces, exposing the frame systems beneath. (Source: AIR)

At the time of the survey, many of the stores along the main road still did not have their electricity restored. Indeed, business interruption may account for a significant percent of the final insured losses.

SOUTH TO CARDWELL

Further south along Highway A1, visible signs of damage were unavoidable. Federal and local work crews were collecting debris, cutting up downed trees and clearing roadways. Storm surge had left a line of debris extending inland to the roadway and up to the first row of structures—some 90 meters from the water line.

Cardwell consists mainly of residential structures, which are dominated by wood-frame buildings with metal roofing. Commercial construction here consists primarily of masonry also with metal roofs, as well as a mixture of metal and wood canopies located above the pedestrian sidewalks. The most noticeable residential damage occurred to roofing, where the team discovered that failure of cladding fasteners (or roof tie-downs) contributed to much of the visible structural damage. In some cases, the team observed failed metal roof sheeting, with battens attached, and pull-out of nails (Figure 6), which did not provide the needed resistance to uplift from the cyclone.

Figure 6. (left) Failure of metal roofing panels at the bolted connections; (right) Failed roofing panel showing nails which would have connected the roofing battens to the frame. (Source: AIR)

Prior to 1975, a common component of cyclone-resistant construction was the retrofit of buildings with so-called "cyclone bolts," connectors that extend from the top to the bottom of a wall for the purpose of tying down the roof. At the time, there was no design requirement for these bolts, and placement was left to the discretion of the builder. The effectiveness of cyclone bolts came into question during Cyclone Tracy and, around the same time, the government embarked on an initiative to standardize the wind loading code for the country. Nevertheless, the team observed instances in which the use of cyclone bolts, as indicated by the building owners, provided little or no effective roof uplift resistance or wall panel support (right panel of Figure 7).

Figure 7. (left) Newly constructed home with no damage; (right) older home, retrofitted with cyclone bolts, sustained significant damage. (Source: AIR)

Preliminary observations by various structural engineering teams, including AIR's, noted that overhead roller doors did not perform well under Yasi's wind loads. During Cyclone Larry in 2006, there was a high incidence of roller door failure and it had been well recognized at that time that roller doors did not adequately satisfy the wind load requirements of the building code. The door pictured in Figure 8 failed as a result of wind lock mechanisms or failure of the attachment to the door frame. While roof damage was not observed in this case, this type of failure can pressurize the building, leading to failure of the roofing system.

Figure 8. Failure of overhead roller door—a repeat of damage patterns seen in 2006 from Cyclone Larry. (Source: AIR)

TREE DAMAGE IN TOWNSVILLE

In Townsville, to the south, a maximum sustained wind speed of 106 km/h and a maximum gust of 135 km/h were recorded. Here, damage to roads, caused by uprooted trees and wind damage to commercial signage and canopies was prevalent. According to the Townsville city council, about three quarters of the city's trees were extensively damaged by Cyclone Yasi.

Considered the unofficial capital of North Queensland, Townsville is a large metropolitan area with a growing tourist population. As such, the dominant commercial construction along the coastal areas and marina consists of high-rise hotels and apartments composed of reinforced concrete and masonry. Figure 9 shows minimal window damage to the Holiday Inn, dubbed the "Sugar Shaker" by local residents. As would be expected in well-engineered steel and reinforced concrete structures, damage was limited to non-structural components.

As in Cairns, damage in Townsville was slight—generally in the form of beach erosion and windows broken by flying debris. A few residential structures sustained roof damage; the ones that did were damaged by fallen tree limbs, rather than by significant wind loading.

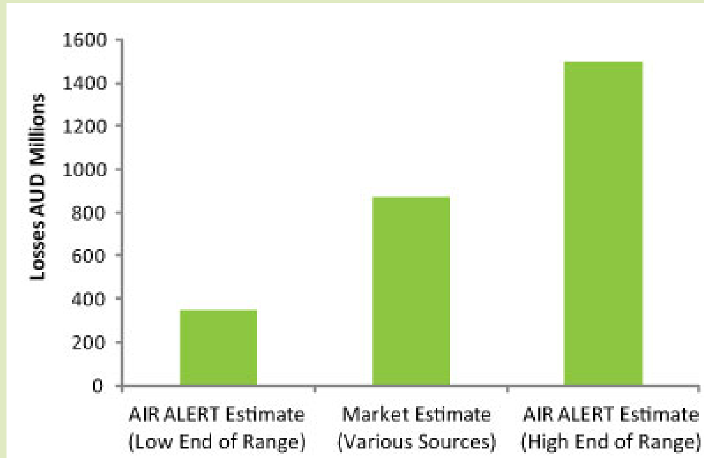
Figure 9. Plywood covering window damage at the Holiday Inn in Townsville. (Source: AIR)

Model Performance in Real-Time

Cyclone Yasi made landfall between Innisfail and Cardwell around midnight (local time) on Feb. 3. On the same day, AIR estimated that insured losses to onshore properties would likely fall between AUD 350 million (USD 354 million) and AUD 1.5 billion (USD 1.5 billion). Within the week, AIR dispatched engineers to survey the damage in Cairns, Townsville, and Cardwell, and Tully. The damage observed in the field was consistent with expectations for a storm of this size and intensity, given the dominant construction types and engineering practices in the region.

After a record number of catastrophes over the last few months, it will take some time before the industry has a final figure of the total insured loss from this event. Model results generated in real time indicated that the modeled market share-based loss estimates for insurers were in good agreement with reported losses. The figure below shows the results of AIR's analysis of market share-based loss estimates (produced using the AXCO Insurance Market Report) compared to insurers' estimates of loss from Cyclone Yasi published as this article went to press.

While companies continue to assess their losses in the months ahead, model users can feel confident that the AIR Tropical Cyclone Model for Australia reasonably reflects losses from this type of event and serves to validate the methodology behind AIR's model.



CLOSING THOUGHTS

Cyclone Yasi was the most powerful category 5 tropical cyclone to cross the Queensland coast since 1918 and put Australia's strict wind engineering building codes, which have been significantly strengthened since Cyclone Tracy in 1974, to the test.

With the exception of the performance of roller doors and tiled roofs in some older buildings, the patterns of damage at the reported wind speeds were consistent with expectations. While modern buildings performed well, this event will likely prompt a reassessment of the building code with respect to wall bracing, tie-down points, and the design criteria of roller doors. Recently, there has also been discussion to extend the parameter of the high-wind zone further inland. However, damage to older houses, particularly ones built before 1975, suggests that there have been challenges to bringing older homes into compliance with current building codes.

Despite the cyclone threat to Queensland, the number and value of exposed properties along the coast continue to increase with growing populations. Building codes and standards continue to be strengthened, although many older structures, susceptible to severe wind damage, remain. For its part, AIR continues to perform post-disaster surveys of significant events around the world, findings from which are used to refine and advance the models.

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