Cyclone Tracy 30-Year Retrospective

Risk Management Solutions

CHARACTERISTICS

Cyclone Tracy struck the city of Darwin on the northern coast of Australia early Christmas Day, 1974, causing immense devastation. Small and intense, Tracy's recorded winds reached 217 km/hr (134 mph; strong category 3 on the 5-point Australian Bureau of Meteorology scale) before the anemometer at Darwin city airport failed at 3:10 am, still 50 minutes before the storm's eye passed overhead. Satellite and damage observations suggest that Tracy's winds topped 250 km/hr (155 mph), and the storm's strength is generally described as a category 4. It was also the smallest tropical cyclone ever recorded in either hemisphere, with gale force winds at 125 km/hr (77 mph) extending just 50 km (31 miles) from the center; the eye was only about 12 km (7.5 miles) wide when it passed over Darwin. Remarkably, Tracy's central pressure was estimated at a somewhat average 950 mb which is unusually low given the wind strength.

Tracy formed on December 20 about 700 km (435 miles) north-northeast of Darwin. It intensified rapidly and became a named storm within 24 hours. Moving south-westwards, Tracy was expected to pass well to the north of Darwin, and ABC radio famously reported that it posed no threat to Australia's mainland on December 22. Early on December 24, however, Tracy made a sudden change in direction steering directly toward land. It passed directly over Darwin between midnight and 7:00 am the next day with a slow forward speed of around 6 km/hr (less than 4 mph).

In addition to the 220+ km/hr (136 mph) winds, close to 255 mm (10 inches) of rain fell on Darwin within the first 24 hours, compounding the damage. Storm surge also reached 1.6 m (5.3 ft) in the city harbour and 4 m (13 ft) at Casuarina Beach to the east of Darwin.

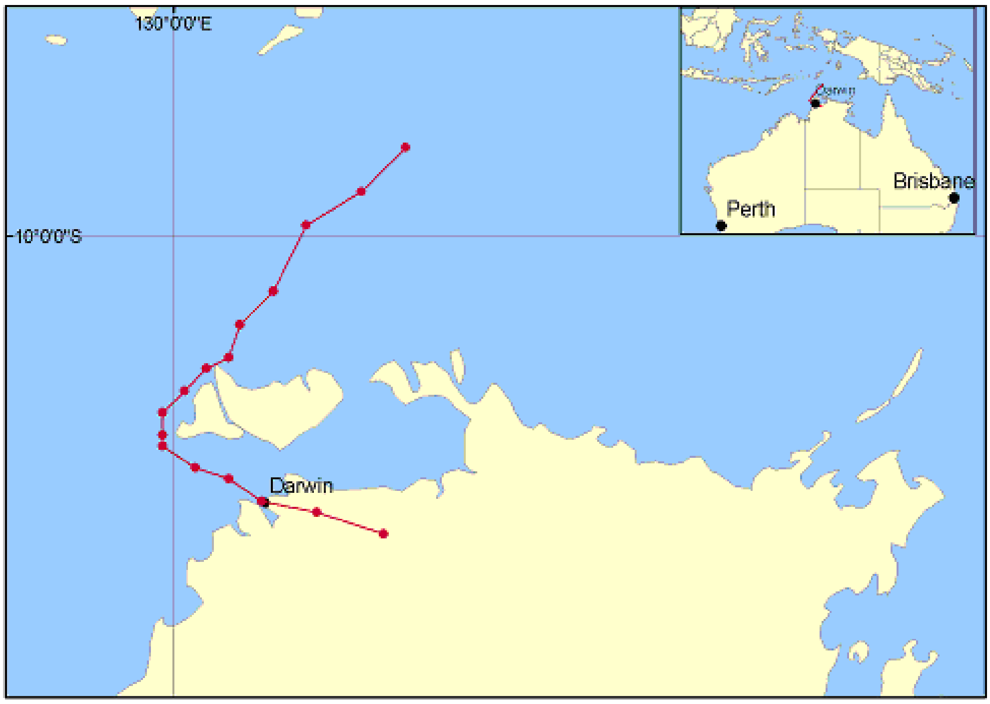

Figure 1: Path of Cyclone Tracy, December 1974

SUMMARY

Tracy was one of the worst natural catastrophes in Australian history. In 1974, Darwin had about 40,000 residents – about half of the Northern Territory population – and Tracy's official death toll reached 45 in Darwin with another 16 deaths at sea; 500 people were injured. But, the legendary nature of Tracy came from its structural devastation. About 60% of the 8,000 houses in Darwin were destroyed, and more than 30% were severely damaged. Only 6% of Darwin's housing stock survived with anything less than minor damage. In the northern suburbs of Darwin, close to 100% of all residential properties were ruined.

Figure 2: Damage from Cyclone Tracy in the residential neighborhood of Amsterdam Circuit (National Archives of Australia (NAA))

The dramatic scale of devastation required drastic measures and government officials aimed to reduce the population by three-quarters, down to 10,500 people, almost immediately. Approximately 10,000 people left within the first two days of the disaster and a number of additional measures were taken to encourage evacuations. Within six days over 25,000 people had been evacuated by air and another 7,000 by road. Armed personnel were recalled from holiday leave, and relief agencies set up depots at airports and kitchens along the road to greet the evacuees. Police also established mobile patrols and emergency shelters along the travel routes. By December 31, only 10,638 people remained in Darwin.

Access to the city was restricted for six months by permit system and only those individuals involved in the relief and reconstruction efforts were allowed into the city. This prevented many evacuees from returning and families and community ties were severed for many as a result. An influx of newcomers, particularly reconstruction workers, restored Darwin's population to around 33,000 by July 1975, and close to its original population by early 1978. In 1980, census data showed that 60% of the registered voters were not registered voters in 1974 – an indication that only 40% of Darwin's original population remained.

In the initial aftermath, the cruise liner Patris berthed at Darwin to provide temporary accommodation for 900 people. Mobile dwellings and pre-fabricated units were shipped in, and by May 1975 permits had been granted to construct 2,000 new homes. The building stock was almost fully restored by 1979.

The insurance payout for Tracy was the largest in Australian history at 200 million AUD (equivalent to 837 million AUD today, adjusting for inflation or US$637 million). Since then, it has been surpassed only by the1989 Newcastle Earthquake at 1.1 billion AUD (US$0.8 billion) and the 1999 Sydney Hailstorm at 1.7 billion AUD (US$1.3 billion). Following Cyclone Tracy, the Insurance Council of Australia established the Insurance Emergency Service which developed into today's Insurance Disaster Response Organization. The organization coordinates different elements of the insurance industry and the government following any disaster in the country in order to provide "timely and efficient assistance" to policyholders.

Reconstruction and Impacts on Building Codes

Tracy's legacy is without doubt the impact it had on wind engineering building codes. At the time, the Commonwealth Government was responsible for infrastructure and much of the housing design and construction through the Commonwealth Department of Housing and Construction (CDHC). Housing construction standards were assumed to have been cyclone resistant at the time of Tracy, and such widespread destruction triggered one of the biggest research initiatives ever undertaken into the cause of the failures. The findings formed the basis of some of the most stringent building codes in the world. The team in charge of the investigation, led by George Walker, then a senior lecturer at James Cook University, North Queensland observed that approximately 90% of all houses and 70% of other structures had lost part or all of their roofs. Loss of wall cladding and severe distortion of the houses were also found to be key characteristics. Buildings that had been certified by a structural engineer survived relatively intact in comparison.

Figure 3: Modern residential neighborhood damage Ross St., Darwin (NAA)

Post-war housing expansion in Darwin had been rapid since the mid 1950s, and it was the housing sector that took the brunt of the storm. In particular, fewer than 5% of the houses in the newer suburbs, built since the mid 1950s, survived. Although the pressure that Tracy's winds exerted on structures was within structural engineering design codes at the time, these codes were not usually applied to housing – they were mainly applied to engineered commercial buildings – leaving the residential building stock extremely vulnerable.

The investigative team discovered three factors that accounted for most of the damage: fatigue failures of cladding fasteners, internal pressures that were not allowed for in design, and lack of design for horizontal forces. Racking failures occurred because the walls did not adequately resist horizontal forces, due to the fact that neither the external wall cladding (typically fibro) nor the internal wall lining was securely fastened to the frame of the structure. The walls tended to "rack" or become unstable when they could not resist the shear forces. Lessons from Cyclone Althea, that struck Townsville three years earlier, had been incorporated into the newest buildings constructed in Darwin. Roof cladding had been tested to twice its working load but the testing had been done for static loads. Initial tests after Tracy showed that under fluctuating loading, such as what occurred during Tracy, the strength of the fastening systems was reduced significantly (to less than

15% of the original strength under static loads). In addition, broken windows, particularly on the windward side, caused greater internal wind pressures than assumed in the design with particularly severe consequences for roof tie-downs.

Figure 4: Damage to Smith St., Darwin (NAA)

A series of recommendations resulting from the investigation were implemented in the reconstruction by the Darwin Housing Commission (DHC). This followed the government's immediate resolution that Darwin should be reconstructed within five years. The government rapidly established a Darwin Reconstruction Commission (DRC), and the DHC was instrumental in testing housing component designs and systems with the latest technologies, including wind-tunnels and prototype GIS modeling of cyclone winds.

One of the key outcomes of the investigation was the requirement that a structural engineer must certify the design of all structures, including housing, in cyclone-risk areas. Design standards were increased to cope with full internal wind pressures and compulsory fatigue testing of roof cladding was implemented across all cyclone-prone regions of Australia. A workshop held in 1977 reviewed the criteria adopted in Darwin and formalized them in the publication known as TR440, Guidelines for Cyclone Product Testing and Evaluation. Its recommendations were adopted widely even before they were incorporated into normal standards and codes a few years later.

Early design rules for wind loading were first set out in 1952 by the Standards Association, which published its own code in 1971 as Australian Standard CA34, Part II. The 1971 revision included a map showing regional wind velocity contours (Regional Basic Design Wind Velocities) along with four terrain categories giving different multipliers for height above ground. The Regional Basic Design Wind Velocities map was updated in 1975 to include a zonal system for a strip along the northern Australian coast. Increased values of negative pressure coefficients were also included. These accounted for the impact of wall openings on internal pressures and resulted in an increase in design forces for structural elements including roof and walls. After several intermediary revisions, a major revision was published in 1989. The revision also simplified the determination of wind loads for low cost structures and those that are not particularly wind-sensitive, such as low-rise office blocks.

Future Concerns

The lessons learned from Cyclone Tracy and the research that followed have resulted in some of the most stringent building codes in cyclone-exposed areas across the world. However, no major storms have hit populated areas of Australia since Tracy and therefore the codes have not yet been fully tested. In Queensland, other notable cyclones, such as Winifred in 1986 and Aivu in 1989, would have tested the post-Tracy building codes but they made landfall in remote areas. There is some evidence from Winifred to suggest that improvements in building codes have reduced vulnerability but it was not a sufficient test from which to draw conclusions. The risk uncertainty has increased dramatically these past decades as significant new developments have occurred in many coastal areas of Australia, particularly Queensland.

Darwin itself was completely rebuilt to very high standards, and the landscape is now dominated by relatively new, structurally sound buildings. Most certainly, Darwin will be better prepared when the next cyclone strikes. But, the building stock in other cyclone-exposed cities of Australia is mixed. Most coastal cities are a blend of old, weak buildings and newer, stronger buildings, and a wide range of damage states are likely in future storms.

RESOURCES

The Impact of Cyclone Tracy on Building Design in Australia. Walker, G., AWES Workshop, Darwin June 2004.

A Commentary on the Australian Standard for Wind Loads, Holmes, J.D., Melbourne, W.H., Walker, G.R., Australian Wind Engineering Society, 1990.

Northern Territory Library Collection Information on Cyclone Tracy http://www.ntlib.nt.gov.au/tracy/

Australian Bureau of Meteorology http://www.bom.gov.au/climate/c20thc/cyclone4.shtml

Australian Government, National Archives of Australia (NAA) http://www.naa.gov.au/

