Cyclone Testing Station
Wind Engineering Research, Testing and Community Education

JAMES COOK UNIVERSITY AUSTRALIA

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Report for:

Suncorp Group Limited

Insurance Claims Data Analysis for Cyclones Yasi and Larry

Report prepared by:
Daniel Smith and David Henderson
Cyclone Testing Station, JCU

Report reviewed by:
J. Ginger and G. Stark
Cyclone Testing Station, JCU

Report prepared for:
Suncorp Group Limited

Cyclone Testing Station
College of Science, Technology and Engineering
James Cook University
Townsville Qld 4811 Australia
Telephone (07) 4781 4340
Email: jcu.cts@jcu.edu.au
www.jcu.edu.au/cts

Executive Summary

Suncorp commissioned the Cyclone Testing Station (CTS) at James Cook University to conduct a comprehensive study to enhance Suncorp's understanding of the vulnerability of houses in North Queensland to natural hazards, particularly tropical cyclones and thunderstorms. CTS is an independent authority on building performance assessment for severe wind events in Australia.

The original report of this work submitted to Suncorp included commercial in confidence sections, including specific policy data. In the interests of a public release, these sections have been removed.

Housing vulnerability is a large contributor towards high claims costs for Suncorp, and the subsequent premium affordability issues for consumers. Reducing this will decrease the risk associated with cyclones events, which can then be reflected in pricing for consumers. Suncorp has sought further understanding of the below challenges associated with housing vulnerability:

- *Property Details* – what property features contribute to increased vulnerability
- *Mitigation* - work that consumers can implement to reduce vulnerability
- *Building Codes* - what can be done to make an existing property more resilient
- *Collective Risk* - what can be done to reduce impact to neighbouring addresses

To address the above challenges, the objective of the study was to analyse Suncorp claims information from Tropical Cyclones Yasi and Larry to determine parameters that differentiate cyclone-resilient housing stock from non-resilient stock. This was achieved by extracting qualitative and quantitative insights from aggregated Suncorp claims and policy data, including properties with and without claims from these events. Assessor reports as a subset of the claims data were also used to support the analysis.

Key Findings

<u>Insurance loss drivers</u>

The claims data clearly indicate the majority of damage sustained in cyclones is a result of:

- Roof damage
- Window damage
- Water ingress (predominantly the entry of wind-driven rain into home structures)

These types of damage are typical for moderate to large sized claims (above 10% of the property's sum insured), which represented 71% of losses from Cyclone Yasi. In the Tully/Mission Beach region, large claims (above 50% of the property's sum insured) accounted for 9% of total claims but 38% of the total claims cost. Reducing the number of major structural failures through retrofit mitigation could therefore be a very effective way of reducing property vulnerability and the cost of cyclones.

There are also significant gains to be made in reducing small claims (less than 10% of the sum insured value). These claims accounted for 29% of total Cyclone Yasi claims costs, but many were preventable. Poor cyclone preparation, including failing to remove or secure items in outdoor areas (such as outdoor furniture, sheds, shade sails etc) is making a significant impact on insurance losses. Better preparation by homeowners would not only prevent damage to these outdoor items, but also stop them from contributing to damaging other structures.

Housing age

The data indicate that houses constructed between 1925 and 1981 are at a higher risk of severe structural failure (including loss of roofing through to collapse of walls) than newer housing stock. Homes built before 1980 suffered higher rates of structural damage than those built post-1980. This shows that building codes, first introduced in Queensland in 1982, have had a positive impact on resilience. However, a significant number of contemporary houses also experienced severe damages. This suggests that modern housing is not performing as expected under the National Construction Code (NCC).

Key recommendations:

Recommendation 1:

Develop a targeted mitigation program that reduces vulnerability to the most common types of damage, focusing on:

- Structural roof upgrades for homes constructed before 1980 and other practical retrofit measures
- Upgrades to opening protections (e.g. windows and doors) for homes of all ages
- Emphasising the importance of regular maintenance

This presents great potential in delivering a range of community benefits, including insurance savings.

Recommendation 2:

Implement community education/awareness campaigns to reduce frequency of small claims, including an emphasis on cyclone preparation activities such as removing shade sales, outdoor furniture, debris and unsecured items from the yard as well as pruning trees.

Recommendation 3:

Use the data provided on failures in newer buildings to drive ongoing work around enhancing building standards to address resilience issues, as well as initiatives to support and encourage designers, builders and homeowners to use more resilient products.

Next steps

Suncorp and CTS will draw on these initial findings to design a mitigation program for vulnerable homes. This also forms the foundation of further research into increasing resilience and lowering insurance premiums in North Queensland.

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Limitations

The Cyclone Testing Station (CTS) has taken reasonable steps and due care to ensure that the information contained herein is correct at the time of publication. CTS expressly exclude all liability for loss, damage or other consequences that may result from the application of this report. This report may not be published except in full unless publication of an abstract includes a statement directing the reader to the full report.

1. Introduction and Scope

Vulnerability of housing in terms of insured losses is associated with not only the house structure (e.g. roof cladding, windows, frame, ceilings, doors), but the internal fitments (e.g. carpets, kitchens), ancillary items (e.g. fences, sheds) and also insured contents (e.g. personal possessions, household electronics).

The vulnerability of the house is a function of its resilience (e.g. strength) in the face of the impacting wind and rain along with wind borne debris etc. So to assess the vulnerability of a population of houses we need to ascertain details of the (a) house types, (b) the surrounds and (c) wind speed. There are also external environmental and planning factors that affect loss and vulnerability, such as proximity to the coast, height of the building above the high-tide level (storm tide is another aspect that must be considered) and the type and extent of surrounding vegetation.

Houses are constructed using many elements, with the interaction of these different components and connections not being well understood. Over time, changes are made to construction practices including building materials, often without a full understanding of how the individual changes might affect the performance of the whole system. In a period where the full "system" is not tested, a false sense of security can develop. Only when a cyclone occurs do the shortcomings become apparent, as noted by Walker (1975). This can be seen in the disproportionate amount of structural damage caused by cyclones Althea and Tracy to housing relative to that of engineered commercial buildings. A different trend has emerged in recent damage investigations, with a disproportionate level of damage to engineered light industrial sheds, where issues have been raised on appropriateness of for example design decisions and detailing (Henderson and Ginger, 2008). Actions have since been taken by the Steel Shed Group aimed at addressing any shortcomings. Damage investigations have also shown the better structural performance of housing built after the introduction of engineered "deemed to comply" provisions in Appendix 4 of the Queensland Home Building Code (1981).

Houses are complex structures and do not lend themselves to simple structural analysis. Some of the best understanding of how elements interact has come from full scale house testing, as conducted at CTS. Findings from damage investigations following severe weather events also play a critical role in understanding housing performance. Full-scale house testing at CTS and damage investigations have shown that typically failures occur at connections between the various elements. The engineering vulnerability model described by Henderson and Ginger (2007) uses this as its basis.

The aim of this pilot study was to identify drivers of insurance loss during extreme wind events. Claims data from Northern Queensland was provided for both Cyclones Yasi and Larry. An analysis area of coastal regions from Bowen to Port Douglas during Cyclone Yasi was selected, as a broad range of large numbers of house types were subjected to a range of wind speeds and subsequently a range of damage intensities. Two subset regions were also examined; (i) one area centred on Mission Beach region as higher wind speed impacts, and (ii) the Townsville region as a large percentage of houses were subjected to winds well below design level.

2. Overview of Data

Three data sets were provided by Suncorp including:

1) "General information" claims data for Cyclones Yasi and Larry supplemented with policy data

2) "General information" for policies in-force at the time of Cyclones Yasi and Larry but without an associated claim for these events

3) Assessors reports for a random subset of the claims data from set 1

It is important to note that the claims information provided by Suncorp, and hence the analysis, did not include contents damage as this study is about examining drivers of loss associated with the building property claim (and not the contents)**.**

Cyclone Yasi was a much larger event than Cyclone Larry and therefore generated much larger bands of consistent wind speed (i.e. larger regions were subjected to the same wind speed). Taking advantage of this, analysis was concentrated on Cyclone Yasi data to allow for comparisons to be made for various housing performance attributes (i.e. age, roofing type, wall types, etc.) within a region of constant wind speed (e.g., wind speed estimates for the entire Townsville region were approximately 135 km/h). The assessor's reports for claims filed after Cyclone Larry are discussed in Section 0, in addition to those for Cyclone Yasi. The data provided by Suncorp were refined into the following three data sets for analysis:

Data Set A

This data set included claims records for Cyclone Yasi. Information provided for each claim included date of occurrence, incurred costs, sum insured, occupancy type, number of storeys, location (including street, suburb and postcode as well as GPS coordinates), age of the customer, number of years insured, year of construction, roof and wall type, and building type.

Data Set B

This data set included policies that were active in the region but did not have an associated claim during the time of Cyclone Yasi. The information provided was similar to the claims data Set A but with a lesser degree of detail (e.g., items such as GPS coordinates were not included). This data set was used to understand relationships between various building attributes and likelihood that a claim was filed.

Data Set C

This data set included 179 assessor's reports from Cyclone Yasi and 56 assessor's reports from Cyclone Larry provided by Suncorp for a random subset of the claims in data set 1. These reports were separated into three groups based on the claim value/sum insured ratio (i.e. loss ratio) in order to compare typical damage modes for similar claim sizes.

3. Claims Analysis (Aggregate Data)

Data for the entire state of Queensland was provided. However, to simplify the analysis in relation to Cyclone Yasi wind damage, the data was filtered to include only those geographic regions for which reliable wind speed estimates were available. Three regions were selected. The boundaries of these regions were selected based on postcode, to allow for a convenient filtering method of policies associated with each region. Table 1 conveys the number of policies with and without claims included in the analysis for each of the three regions.

Table 1. Ratio of policies that claimed in the three analysis regions

Analysis Region	# Claim vs # Policies
North Qld Coastal	26%
Townsville	30%
Tully/Mission Beach	67%

Northern Queensland Coastal Region (entire affected area)

This represents the bulk area affected by Cyclone Yasi. This analysis area was of larger scale and included coastal towns from Bowen to Port Douglas. Policies in the Townsville and Tully/Mission Beach regions are also included in this region.

Townsville Region (low wind speed)

This region was isolated to Townsville and surrounding suburbs to provide a more detailed assessment of vulnerability. Townsville was selected because most of the homes in the area experienced similar wind loading (i.e. intensity, duration, and direction) and rainfall during Cyclone Yasi, which facilitated comparative performance assessment between homes of various age, construction type, etc.

Tully/Mission Beach Region (high wind speed)

This region represents the area subjected to highest wind speeds from Cyclone Yasi. Similar to the rationale for choosing the Townsville region, wind speeds in the Tully/Mission Beach region of analysis were of similar intensity, duration, and direction to facilitate comparative performance assessments of various building attributes.

3.1. Loss Ratios

Loss ratio refers to the ratio of the claims cost over the sum insured of a property i.e. what proportion of the sum insured was claimed. The claims and policy data were analysed to determine trends in vulnerability due to various building attributes and relationships between damage and wind speed. In order to make inferences about damage from claims information, five damage levels were established. **Each damage level corresponds to range of loss ratios (claim value/sum insured).** The five loss ratio bins are as described in Table 2.

Table 2. Loss ratio bins for claims analysis with description and typical damage modes (note: typical damages for higher loss ratio bins also include all damages from lower ratio bins)

Loss Ratio Bin	Damage Type	Typical Damage
0	No claim filed	N/A
0 – 0.09	Minor damage	Minor roofing issues and water ingress, minor tree damage, fencing, shade sails, whirly birds, etc.
0.1 – 0.49	Moderate damage	Roofing and water ingress, ceiling damage, broken windows, wall cladding, etc.
0.5 – 0.99	Severe damage	Major roofing failures, water ingress damages, and broken windows, etc.
> 1.0	Severe+ damage/underinsured	Major roofing failures, water ingress damage, etc.

The five loss ratio bins were selected based on a general estimation of the type of damage expected for a given range of claim values. For example, the “No damage filed” bin refers to the number of policies that did not file a claim following Cyclone Yasi and hence are assumed to have avoided damage. The “Minor damage: 0-0.09” bin refers to claims with a very small loss ratio (< 10%), which generally seem to be associated with ancillary damages i.e. shade sails, fencing, whirly birds, etc. The “Moderate damage: 0.1-0.49” bin refers to claims with larger loss ratios associated with major damages typically to roofing, interior, wall cladding, etc. The “Severe damage: 0.5-0.99” bin refers to claims with very large loss ratios associated with severe damages typically to including major roofing failures, water ingress damage to building contents, etc. The “Severe+ damage/underinsured: > 1.0” bin refers to claims with loss ratios greater than one (meaning the loss exceeds the policy limit) and generally associated with very severe damages typically including major roofing failures, water ingress damage to building contents, the need to relocate occupants etc. and can also be indicative of underinsured policies.

3.1.1. Loss Ratios – Northern Queensland Coastal Region

Figure 1 shows the spatial distribution of properties falling within the four non-zero loss ratio bins (i.e. policies with claims) for the Northern Queensland Coastal Region. Figure 2 shows the estimated track for Cyclone Yasi and Figure 3 shows the estimated wind field near the point of landfall. As expected, loss ratios increase directly with wind speed. The frequency of large loss ratios (i.e. large claims) was greatest, in locations nearest the point of landfall (i.e. Cardwell, Mission Beach, etc.) where wind speed estimates were 210-240 km/h. However, claims were filed across the entire North Queensland region, even in areas of significantly lower wind speed (i.e. ~135 km/h in Townsville, ~90 km/h in Cairns).

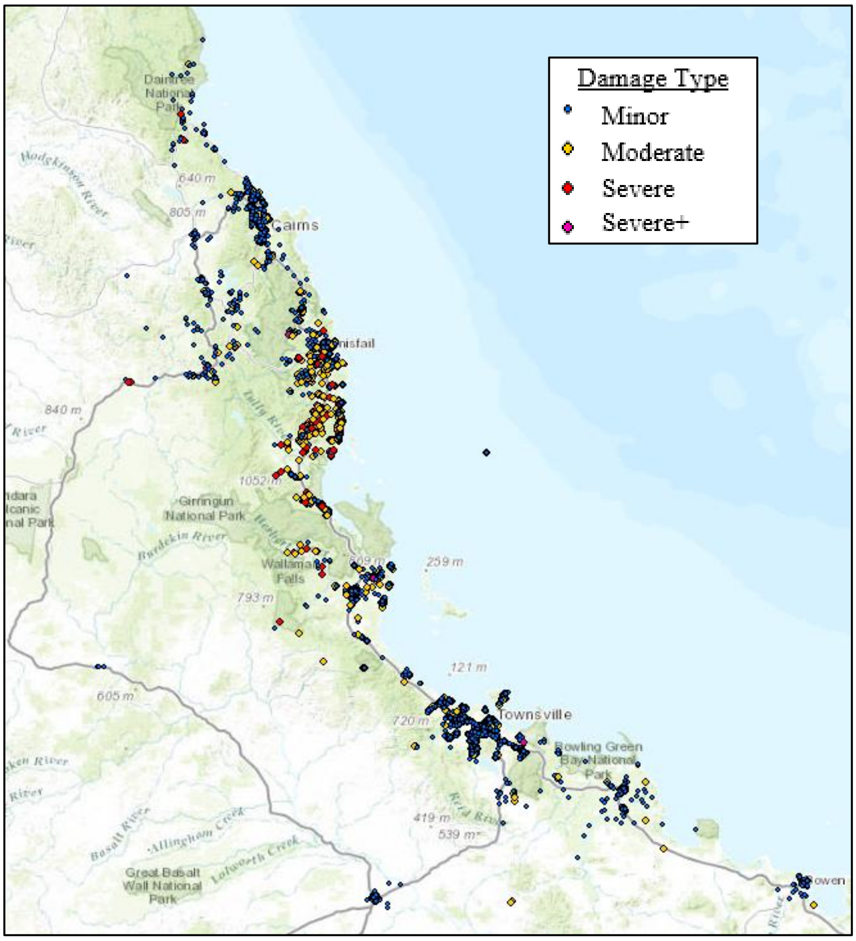


Figure 1. Northern Queensland Coastal Region impacted by Cyclone Yasi and selected for analysis including the distribution of damage types

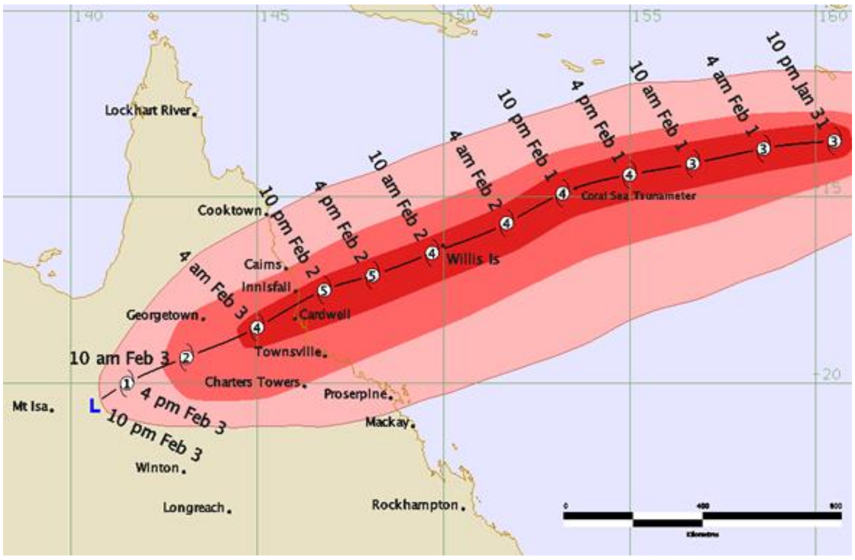


Figure 2. Cyclone Yasi track map before and after landfall (source: Bureau of Meteorology)

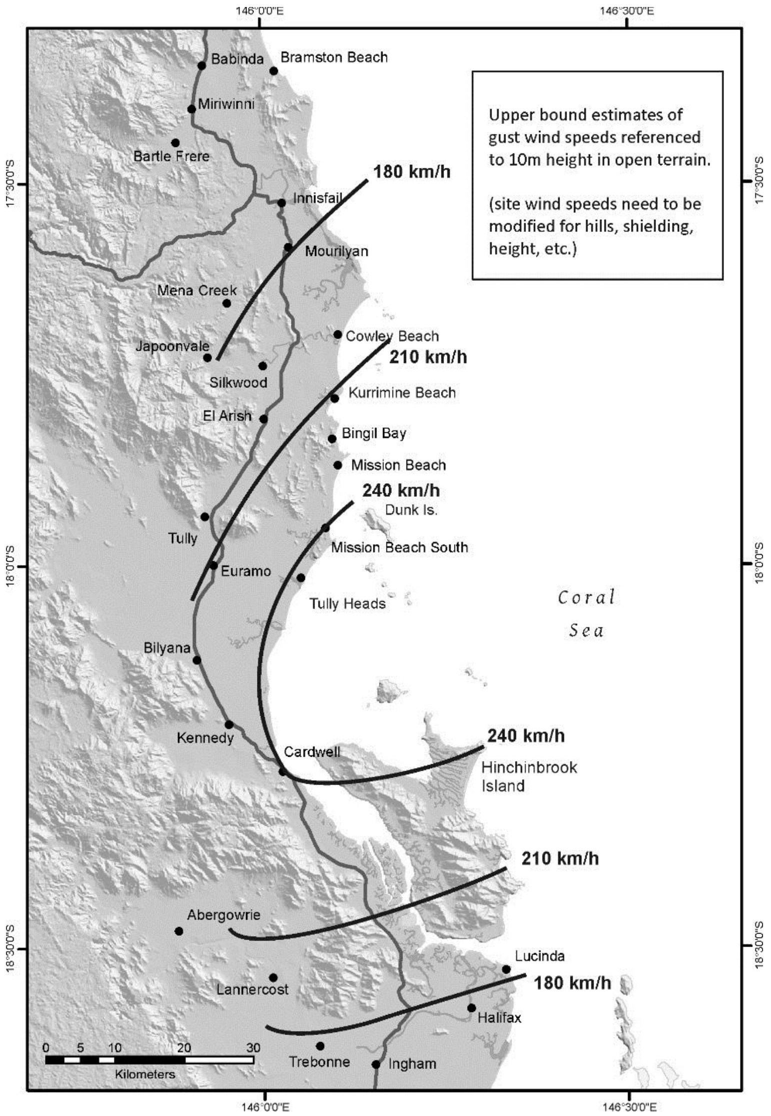


Figure 3. Cyclone Testing Station wind field estimation for Cyclone Yasi

The claims filed in the North Queensland Coastal Region were separated into four bins based on loss ratio. Figure 4 shows the proportion and number of claims allocated to each bin.

Table 3 displays the percentage of claims for each damage level by analysis region while Table 4 shows the costing statistics for each damage intensity type.

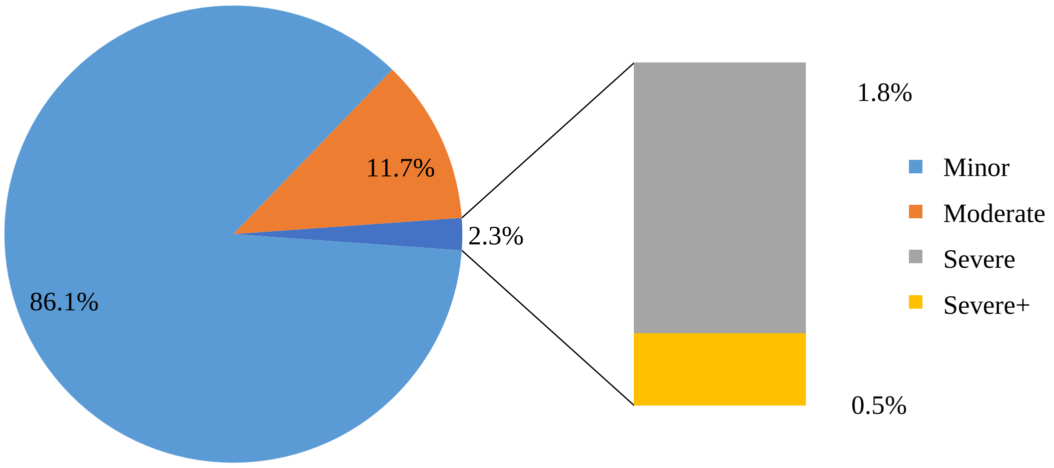


Figure 4. Proportions of damage types for the North Queensland Coastal Region

Table 3. Percentage of claims for each damage level by analysis region

Damage Type	**% of Claims by Analysis Region**		
	N. QLD	*Townsville*	*Tully/Mission Beach*
Minor	86.1%	94.2%	55.2%
Moderate	11.7%	5.4%	35.4%
Severe	1.8%	0.4%	7.5%
Severe or underinsured	0.5%	0.1%	1.9%

Table 4. Costing statistics for the four damage levels selected to describe claims in the North Queensland Coastal Region

Damage Type	**Avg. Loss Ratio**	**Avg. Sum Ins.**	**Max Cost**	**Avg. Cost**	**Median Cost**	**Sum Cost**	**% Total Cost**	**% of Claims**
Minor	0.02	$330,579	$236,727	$5,976	$3,365	$73,470,201	29%	86%
Moderate	0.22	$303,496	$533,466	$66,309	$54,504	$110,404,702	44%	12%
Severe	0.70	$275,176	$710,084	$188,297	$165,482	$48,015,736	19%	2%
Severe+	1.20	$241,429	$1,968,469	$290,492	$254,633	$19,753,513	8%	<1%
Total	**0.06**	$326,008	$1,968,469	$17,619	-	$251,644,154	**100%**	**100%**

Minor Damages (claim/sum insured = 0-9%)
Approximately 86% of claims were between 0 and 9% of the policy sum insured value. Review of the detailed claims information (Data Set C) suggests that claims in this range were most often associated with minor damages (i.e. fence damage, awnings, gutters, water ingress, shade sails, whirly birds, etc.) rather than significant structural damages. Claims in this loss ratio bin represent 29% ($73,470,201) of the total claims payout cost ($251,644,154) for Cyclone Yasi in the North Queensland Coastal Region. The average and median costs of

claims in this bin were $5,976 and $3,365 respectively. Claims of this size were filed across the entire North Queensland Coastal Region. However, **due to a relatively large population size, claim trends in the Townsville Region generally tend to dominate aggregate claims trends for the entire North Queensland Coastal Region.**

The contribution of small claims to overall losses was significant (29%). The CTS suggests that community education/awareness campaigns may be the most effective method of reducing the frequency of claims of this size. Such campaigns should emphasise the importance of cyclone preparation activities in the short-term like; removing shade sails, pruning trees, removing debris and unsecured items from the yard, etc. The campaigns should also focus on implementing a home maintenance routine in the long-term, e.g. repairing corroded metal supports, monitoring roof cladding tie-downs and water-tightness, replacing degraded timber, etc.

Moderate Damages (claim/sum insured = 10-50%)

Approximately 12% of claims in the North Queensland Coastal Region were between 10 and 50% of the policy sum insured value. These claims were generally associated with more extensive damage to roofing systems and water ingress related issues in addition to the typical damage modes described for claims in the 0-10% loss ratio bin. Claims in this loss ratio bin represent 44% ($110,404,702) of the total claims payout cost ($251,644,154) for Cyclone Yasi in the North Queensland Coastal Region. The average and median costs of claims in this bin were $66,309 and $54,504 respectively. Of the 12% of claims in this ratio bin, the majority were filed in the Tully/Mission Beach Region but many also were filed in the Townsville Region. A majority proportion of this claim size in the Tully/Mission Beach Region was expected considering wind speeds in this region (~240 km/h) did approach the design wind speed of 250 km/h. However, the proportion of moderate sized claims in the Townville Region was counterintuitive considering wind speed estimates in this region (~135 km/h) were significantly lower than design level (250 km/h). Claims in the Townsville Region are discussed in further detail in Section 0.

Moderate damages in this claim ratio bin represent the largest proportion of claim related losses (44% = $110,404,702) for the Northern Queensland Coastal Region and therefore present the strongest case for mitigation. Roofing and water ingress related issues are typical for claims of this size (see Section 0). To reduce losses (i.e. claim frequency) from moderate claims, the CTS recommends a mitigation program that emphasizes structural roofing upgrades to older homes (pre-1980s) and opening protection upgrades (i.e. shutters for windows, roller door bracing, etc.) for homes of all ages.

Severe Damages (claim/sum insured = 50-100%)

Approximately 2% of claims in the North Queensland Coastal Region were between 50 and 100% of the policy sum insured value. These claims were associated with severe damage to roofing systems, broken windows, and extensive water ingress related issues in addition to damage modes for smaller claims. Claims in this loss ratio bin represent 19% ($48,015,736) of the total claims payout cost ($251,644,154) for Cyclone Yasi in the North Queensland Coastal Region, despite only representing 2% of the total number of claims. The average and median costs of claims in this bin were $188,297 and $165,482 respectively. Of the 2% of claims in this ratio bin, the majority were filed in the Tully/Mission Beach Region.

Severe Damage/underinsured (claim/sum insured = >100%)
Less than 0.5% of claims in the North Queensland Coastal Region were greater than 100% of the policy sum insured value. These claims were associated with severe damages as defined by the 50-100% loss ratio bin (i.e. roofing systems, broken windows, and extensive water ingress related issues in addition to damage modes for smaller claims). Claims in this loss ratio bin represent 8% ($19,753,513) of the total claims payout cost ($251,644,154) for Cyclone Yasi in the North Queensland Coastal Region. The average and median costs of claims in this bin were $290,492 and $254,633 respectively. Of the 0.5% of claims in this ratio bin, the majority were filed in the Tully/Mission Beach Region and the majority of the rest were filed in the Townsville Region. It is understood that certain policies offered by Suncorp Group offer a "safety-net" coverage option that allows for payout above the sum insured value of a home. This may have impacted the number of claims with loss ratios greater than one.

Severe damage claims (including underinsured bin) represent at total of 27% ($67,769,249) of the claim-related losses for the Northern Queensland Coastal Region. Typical damage modes for claims of this size generally more extreme version than those described for the moderate damage bin (i.e. roofing, water ingress, broken windows, etc.). A mitigation program focused on structural roofing and opening protection upgrades (as suggested above) also has potential to dramatically reduce the frequency of severe damage claims.

3.1.2. Loss Ratios - Townsville
In general, loss ratio trends for the Townsville Region are similar to those for the North Queensland Coastal Region (Section 3.1.1) due to the number of policies in Townsville relative to the other affected areas (see Table 1).

Figure 5 shows the distribution of loss ratio by bin for the Townsville Region. Minor claims (loss ratio of 0-0.9) are dominant and occur uniformly throughout the region. The occurrence of minor claims appears to be independent of housing age and proximity to the coast. However, moderate and severe loss ratio claims (0.1-0.49 and 0.5-0.99) are more prevalent moving toward the coast where older housing is also prevalent.

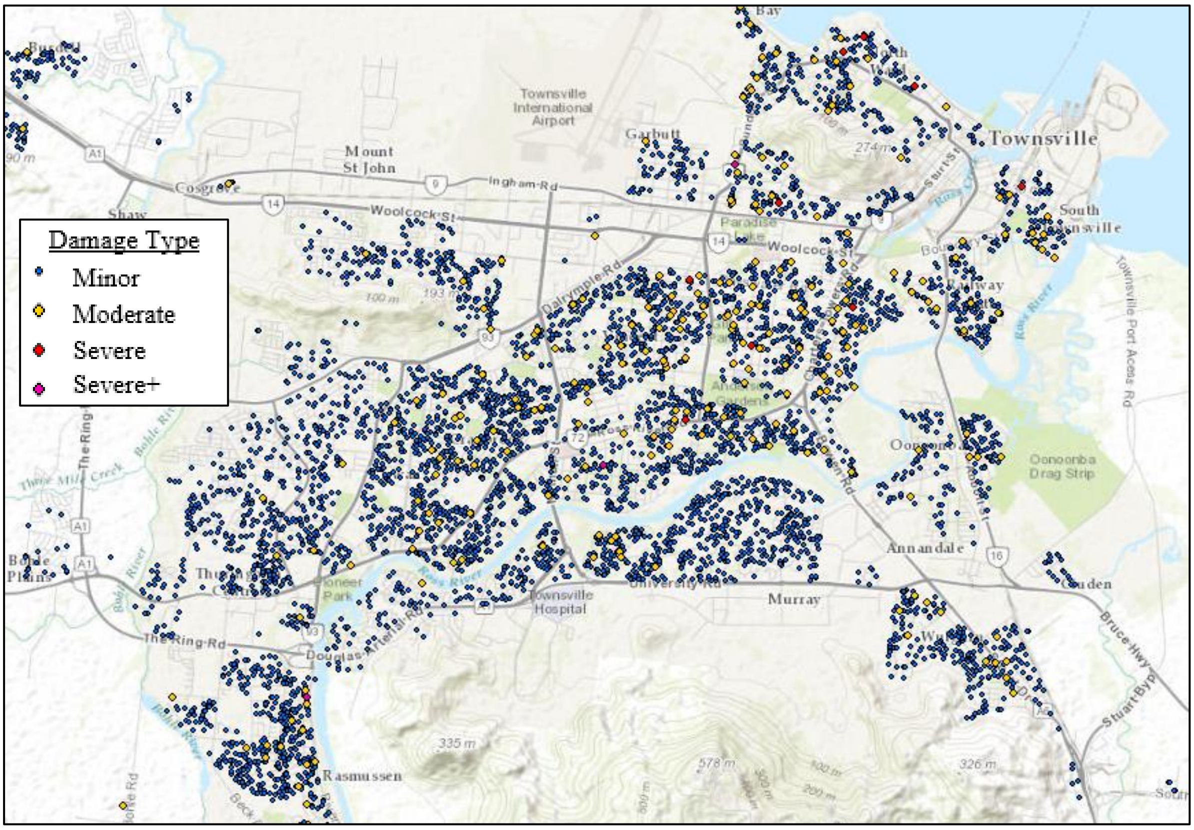


Figure 5. Locations and severity of damage across Townsville Region

Table 5 shows the relative contributions of claims in each loss ratio bin as a proportion of the total number of claims filed in the Townsville Region. As suggested by Table 5, the overwhelming majority of claims (~94%) were between 0 and 0.09 of the sum insured value. These minor claims (e.g., fencing, shade sails, creased garage doors, etc.) accounted for $38,169,597 (60%) of the total claims related cost ($63,575,021) of Cyclone Yasi for the Townsville Region. The CTS recommends a community education approach to mitigating.

Table 5. Costing statistics for the four damage levels selected to describe claims in the Townsville Region

Damage Type	Avg. Loss Ratio	Avg. Sum Ins.	Min Cost	Max Cost	Avg. Cost	Sum Cost	% Total Cost	% Claims
Minor	0.02	$338,323	-	$236,727	$5,571	$38,169,597	60%	94%
Moderate	0.19	$278,766	$2,004	$259,731	$52,163	$20,343,691	32%	5%
Severe	0.70	$215,327	$68,027	$246,653	$148,077	$3,998,082	6%	<0.5%
Severe+	1.14	$189,420	$146,300	$320,010	$212,730	$1,063,650	2%	<0.1%
Total		$334,571	-	$320,010	$8,741	$63,575,021	**100 %**	**100%**

For moderate claim loss ratios (0.1-0.49) in the Townsville Region, only 5% of claims were filed with an average value of $52,000. (That is, **5% of the Townsville regions claims accounted for 30% of the total claims cost**) These claims are generally associated with moderate structural damage to the roofing structure (typical roofing replacement costs $20-40k), water ingress damages, etc. and have occurred in an area where wind speed estimates were 135 km/h despite the design wind speed for the region being 240 km/h. **This finding**

provides an evidence base to support the need for improved building standards for both upgrading of older housing and maintenance and certification for newer construction.

3.1.3. Loss Ratios – Tully/Mission Beach

The Tully/Mission Beach Region was the most severely impacted area during Cyclone Yasi (i.e. most intense wind, rain, and storm tide). Figure 6 shows the distribution of loss ratio by bin for the Tully/Mission Beach Region. Table 6 shows the costing statistics for the four damage levels in the Tully/Mission Beach Region. Minor claims (loss ratio of 0-0.09), while still frequent, were not as dominant as for the Townsville Region. **While the number of policies in the Tully/Mission Beach Region are nearly <u>a tenth</u> of those in the Townsville Region**, **the total claims cost for the Tully/Mission Beach Region was <u>more than twice</u> that of the Townsville Region** ($140,511,665 vs $63,575,021)**. This is due to the increased proportion of moderate and severe loss ratio claims (0.1-0.49 and 0.5-0.99) which generally include structural damage.** Claim-related losses would have been significantly higher (potentially by factor of 5-10) if the most severe winds of Cyclone Yasi had been in the Townsville Region**.**

A large portion of claims (~55%) were between 0 and 0.09 of the sum insured value. **Despite the high frequency, minor claims (e.g., fencing, shade sails, minor water ingress, etc.) only accounted for 11% ($15,281,323) of the total claims related cost ($140,511,665) of Cyclone Yasi for the Tully/Mission Beach Region.** A proportion of this loss is due to storm tide affecting some properties in this high impact area. Damage from the storm tide ranged from; some water through the carport to major structural damage. Attempts were made to separate the major storm tide damage from the data set.

The largest contribution to losses (51%) came from claims with moderate loss ratios (0.1-0.49), with an average value of $75,104. These claims were generally associated with structural damage to the roof (roofing replacement = $20-40k), water ingress damages, etc. in addition to the typical damages seen in minor claims. These claims are frequent throughout the Tully/Mission Beach Region despite the fact that wind speed estimates (see Figure 3) only approached design level (240 km/h) along the coast line (e.g., Tully Heads, Mission Beach, Cardwell) and gradually tapered to 180 km/h near Innisfail.

Severe claims (0.5-1 and >1) in the Tully/Mission Beach Region, including the underinsured bin, comprise 38% of the total cost for this region despite only accounting for 9% of the total number of claims. In other words, major failures to even a relatively small number of houses can be a dominant driver of loss. This suggests that preventing even a small portion of major structural failures through structural retrofit mitigation could be very effective in reducing losses. The type of mitigation would also reduce losses from claims with moderate loss ratios, which comprise 51% of the total cost.

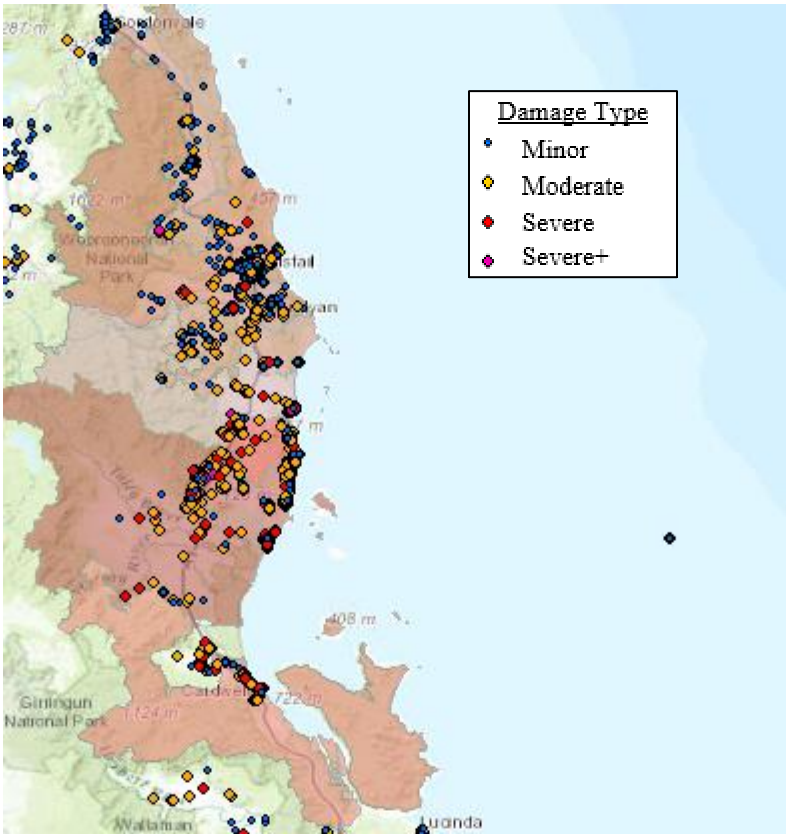


Figure 6. Locations and severity damage across the Tully/Mission Beach Region

Table 6. Costing statistics for the four damage levels selected to describe claims in the Tully/Mission Beach Region

	Avg. Ratio	**Avg. Sum Ins.**	**Min Claim**	**Max Claim**	**Avg. Claim**	**Sum of Claims**	**% Total Cost**	**Count %**
Minor	0.03	$317,007	-	$156,968	$10,249	$15,281,323	11%	55%
Moderate	0.24	$318,607	$3,385	$533,466	$75,104	$71,724,442	51%	35%
Severe	0.69	$283,972	$16,371	$710,084	$192,721	$38,929,654	28%	7%
Severe+	1.20	$238,675	$43,320	$1,968,469	$285,808	$14,576,245	10%	2%
Total						$140,511,665	100%	100%

3.2. Damage vs Building Age

3.2.1. Damage vs Building Age – Northern Queensland Coastal Region

Age of construction is often used as an indicator of general construction trends and therefore is often used for estimating the relative vulnerability of homes built in different eras. Figure 7 shows the correlation between claim ratio and age of construction for homes in the North Queensland Coastal Region after Cyclone Yasi. The proportion that each loss ratio bin (see Section 3.1.1 for description) contributed to the total number of claims for a specified construction age range is shown (i.e. each percentage represents the numbers of claims in that loss ratio bin divided by the total number of claims for the age grouping). The five construction time periods were selected based on the progression of typical housing characteristics in Queensland as described in Section 6.4.

The plot shows that the majority of homes for all ages did not file a claim after Cyclone Yasi. The implication is that the total claim-related loss in this region ($251,644,154) was the result of claims from just ~25-30% of the housing stock. **The data suggests the likelihood of a claim being filed is higher for housing constructed between 1925 and 1981. In addition, claims filed for housing in this range are more likely to be of a higher severity than housing constructed after 1981.**

Figure 7 shows clearly that minor claims are prevalent for housing of all ages (i.e. minor claims are independent of housing age). Figure 8 shows a closer view of the higher intensity damage types and Figure 9 and Figure 10 provide similar plots for comparison of pre- and post-1980s (modern code era) housing. While the frequency of moderately sized claims (2.4%) for modern housing was lower than housing constructed between 1925 and 1981, these claims are often associated with structural damages which should not occur for housing built to modern standards. **Considering this, future work should investigate drivers of loss for modern housing (e.g., insufficient opening protection, etc.) so that retrofit solutions can be developed for existing housing and code-improvement solutions can be developed for future housing.**

Housing built prior to 1925 exhibits similar vulnerability to modern housing, however it should be noted that there are relatively few houses of this age in the North Queensland Coastal Region portfolio. Materials in these houses may be less prone to water damages due to the construction materials of the time period (e.g., water goes through timber floors, fibro/timber ceilings are water-resistant, etc.). Also many of these older houses are more likely to be upgraded structurally or renovated because of increased market value, historic value, etc. **The insured's policy recorded 'age of construction' is based on the original house and does not take into account appropriate structural retrofitting or upgrading that may have occurred to houses built prior to the 80s.** There may be some percentage of skew in the age comparison data due to some older housing having appropriate structural retrofitting undertaken as well as some modern housing suffering significant damage due to having construction or design issues.

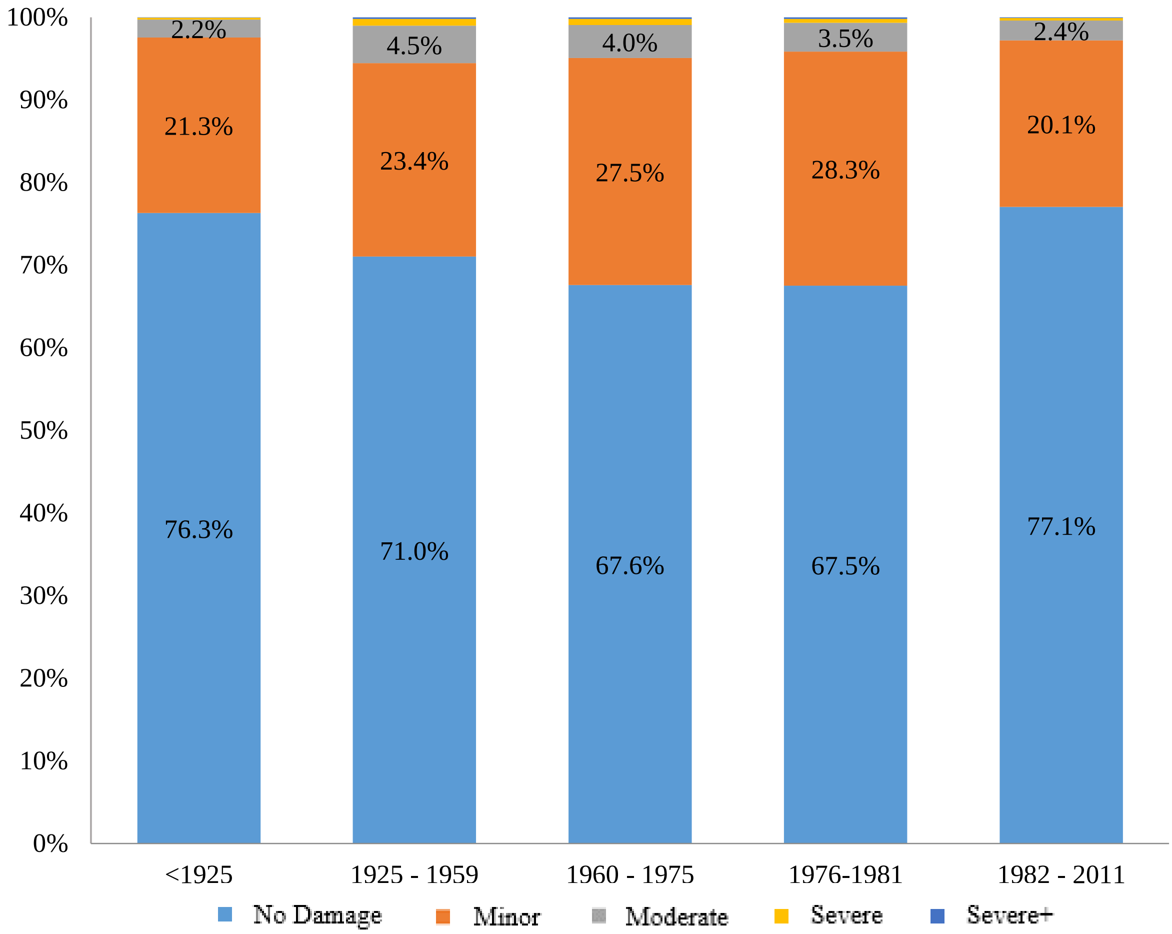


Figure 7. Building age vs damage type contributions to the total number of claims filed in relation to Cyclone Yasi for the North Queensland Coastal Region (note: "Severe" and "Severe+" bin proportions are less than 1% each and text omitted from this figure for clarity)

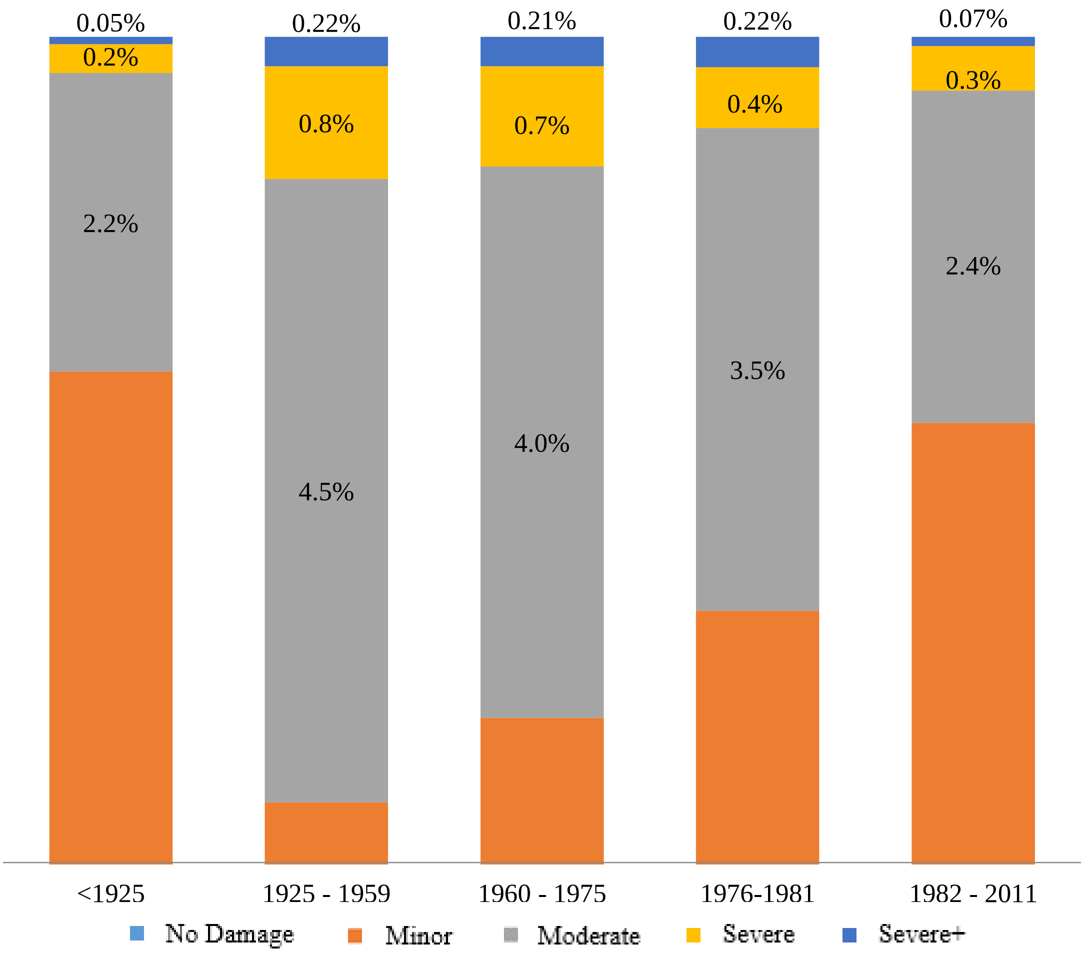


Figure 8. Building age vs damage type contributions to the total number of claims filed in relation to Cyclone Yasi for the North Queensland Coastal Region (Note: This figure is a magnified view of higher intensity damage types in Figure 7 per Suncorp request)

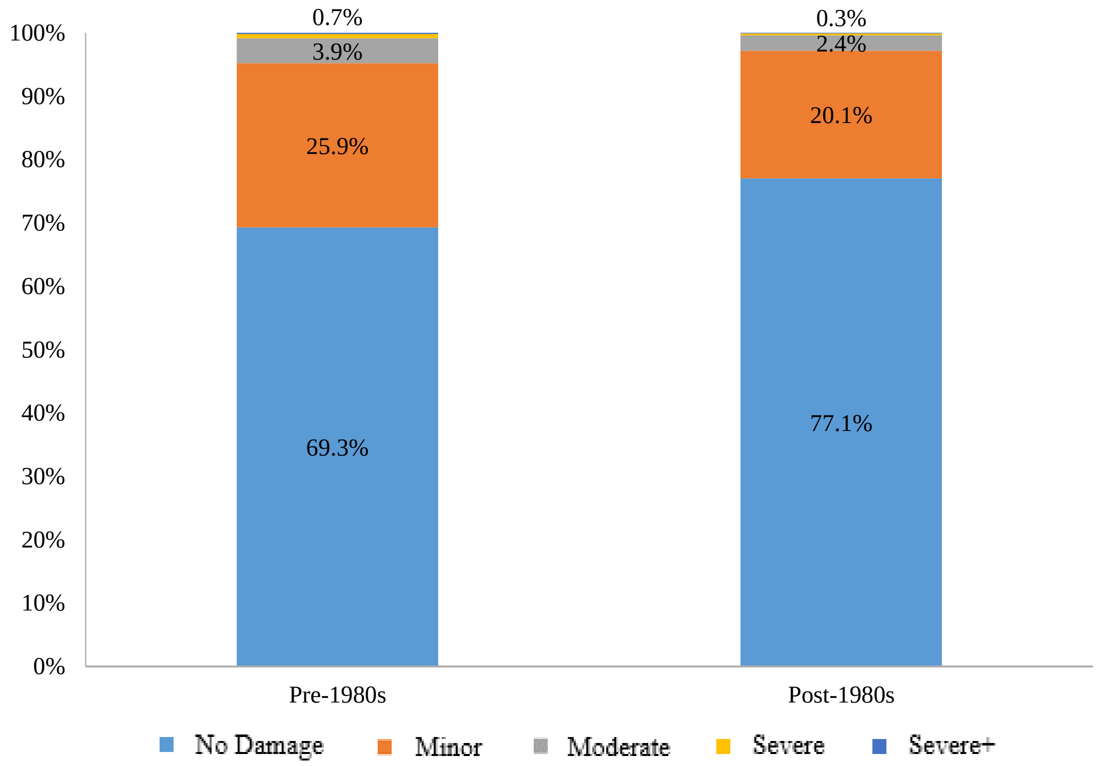


Figure 9. Building age vs damage type contributions (pre- and post-1980s) to the total number of claims filed in relation to Cyclone Yasi for the North Queensland Coastal Region (note: "Severe+" bin proportions are less than 1% each and omitted from this figure for clarity)

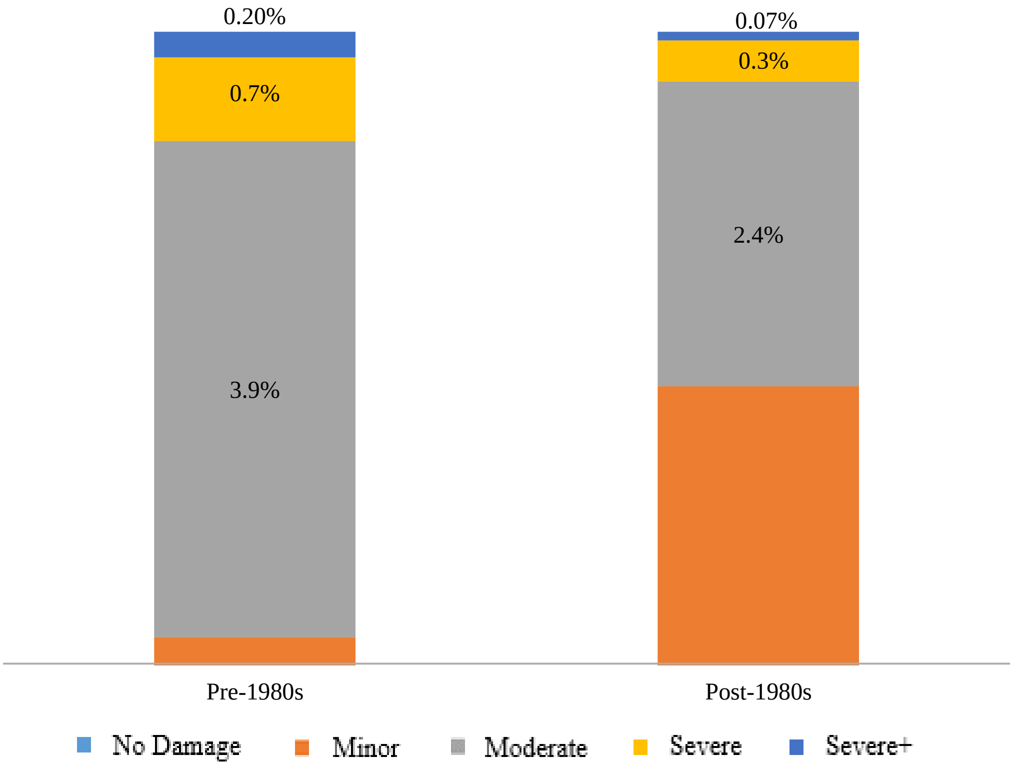


Figure 10. Building age vs damage type contributions (pre- and post-1980s) to the total number of claims filed in relation to Cyclone Yasi for the North Queensland Coastal Region (Note: This figure is a magnified view of higher intensity damage types in Figure 9 per Suncorp request)

3.2.2. Damage vs Building Age - Townsville

Figure 11 shows the relationship between claim ratio and age of construction for homes in the Townsville Region. Figure 12 is shows a closer view of the higher intensity damage types and Figure 13 and Figure 14 provide similar plots for comparison of pre- and post-1980s (modern code era) housing. Each percentage represents the number of claims in that loss ratio bin divided by the total number of claims for the age grouping. The five construction time periods were selected based on the progression of typical housing characteristics in Queensland as described in Section 6.4.

The loss ratio trends for the Townsville Region are similar to those for the North Queensland Coastal region. Key findings include:

1. The proportion of policy holders that did not file a claim (e.g., 70.8%, 65.9%, 64.7%, etc.) were lower for the Townsville Region than for the North Queensland Coastal Region (see Figure 7) for all ages of housing. In other words, the likelihood that a claim was filed in the Townsville Region was higher than for the entire Cyclone Yasi affected area, despite the relatively low wind speeds that were generated in the area.

2. The Townsville Region data is similar to the overall North Queensland Coastal Region data set that housing constructed between 1925 and 1981 does not perform as well as housing constructed either before or after this time period. Examples of roof loss and other significant damage were observed in Townsville during CTS damage survey.

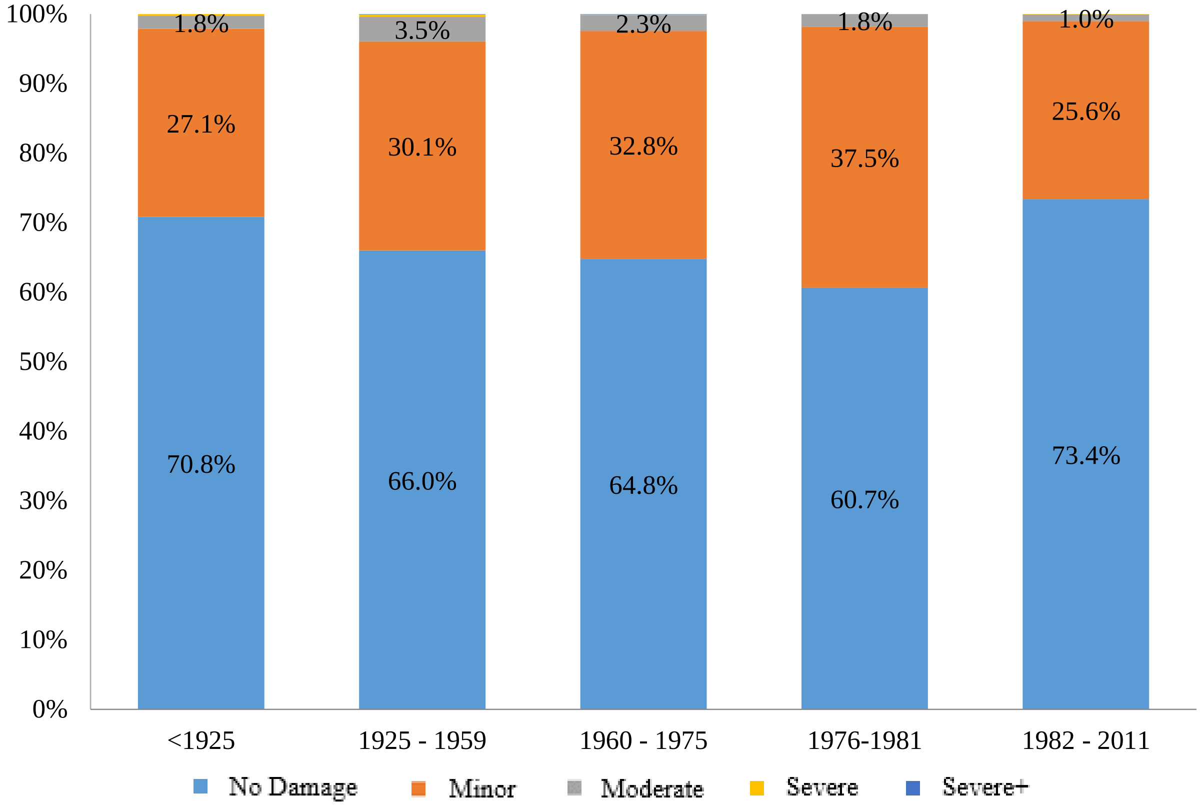


Figure 11. Building age vs damage type contributions to the total number of claims filed in relation to Cyclone Yasi for the Townsville Region (note: “Severe” and “Severe+” bin proportions are less than 1% each and omitted from this figure for clarity)

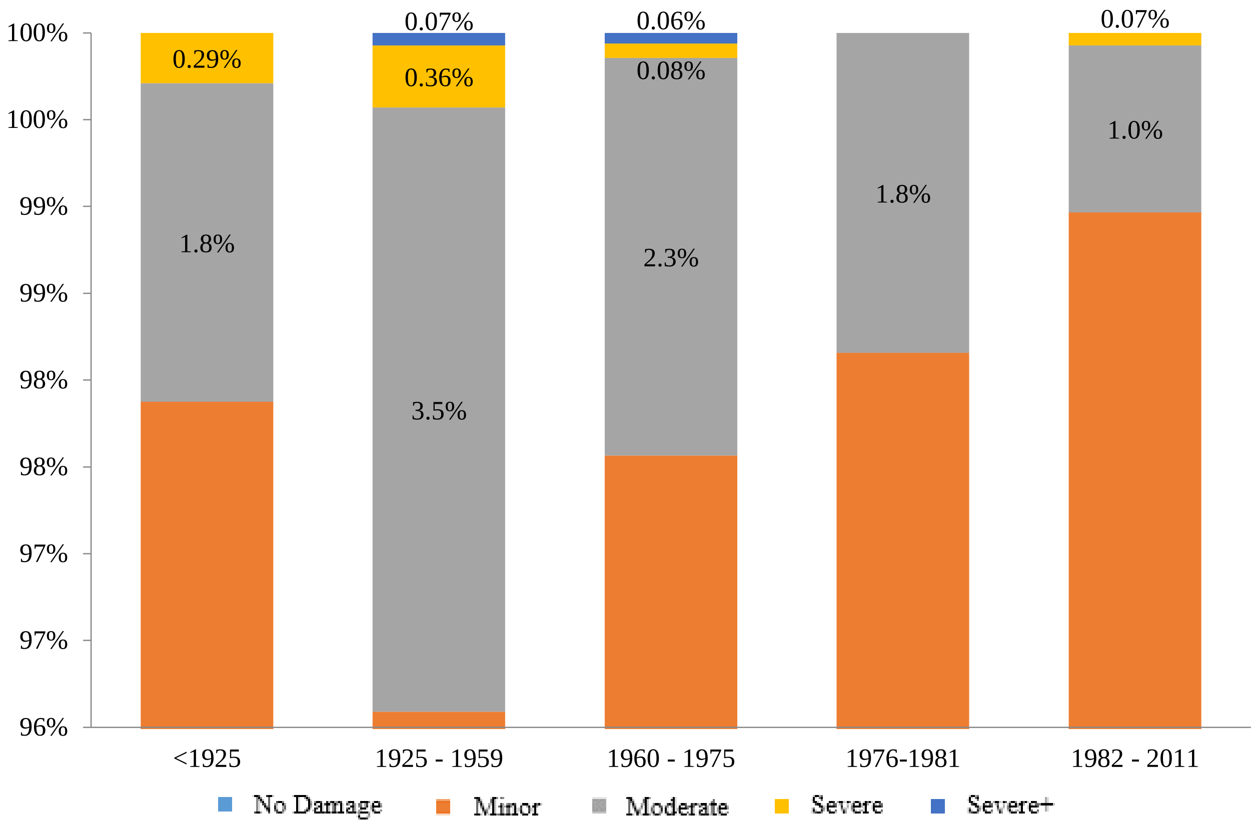


Figure 12. Building age vs damage type contributions to the total number of claims filed in relation to Cyclone Yasi for the Townsville Region (Note 2: This figure is a magnified view of higher intensity damage types in Figure 11 per Suncorp request)

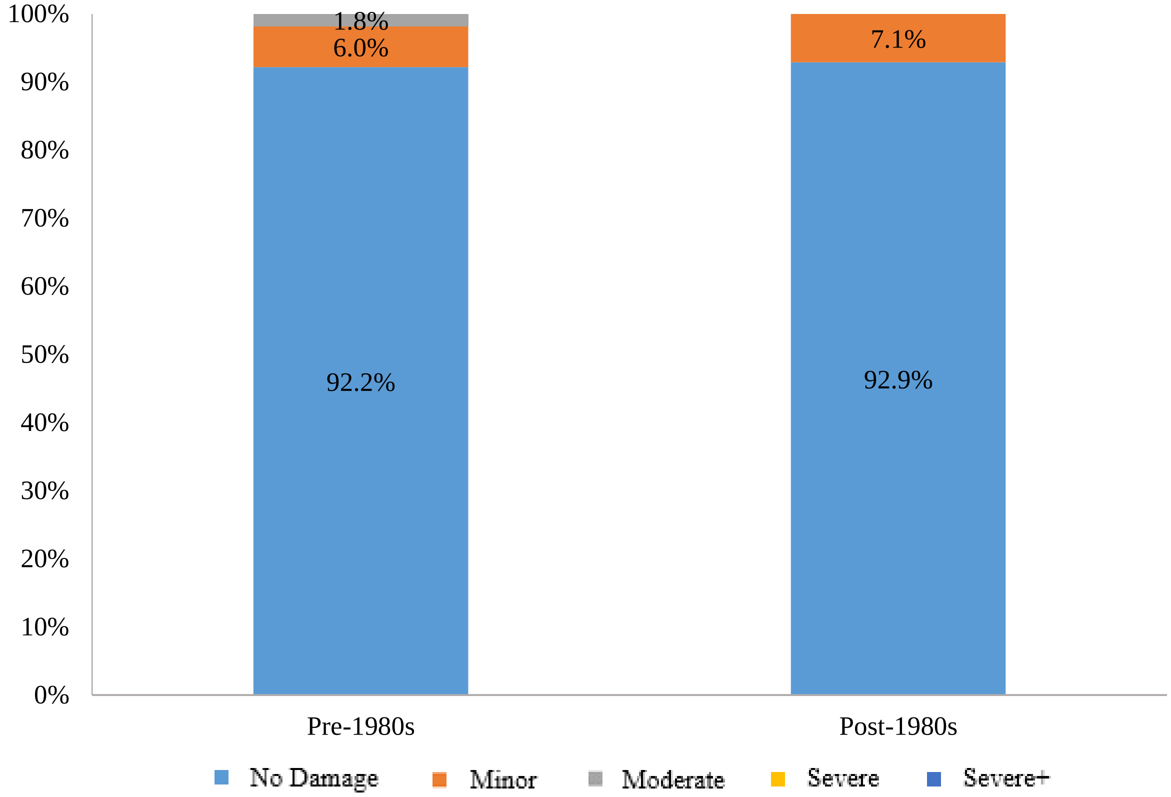


Figure 13. Building age vs damage type contributions (pre- and post-1980s) to the total number of claims filed in relation to Cyclone Yasi for the Townsville Region (note: “Severe” and “Severe+” bin proportions are less than 1% each and omitted from this figure for clarity)

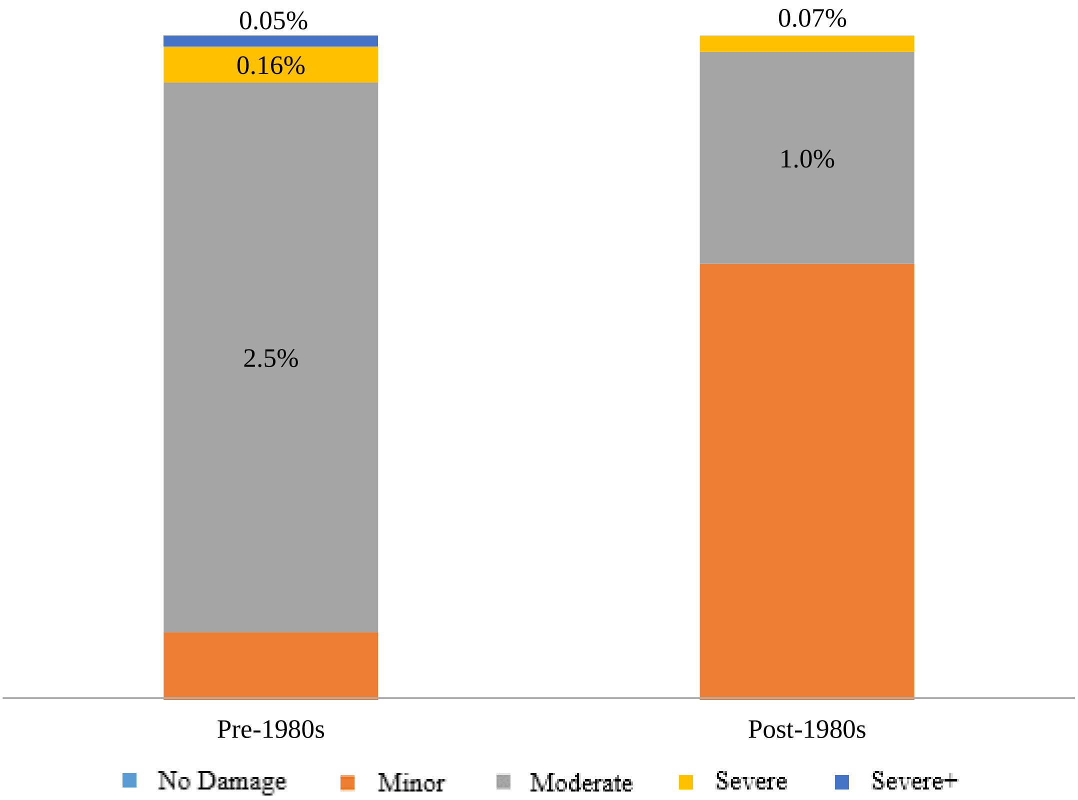


Figure 14. Building age vs damage type contributions (pre- and post-1980s) to the total number of claims filed in relation to Cyclone Yasi for the Townsville Region (Note 2: This figure is a magnified view of higher intensity damage types in Figure 13 per Suncorp request)

3.2.3. Damage vs Building Age – Tully/Mission Beach

Figure 15 shows the relationship between claim loss ratio and age of construction for homes in the Tully/Mission Beach Region. Each percentage represents the number of claims in that loss ratio bin divided by the total number of claims for the age grouping. The five construction time periods were selected based on the progression of typical housing characteristics in Queensland as described in Section 6.4.

The likelihood of a policy not filing a claim in this region was much lower than for the Townsville Region, i.e. 56%, 41%, 32%, etc. for Tully/Mission Beach versus 71%, 66%, 65%, etc. for Townsville (see Figure 11). Higher claim frequencies were expected due to the more extreme wind conditions in this area. However, trends in claim frequency for individual construction age groups are also different than those for the low wind speed Townsville Region.

The data support the previously stated finding that housing constructed between 1925 and 1981 is at a relatively higher risk of severe structural failure.

Figure 166 highlights typical examples of major structural failures of older housing (TC Yasi damage survey). In many cases this damage propagated. Following TC Yasi, the CTS estimated that approximately 20 to 40% of major elements from a damaged house went on to impact other houses downwind (Figure 17).

A significant proportion of contemporary housing also experienced severe loss ratio damages, which supports the previously stated finding that modern housing did not perform as expected per the National Construction Code (NCC). The data demonstrate the need for change and can help to facilitate change within building standards and education of designers, builders and homeowners. Some changes to modern housing design criteria and components have been made since TC Yasi. For example, hip and ridge roof tiles now need to be appropriately fixed to roof structure, garage doors now need to be cyclonic wind load rated in accordance with latest Standard, and soffits have specific wind load requirements, to name a few.

Typical damage patterns are discussed in Section 4. **Wind-driven rain (water ingress) is a major driver of loss for housing of all ages (including contemporary construction)**. This is supported by CTS damage surveys where approximately 80% of surveyed housing had water damage.

In addition to severe claims, a significant proportion of minor claims were filed across all ages of housing. This, in light of findings from the Townsville Region, suggests minor claims are equally likely to be filed by housing of all ages in both high-wind and low-wind areas of a cyclone.

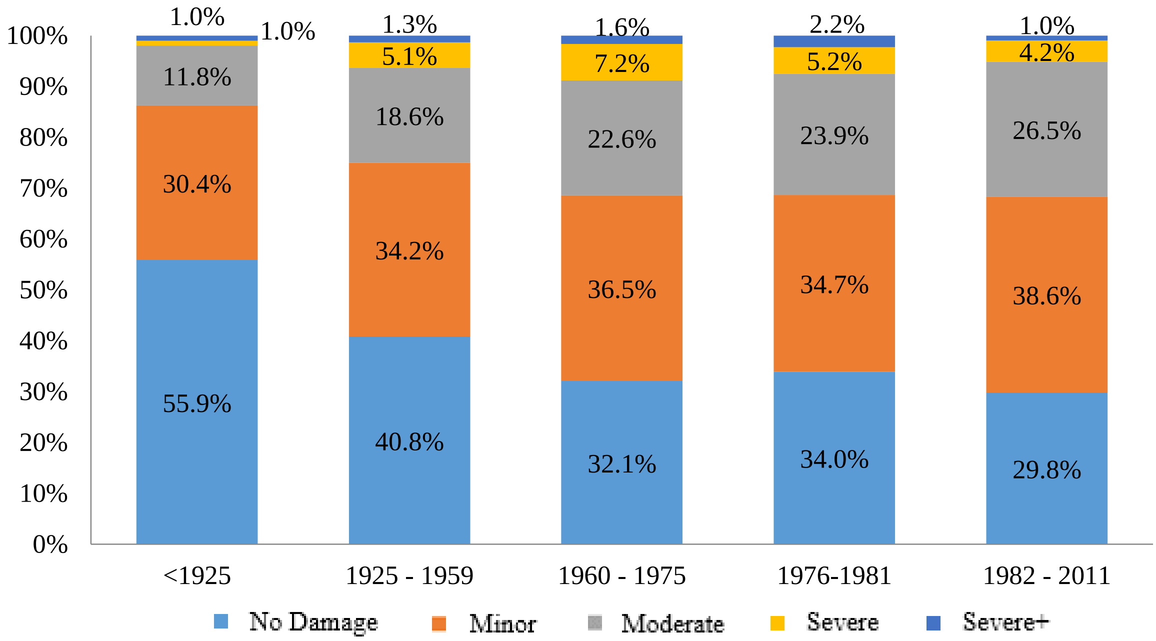


Figure 15. Building age vs loss ratio bin (see legend) contributions to the total number of claims filed in relation to Cyclone Yasi for the Tully/Mission Beach Region (note: "Severe" and "Severe+" bin proportions are less than 1% each and omitted from this figure for clarity)

Figure 16. Examples of roofing failures from post-1980s housing following Cyclone Larry

Figure 17. Wind-driven debris damage from structural failure of neighboring housing

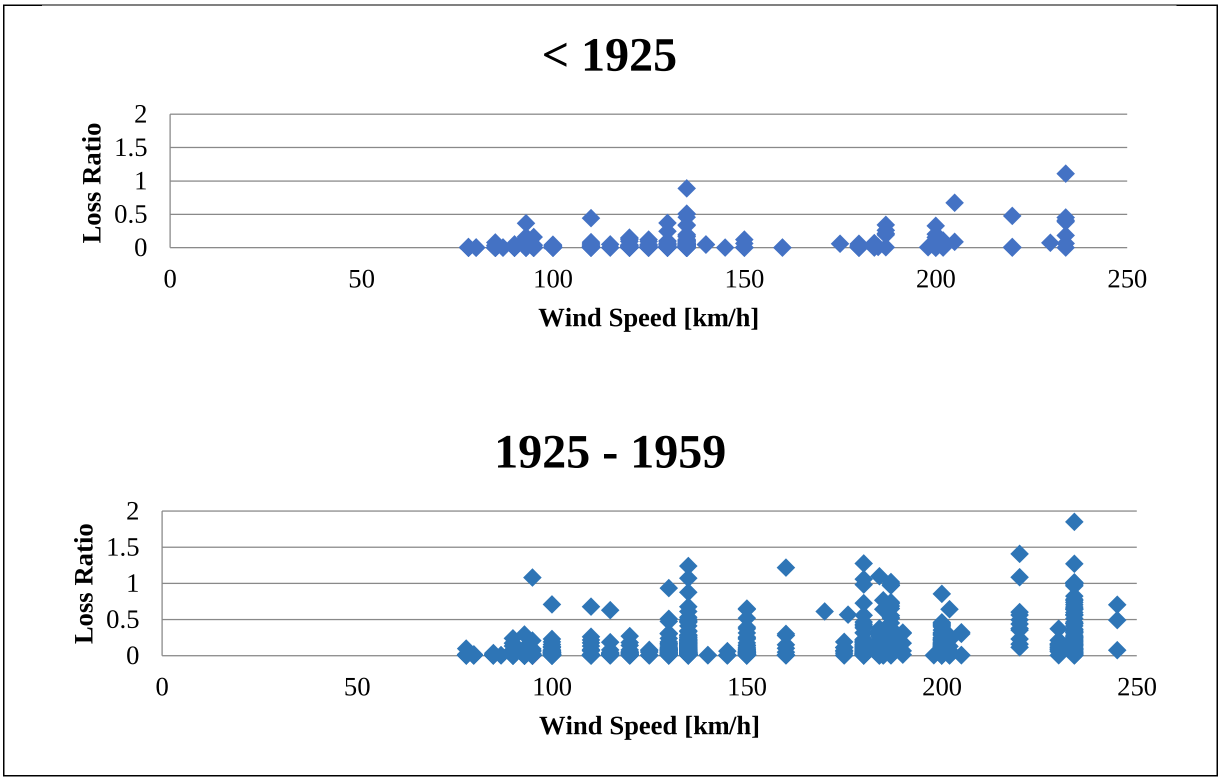
3.3. Damage vs Wind Speed

To analyse correlation between loss ratio and wind speed, these two parameters were plotted for each of five housing age groups in Figure 18. For these relationships, data is filtered to include only housing structures. Due to the nature of the wind field in relation to highly populated areas (i.e. Townsville), a large number of data points are available for the wind speed 135 km/h. The age group ranges were selected based on the progression of typical housing characteristics as described in Section 6.4.

Minor damage claims (e.g., shade sails, fences, "whirly birds", minor water ingress, etc.) are prevalent at all wind speeds and for all housing ages. These claims are, in general, not caused by structural-related issues and may be prevented by improved cyclone preparedness (e.g., remove shade sails, prune trees, install window protection, etc.).

Claim instances where loss ratio is high for relatively low wind speed (e.g., <50 km/h) are more common for homes built between 1925 and 1975. This suggests that homes built before 1925 or after the 1970s (i.e. modern building code era) are less likely to experience severe damage at relatively low wind speeds. This trend is expected for modern housing, which is engineered to a higher performance requirement than "pre-code" housing. Housing built prior to 1925 often included stronger structural members than newer construction (i.e. >1925), which may act to mitigate severe damages at low wind speeds for this age of housing.

Design wind speed in the North Queensland Coastal Region is 240 km/h. Engineering requirements for housing constructed after 1982 are designed to ensure structural stability, minimised local damage and loss of amenity, and avoid damage other properties. The high occurrence rate of large claims at wind speeds from 150-240 km/h for modern housing indicates that modern housing did not perform as predicted by the National Construction Code (NCC).



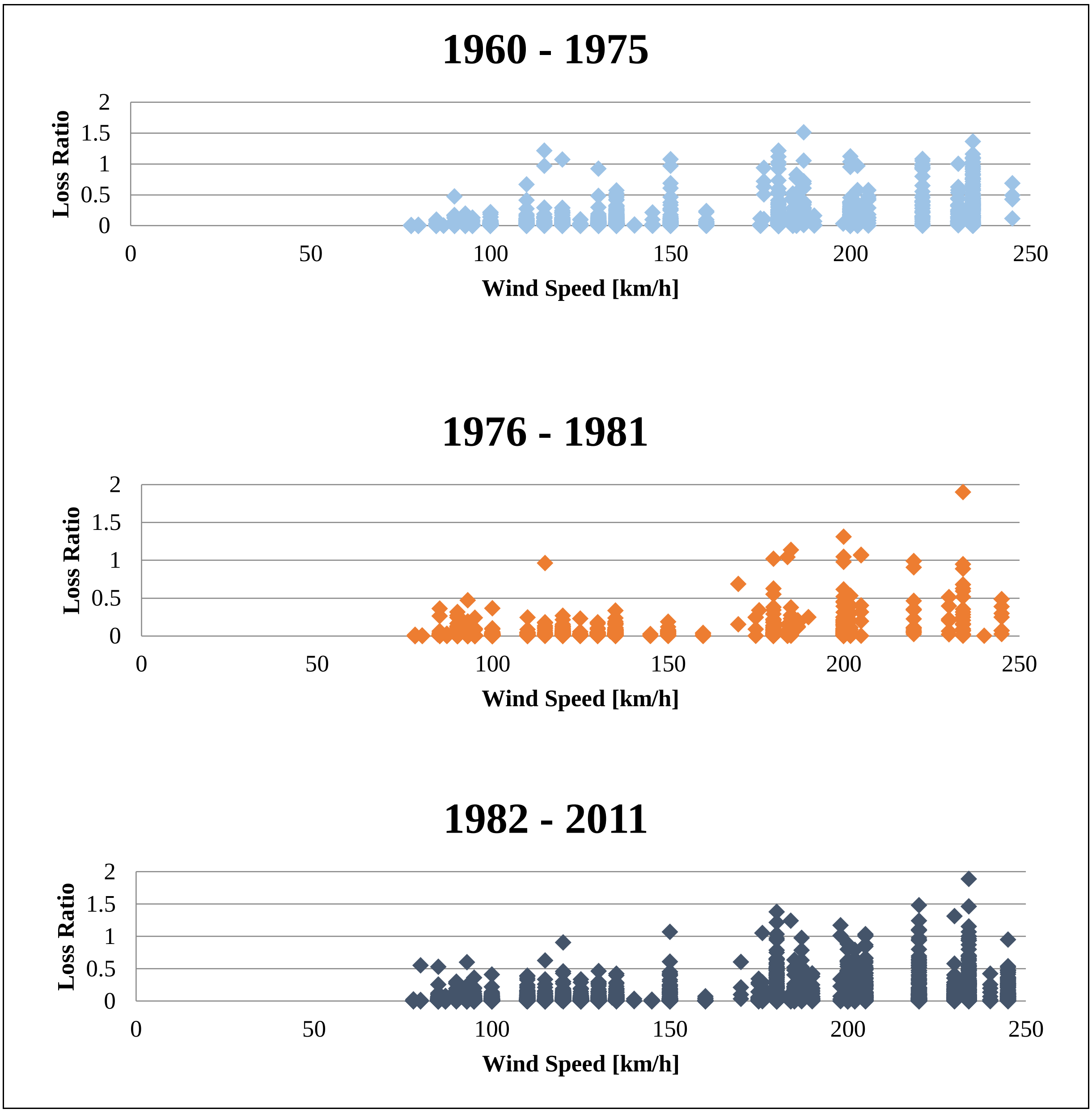


Figure 18. Loss ratio vs wind speed grouped by age for all claims in the North Queensland Coastal Region

3.4. Key Building Attributes

3.4.1. Roofing Type

Roofing type is potentially the most important building attribute in predicting vulnerability and potential modes of failure due to wind and water ingress. As discussed in the Section 4 assessor's reports analysis, **roof damage is very strongly correlated to wind and water ingress induced losses.** The mechanism by which wind and water interact with roof cladding is very different depending on the type of cladding material. Each roofing type has a unique set of vulnerability-related strengths and weaknesses. For example, sheet metal cladding comes in much larger sections than individual tile roofing elements, which changes the area on which wind-induced pressures act. In addition, sheet metal roofing is more continuous than tiled roofing (i.e. sheeting overlap regions have less profile than tile overlap regions), which affects modes of water ingress (and wind loading).

The largest proportion of roofing type in the Northern Queensland Coastal Region is "iron/steel" roofing which comprises ~68%.

The remaining proportion of roofing classifications includes "Tiles", "Aluminium", and a combination of others. Reconstruction costs of different roofing types can vary dramatically (e.g., asbestos (fibro) roofing is much more expensive than for other materials due to the hazardous nature of the material).

Figure 21 shows the proportion of roof loss damage (damage index 0 to 4+) as observed by CTS teams conducting street surveys in the Mission Beach, Tully, Cardwell areas following TC Yasi (Boughton et al 2011). Notwithstanding the low proportion of concrete tile roofs compared to metal sheet roofs, Figure 21 indicates a disproportionate level of damage of tile vs metal roofs. Roof damage does lead to interior damage via wind driven rain ingress.

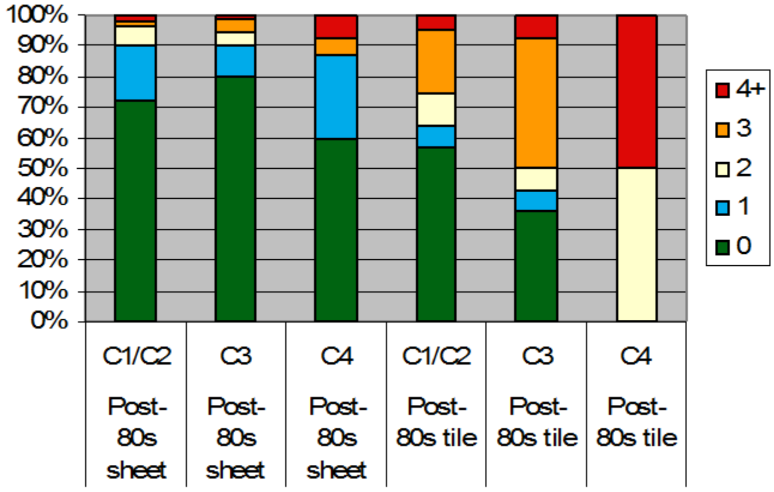


Figure 19. Roof damage index for post-1980s housing following TC Yasi determined from street survey data from the Cassowary Coast region (Boughton et al 2011)

3.4.2. Year of Construction

The age of construction for a home is used to estimate construction features when more detailed information is unavailable. This is generally done by reviewing the building standards that were in effect at the time of construction. Figure 22 details 43% of the policies are for homes built prior to the 80s, with 57% built subsequent to the mid-80s.

Tropical Cyclone Tracy resulted in extreme damage to housing in December 1974, especially in the Northern suburbs of Darwin (Walker, 1975). Changes to design and building standards of houses were implemented during the reconstruction. The Queensland Home Building Code (HBC) was introduced as legislation in 1982 with realization of the need to provide adequate strength in housing. By the mid-1980s it is reasonable to presume that houses in the cyclonic region of Queensland were being fully designed and built to its requirements. This information can be used to aid estimations of building performance at an aggregate level.

However, prior to the 1980s building standards in Australia were not as uniform as they are today. Building features were highly dependent on geographic location, availability of materials, and the construction practices within local regions. Through years of building science research, the CTS has estimated typical construction features for several broad time periods as discussed in Section 6.4.

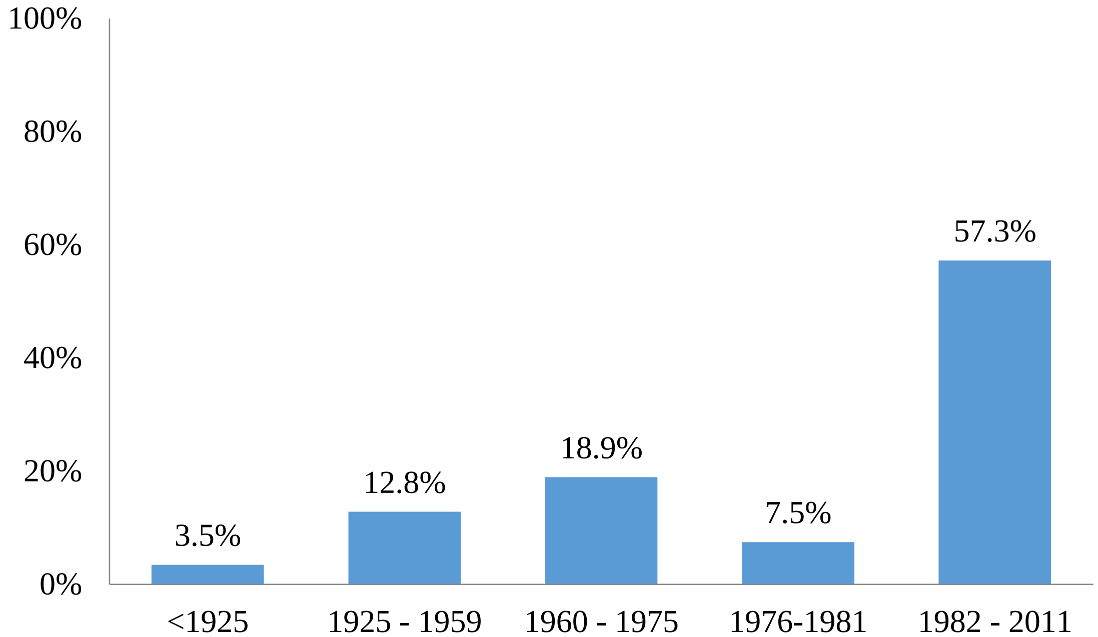


Figure 20. Proportions of property age groups in the North Queensland Coastal Region of analysis

3.4.2.1. Year of Construction - Townsville

Figure 23 shows the age of housing by construction period for policies in the Townsville Region that filed a claim for Cyclone Yasi. For clarity, extreme northern and southern areas of the Townsville Region are not included in the figure. The inland moving housing development of the central area over time is clearly shown. In general, for the main part of the city, the housing stock near the coastline is of an older construction age. This is an important finding from a risk modelling perspective, considering that wind conditions near the coast will generally be more severe than inland areas during a cyclonic event.

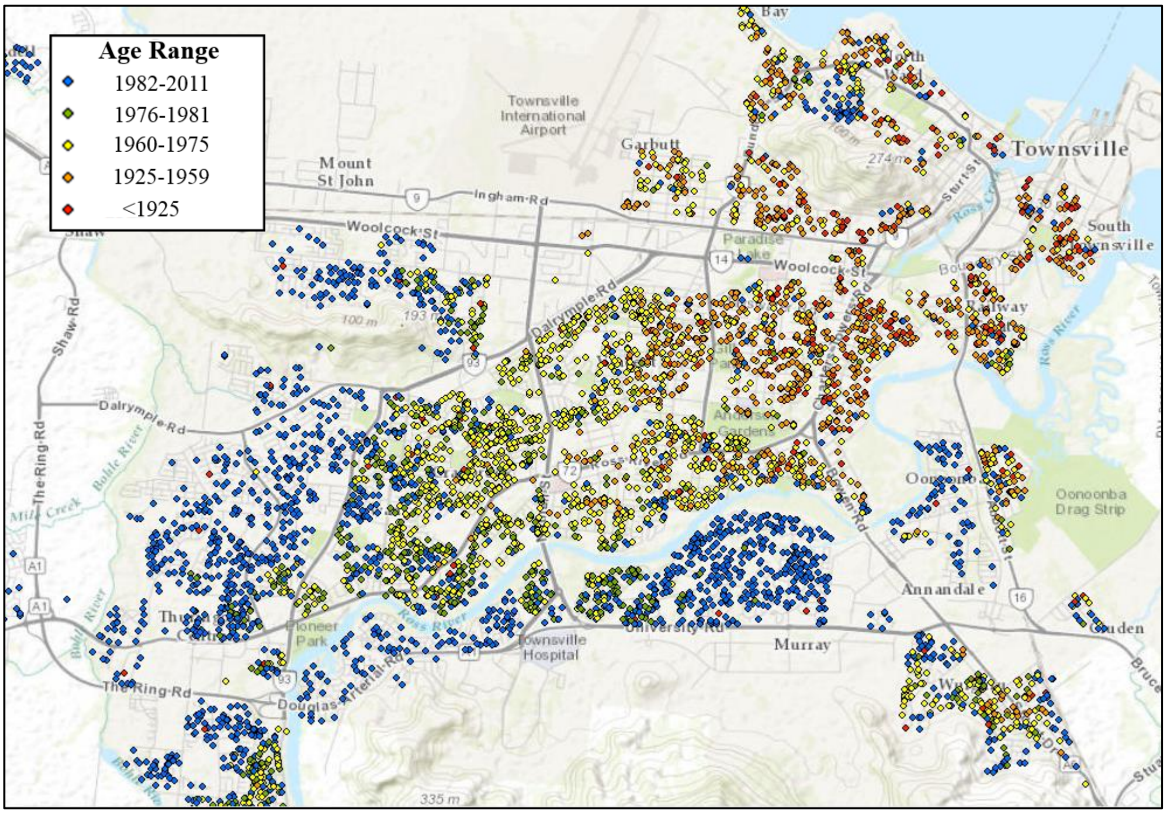


Figure 21. Distribution of property age groups across the Townsville Region

3.4.2.2. Year of Construction – Tully/Mission Beach

Figure 24 shows the age of housing by construction period for policies in the Tully/Mission Beach Region. The distribution of ages in this region does not follow the same pattern of inland expansion shown for the Townsville Region. Instead, construction age in the Innisfail and Mission Beach area appears to be evenly distributed between the five age ranges. However, moving to the south and in particular to the north of these areas, modern construction is more common. The quantity of housing constructed prior to 1925 is very small and generally confined to the Innisfail area. This should be considered when reviewing loss ratio trends (Sections 3.1.3 and 3.2.3) for housing in this age group.

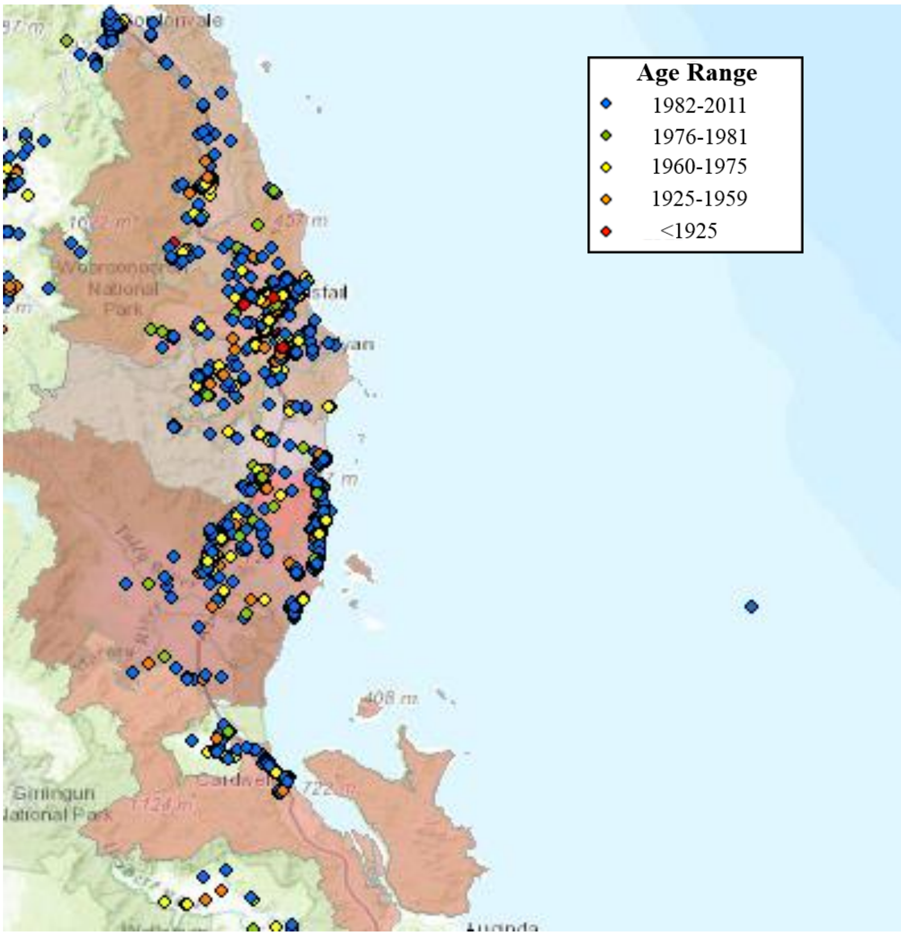


Figure 22. Distribution of property age groups across the Tully/Mission Beach Region

4. Claims Analysis (Assessors Reports)

The assessors reports provided by Suncorp were randomly sampled (*Data Set C*) in each of the three analysis regions for both Cyclones Yasi and Larry. In general, claims were classified based on a tabulation of words mentioned in the assessors reports (i.e. roof damage, water damage, etc.) to determine common themes or drivers of loss.

This data set included 179 assessor's reports from Cyclone Yasi and 56 assessor's reports from Cyclone Larry for a random subset of the claims data provided by Suncorp. These reports were separated into three groups based on loss ratio (claim value/sum insured) to compare typical damage modes for similar claim sizes. Table 7 shows the typical damage modes mentioned in assessors reports for each loss ratio bin and region of analysis.

The data clearly indicate that roofing damage, window damage, and water ingress are major drivers of loss during cyclones for claims of all sizes. The data also suggest that if a claim loss ratio is high, it is very likely that roofing damage (e.g., cladding failure, etc.), window damage (i.e. broken glass or casing damage), and water damage (e.g., ingress through windows/roofing) have occurred. **This implies that a targeted mitigation program that reduces vulnerability to these damage modes, will reduce losses from insurance claims. Furthermore, reducing the frequency of severe claims by even a small proportion, has the potential to greatly decrease loss potential.**

Table 7. Damage modes (by word mention) from claim assessor's reports for Cyclones Yasi and Larry grouped by loss ratio and analysis region

Loss Ratio	Cyclone/ Region	# of Claims	Tree	Roof	Window	Ceiling	Roller Door	Water Damage
0-.09	TC Yasi/ Townsville	157	21%	31%	15%	17%	2%	30%
0.1-.49	TC Yasi/ Townsville	9	22%	89%	33%	67%	0%	78%
0.1-.49	TC Larry/ Innisfail	43	14%	91%	67%	56%	16%	88%
>= 0.5	TC Larry/ Innisfail	13	15%	100%	77%	69%	31%	92%
>= 0.5	TC Yasi/ N. QLD	13	31%	100%	85%	100%	8%	100%

General observations on damage from assessor's reports:

- "Roof" damage includes guttering, downpipes, fascia board, 'whirly bird' type roof ventilators, as well as the cladding and flashing etc.
- For older housing, vulnerability to roof leakage was generally increased due to age, neglect and lack of maintenance
- For modern construction, roof leaking was caused by poor design, inadequate flashings, overflowing gutters etc.
- A commonly reported damage was to shade sails. There are no cyclone ratings for shade sails. They should be removed as part of a comprehensive cyclone preparation protocol.
- Fences and garden sheds were both featured heavily in the descriptions of loss. Fences were predominantly damaged by trees, with some blowing over of larger solid styles of fence. Shed damage from trees was also common.

- Cracked block walls were also mentioned in claims but not strictly cyclone related damage, rather poor construction and shrink swell behaviour of the soil.
- A number of the properties had roofs in poor condition.
- Damage/removal of components on one home, was often reported as having caused damage to and adjacent or neighbouring home.
- In one instance, a home constructed in the 1980s did not meet modern construction standards or typical features used at that time.
- Guttering was often reported as being unclipped and removed by wind.

5. Summary of Findings/Recommendations

Drivers of loss

The data clearly indicates that roofing damage, window damage, and water ingress are major drivers of loss during cyclones for claims of all sizes. The data also suggest that if a claim loss ratio is high, it is very likely that roofing damage (e.g., cladding failure, etc.), window damage (i.e. broken glass or casing damage), and water damage (e.g., ingress through windows/roofing) have occurred. *Current design and test criteria for water penetration of windows and doors is typically a tenth of the wind load design pressures.* **A targeted mitigation program that reduces vulnerability to these damage modes, will reduce losses from insurance claims.**

Moderate sized claims (claim/sum-insured = 0.1-0.5) represent the largest proportion of claim related losses (44% = $110,404,702) for the Northern Queensland Coastal Region from Cyclone Yasi. Roofing damage, window damage, and water ingress related issues are typical for claims of this size. Large sized claims (claim/sum-insured = >0.5) represent at total of 27% ($67,769,249) of the claim related losses for the Northern Queensland Coastal Region. Typical damage modes for claims of this size are generally more extreme versions of those described for moderate sized claims. **To reduce losses (i.e. claim frequency), the CTS recommends a mitigation program that emphasizes structural roofing upgrades (e.g., batten/rafter connections, etc.) to older homes (pre-1980s) and opening protection upgrades (i.e. shutters for windows, roller door bracing, etc.) for homes of all ages. Programs should also emphasise the importance of implementing a home maintenance routine in the long-term (e.g., repairing corroded metal supports, monitoring roof cladding tie-downs and water-tightness, replacing degraded timber, etc.).**

Large claims (claim/sum-insured = >0.5) in the Tully/Mission Beach Region, including the underinsured bin, comprise 38% of the total cost for this region despite only accounting for 9% of the total number of claims. In other words, major failures to even a relatively small number of houses can be a dominant driver of loss. *Preventing even a small portion of major structural failures through structural retrofit mitigation could be very effective in reducing losses.*

Minor claims (e.g., fencing, shade sails, minor water ingress, etc.) represent 86% of the total number of filed claims for Cyclone Yasi in the North Queensland Coastal Region and comprise 29% of the total cost (not including Suncorp processing overhead). Minor claims are equally likely to be filed by housing of all ages in both high-wind and low-wind areas of a cyclone. **The CTS suggests that community education/awareness campaigns may be the most effective method of reducing the frequency of claims of this size. Including emphasis on cyclone preparation activities such as removing shade sales, outdoor furniture, debris and unsecured items from the yard as well as pruning trees.**

Housing Age

The data indicate that housing constructed between 1925 and 1981 is at a relatively higher risk of structural damage. However, a significant proportion of contemporary housing also experienced severe loss ratio damages, which suggests that modern housing did not perform as expected per the National Construction Code (NCC). **This Suncorp data can provide a cost of this issue to the community and provide significant impetus in enhancing building standards to address water ingress, as well as to the education of designers, builders and homeowners to use more resilient products in the market.**

<u>Key recommendations:</u>

Recommendation 1:

Develop a targeted mitigation program that reduces vulnerability to the most common types of damage, focusing on:

- Structural roof upgrades for homes constructed before 1980 and other practical retrofit measures
- Upgrades to opening protections (e.g. windows and doors) for homes of all ages
- Emphasising the importance of regular maintenance.

This presents great potential in delivering a range of community benefits, including insurance savings.

Recommendation 2:

Implement community education/awareness campaigns to reduce frequency of small claims, including an emphasis on cyclone preparation activities such as removing shade sales, outdoor furniture, debris and unsecured items from the yard as well as pruning trees.

Recommendation 3:

Use the data provided on failures in newer buildings to drive ongoing work around enhancing building standards to address resilience issues, as well as initiatives to support and encourage designers, builders and homeowners to use more resilient products.

References

AS-4055, 2006. Wind Loads for Housing. Standards Australia.

AS/NZS-1170.2, 2002. Structural design actions Part2: Wind actions. Standards Australia.

Boughton, G., Falck, D., 2007. Tropical Cyclone George Damage to buildings in the Port Hedland area. Cyclone Testing Station, James Cook University, Townsville. TR 52.

Boughton, G.N., Henderson, D.J., Ginger, J.D., Holmes, J.D., Walker, G.R., Leitch, C., Somerville, L.R., Frye, U., Jayasinghe, N.C., Kim, P., 2011. Tropical Cyclone Yasi Structural Damage to Buildings. Cyclone Testing Station, James Cook University, Townsville. TR 57.

Crandell, J.H., 1998. Statistical assessment of construction characteristics and performance of homes in Hurricanes Andrew and Opal. J Wind Eng Ind Aerod 77–78, 695-701.

Crowder, B., 1995. The Wonders of Weather. Australian Government Publishing Service, Canberra.

Franco, G., Green, R., Khazai, B., Smyth, A., Deodatis, G., 2010. Field Damage Survey of New Orleans Homes in the Aftermath of Hurricane Katrina. Natural Hazards Review 11, 7-18.

Gurley, K., Masters, F., 2011. Post-2004 Hurricane Field Survey of Residential Building Performance. Natural Hazards Review 12, 177-183.

Henderson, D., Ginger, J., 2007. Vulnerability model of an Australian high-set house subjected to cyclonic wind loading. Wind and Structures 10, 269-285.

Henderson, D.J. and Ginger, J.D. (2008). *Role of building codes and construction standards in windstorm disaster mitigation*. Australian Journal of Emergency Management, Vol 23 No 2

Henderson, D.J., 2013. Pilot study: Examination of strata building risks from cyclonic weather by utilizing policy claims data. Cyclone Testing Station, JCU, Townsville.

Henderson, D.J., Ginger, J.D., Leitch, C., Boughton, G., Falck, D., 2006. Tropical Cyclone Larry – Damage to buildings in the Innisfail area. Cyclone Testing Station, James Cook University, Townsville.TR51.

Henderson, D.J., Leitch, C., 2005. Damage investigation of buildings at Minjilang, Cape Don and Smith Point in NT following Cyclone Ingrid. Cyclone Testing Station, James Cook University, Townsville. TR 50.

Henderson, D.J., Leitch, C., Frye, U., Ginger, J.D., Kim, P., Jayasinghe, N.C., 2010. Investigation of Housing and Sheds in Procerpine, Midge point, and Airlie Beach, Following Tropical Cyclone Ului. Cyclone Testing Station, James Cook University, Townsville.TR 56.

Holmes, J.D., 2001. Wind loading of structures. Spon Press, London.

Leitch, C., Ginger, J.D., Harper, B., Kim, P., Jayasinghe, N.C., Somerville, L.R., 2010. Performance of Housing in Brisbane Following Storms on 16 November 2008. Australian Journal of Stuctural Engineering Vol 11.

Melita, B., 2007. Performance of Housing Envelope in Tropical Cyclone Larry, School of Engineering. James Cook University, Townsville.

Minor, J.E., 1994. Windborne debris and the building envelope. J Wind Eng Ind Aerod 53, 207-227.

Pita, G., Pinelli, J.P., Cocke, S., Gurley, K., Mitrani-Reiser, J., Weekes, J., Hamid, S., 2012. Assessment of hurricane-induced internal damage to low-rise buildings in the Florida Public Hurricane Loss Model. J Wind Eng Ind Aerod 104-106, 76-87.

Pringle, T., 2003. Working from basics- Reverse-slope eves. http://www.branz.co.nz/cms_show_download.php?id=99b7ef8339d6285b3d068f9aeb0683f9f72590f5.

Queensland Home Building Code (1981) Appendix 4 to the Standard Building By-Laws 1975 Under the
Building Act 1975-1981, Government Printer, Queensland.

Reardon, G., Henderson, D., Ginger, J., 1999. A structural assessment of the effects of Cyclone Vance on houses in Exmouth WA Cyclone Testing Station. 1999, James Cook University, Townsville.TR48.

Reardon, G.F., Walker, G.R., Jancauskas, E.D., 1986. Effects of Cyclone Winifred on Buildings. Cyclone Testing Station. James Cook University, Townsville.TR27.

Salzano, C.T., Masters, F.J., Katsaros, J.D., 2010. Water penetration resistance of residential window installation options for hurricane-prone areas. Building and Environment 45, 1373-1388.

Sheffield, J., 1994. Survey of building performance in hurricane iniki and typhoon omar. Hurricanes of 1992: Lessons Learned and Implications for the Future, 446-455.

Sparks, P.R., Schiff, S.D., Reinhold, T.A., 1994. Wind damage to envelopes of houses and consequent insurance losses. J Wind Eng Ind Aerod 53, 145-155.

Van De Lindt, J.W., Graettinger, A., Gupta, R., Skaggs, T., Pryor, S., Fridley, K.J., 2007. Performance of wood-frame structures during hurricane Katrina. Journal of Performance of Constructed Facilities 21, 108-116.

Walker, G.R., 1975. Report on Cyclone Tracy-Effect on buildings- Dec 1974. Australian Dept of Housing and Construction

Appendix A: Background Information

This section provides relevant background information on building damage induced by extreme wind events (e.g., common modes of damage, vulnerability modelling techniques, etc.). This information has been compiled from multiple sources of building science research, including the Cyclone Testing Station database.

6.1. Tropical Cyclone Wind Speeds

The destructive force of tropical cyclones is usually expressed in terms of the strongest gusts likely to be experienced, which is related to the central pressure, speed of movement and internal structure of the storm system. The Bureau of Meteorology uses the five-category system shown in Table 8 for classifying tropical cyclone intensity in Australia.

Table 8. Bureau of Meteorology Cyclone Categories

Cyclone Category	Gust Wind Speed at 10 m height in flat open terrain (V_R)			Central Pressure
	km/h	*knots*	*m/s*	hPa
1	<125	<68	<35	990
2	125-170	68-92	35-47	970-985
3	170-225	92-122	47-63	950-965
4	225-280	122-155	63-78	930-945
5	>280	>151	>78	<925

The main features of a severe tropical cyclone at the earth's surface are the eye, the eye wall and the spiral rain bands. The eye is the area at the centre of the cyclone at which the surface atmospheric pressure is lowest and where the wind is slight and the sky is often clear. The cyclone's intense winds are associated with the eye wall. For any given central pressure, the spatial size of individual tropical cyclones can vary enormously. Severe cyclones can have eye diameters from 15 to 50 km.

6.2. National Construction Code (NCC) of Australia

The NCC's structural performance requirements specify that a building or structure, to the degree necessary, must resist the wind actions to which it may reasonably be subjected and also:

- Remain stable and not collapse
- Prevent progressive collapse
- Minimise local damage and loss of amenity
- Avoid causing damage to other properties

The Australian Building Codes Board sets the societal risk for the ultimate limit state strength of a structure, in the NCC (2014). The level of risk is evaluated depending on the location and type of structure. The wind loads for housing standard (AS-4055 2006) derives its wind loads for housing based on Level 2 importance which has a minimum annual probability of exceedance of 1:500. Other structure types assume a different level of importance. For example, a hospital has a higher level of importance (Level 3) than an isolated farm shed (Level 1). The design level for housing (Importance Level 2 as noted in the Guide to the BCA 2007) is to be a minimum annual probability of exceedance of 1:500.

Accordingly, a house is required withstand its ultimate limit state design wind speeds thereby protecting its occupants. For cyclonic Region C (Figure 25) as defined in AS/NZS 1170.2, the regional 10 m height 3-second gust wind speed (V_R) for a 1:500 probability is 69 m/s, **a mid-range Category 4 cyclone. This wind speed has a nominal probability of exceedance of about 10% in 50 yrs**.

6.3. Wind Regions for Design

Windstorms can broadly be classified according to their meteorological parameters as: tropical cyclones, thunderstorms, tornados, monsoons and gales. Different parts of the world are influenced by these various types of storms. Cyclones generally impact on coastal regions in the tropics, and extend hundreds of kilometres and therefore have the potential to cause the most damage. Thunderstorms and tornados are much more local, with their influence affecting distances of up to 10's of kilometres. A tornado impacting on a community in Australia is a relatively rare occurrence, compared to that of the US. Nevertheless, tornadoes can generate extremely high wind speeds and cause extensive destruction in local areas. For more detailed information on the different types of windstorms see texts such as Crowder (1995) and Holmes (2001).

These variations in weather systems are accounted for in the Australian and New Zealand Standard for structural design wind actions, AS/NZS 1170.2-2011, which divides Australia into several regions, as shown in Figure 25. Wind loads used in the design of structures (e.g. houses, shops, large storage sheds, 4 to 5 storey apartments, etc) are calculated from the data specified in AS/NZS 1170.2 which excludes tornados from its scope of wind actions.

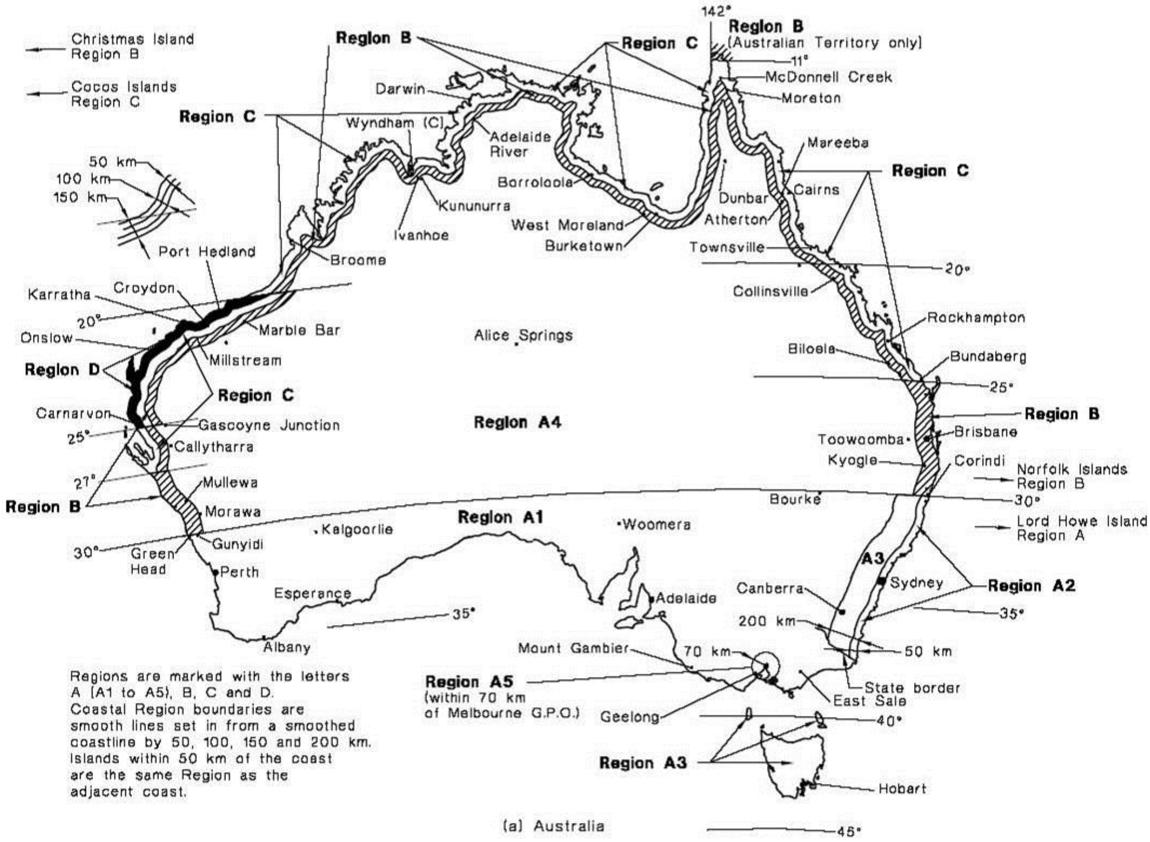


Figure 23. Wind Regions of Australia (AS/NZS-1170.2 2002)

6.4. Typical Housing Construction Types

Populated regions are typically comprised of a mixture of house types. There are differences in size, shape, window size, cladding type, roof shape, age, and methods of construction. Each of these parameters can have an effect on the resilience of the house to resist wind forces. For the purpose of vulnerability analysis, these details are averaged over a population of similar style/types of houses. Thus, any analysis is therefore representing a population and not individual examples.

Older housing types were generally designed to deal with humid climate and not destructive winds. A "Queenslander" style home was common in northern regions of Queensland and consists of a timber frame house elevated to up to a second storey on timber or concrete stumps. These older houses now often have had their open area under the house partially or completely enclosed, which may have implications for vulnerability (both in terms of wind load resistance and increased interior living space and contents loss).

Timber framing can have many different types of cladding attached to it, such as brick, metal, fibre cement or timber weatherboards. There are many types of connections needed in timber frame houses since a variety of different members need to be connected. Connections can be made using nails, screws, glue, bolts, plates, straps or a combination of them. A common form of connection used in older houses is a mortice and tenon joint. Standards such as AS1684, specify the appropriate type of connections. Figure 25 shows general structural systems in timber frame houses and the compents used.

Brick veneer housing uses typically a timber frame to provide the structural wind load resistance. The brickwork is merely a cladding that is supported horizontally by a timber frame. It consists of a single external brick layer which is attached to the timber frame using brick ties.

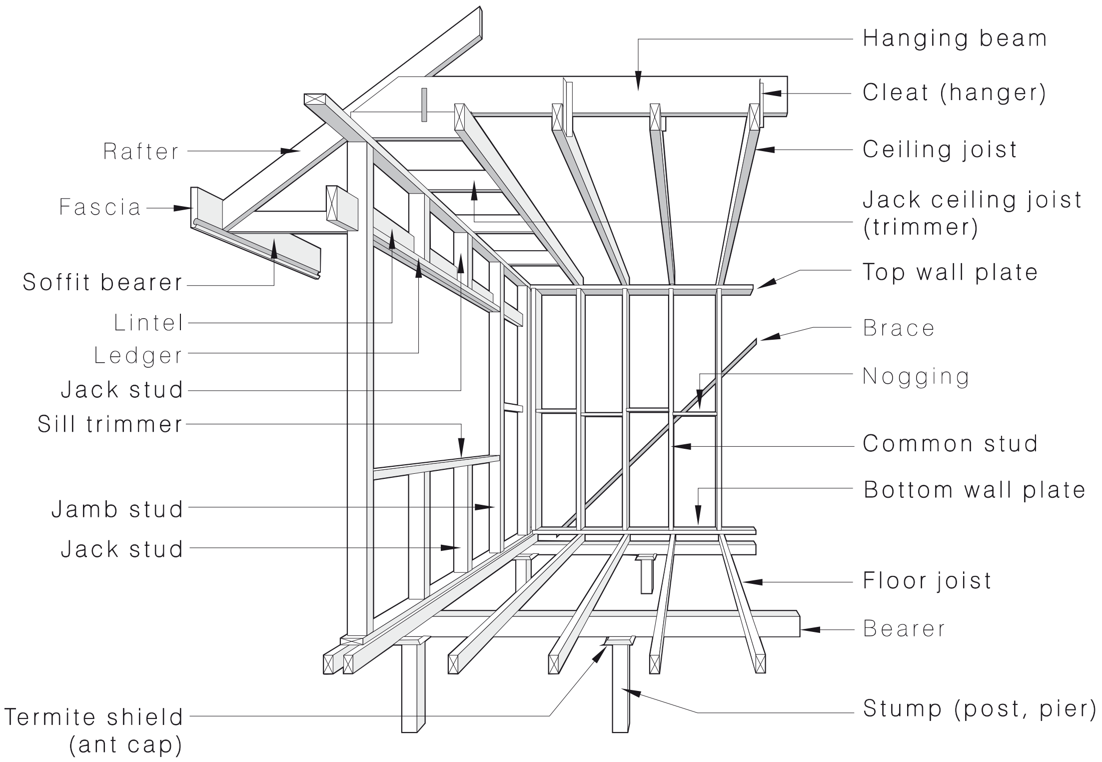


Figure 24. Typical arrangement of timber framing, Source: AS1684.3

Reinforced masonry (concrete) block houses have become very common in North Queensland since the late 80s. Masonry blocks are bigger than traditional bricks and have large hollow sections called cores. Steel reinforcing is placed both vertically and horizontally in the cores which are then filled with concrete. The houses are built on concrete slabs (foundation) with the reinforcing starter embedded in the concrete slab to provide tie down and load path for the walls and roof. Horizontal steel reinforcement is used along with shear ties in the concrete bond beam at the top of the walls. The roof frame is generally timber, and is bolted to brackets or cleats on the bond beam (Figure 27).

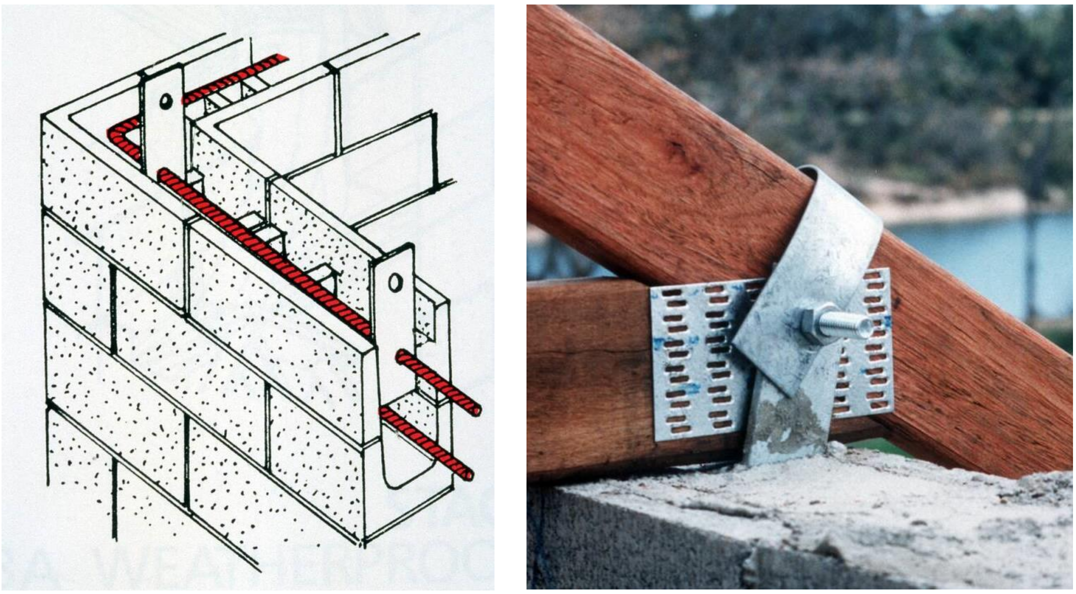


Figure 25. Bond beam reinforcing and truss cleat plate (left) and cleat plate with overstrap providing hold down to hardwood truss in cyclonic region (right)

6.4.1. Early 1900s

Houses built in the early part of the century were considerably smaller than current houses. They commonly have a central square core with verandas on two or three sides. Usually a high-pitched pyramid shaped roof for the core with the veranda roofs at a lower pitch. Mostly mortice and tenon construction for the wall frame. Supported by stumps on which bearers were bolted to.

6.4.2. 1920s to 1950s

Gables were common as housing shapes were no longer square or rectangular. Mortice and tenon wall frames were still used. Also still supported by stumps on which bearers were bolted to. Many houses have vertically joined internal timber lining, which connected from joists to battens and provided tie down. External cladding was usually timber weatherboards.

6.4.3. 1960s and 1970s

Commonly timber framed houses with a rectangular shape and elevated on stumps around 2.5 m high. External walls were usually clad with fibre cement or timber weatherboards. The vertical timber lining in earlier vintage houses was replaced by sheet lining, which provided reduced tie-down capacity. Cyclone rods were used in perimeter walls at about 3 m spacing. Single storey brick veneer houses were also present and were becoming increasingly common. This house type typically has a low pitch to flat roof. Roofing for both styles was generally metal sheeting.

6.4.4. 1980s and 1990s

Queensland Home Building Code was introduced in 1982, so houses built prior to this are assumed to be designed and built to requirements for cyclonic conditions. Typically single storey houses with truss roofs ranging from low to high pitch. External cladding is reinforced masonry block or brick veneer. Steel roof cladding is most common.

North Queensland
Most new houses tend to be single storey, slab on ground, reinforced masonry block. Roofing structure is still predominantly timber however provisions at connections, such as nail plates and metal straps, are used to ensure sufficient tie down capacity. Metal roof cladding is almost exclusively used in new homes. Steel frames are also used in some houses.

South Queensland
Unlike north Queensland, the predominant structural system is light weight timber framing Often with a brick veneer cladding. Local councils particularly in Brisbane recognize the cultural significance of Queenslander style houses and put restrictions on their demolition. This has led to an increase in the number of renovations and additions made to old Queenslander houses to allow for a more modern life style and upgrade them to meet the current building code.

Table 9. Generalized examples of housing construction types in North Queensland

Built During	Example of geometry and features	Generalised features
< 1920s		Hip roof, reduced rafter spans, central core, exposed studs, on stumps (low and high)
1925 – 1959		Hip and gable, VJ lining, reduced rafter spans, on stumps (low and high)
1960s – 1981		Gable low pitch, vermin proof flooring (studs not mortice and tennon into bearers), panel cladding, on stumps
1981 - present		Reinforced masonry block, hip and gable, large truss spans, medium roof pitch, slab on ground

6.5. Wind Speed

Winds impacting the house cause both positive pressures pushing on wind ward walls as well as large negative pressures (suctions) acting on roofs as well as side and leeward walls. In addition, sudden openings in the building envelope, typically caused by wind-borne debris, can lead to an increase in the pressure inside the building, adding to the overall load on roof cladding, walls, etc. (Figure 28). Small increases in wind speed result in larger increases in pressure. It is therefore important to ascertain the impacting wind speed at a location.

The loads induced by wind flow are also affected by the terrain over which it blows (e.g. accelerates up a slope; reduces with increasing terrain roughness such as suburbs as opposed to open fields; and increases with height above ground) and by shielding from nearby similarly sized objects such as houses immediately in front of the "target" house.

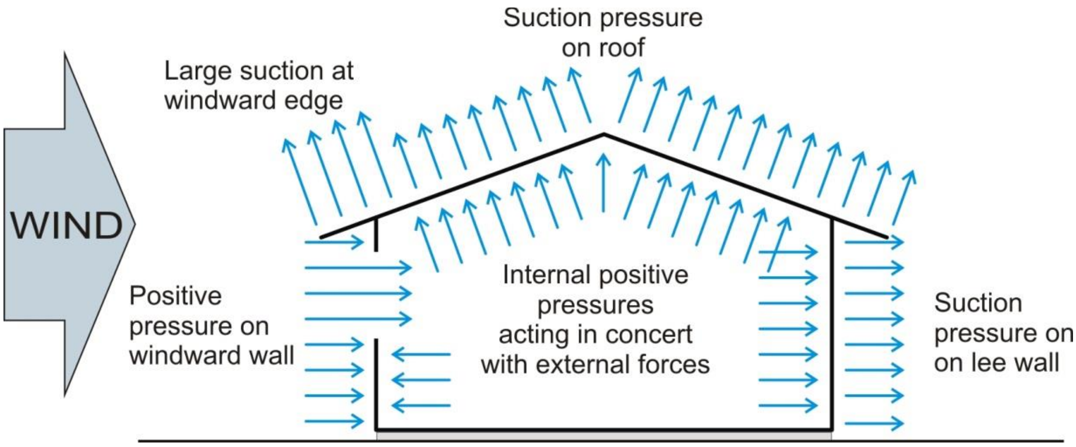


Figure 26. Simplified representation of wind pressures acting on building

6.6. Water Ingress Through Wind-driven Rain

Water ingress can cause damage to internal linings, resulting in costly repairs, potential long term durability concerns and mould growth, in addition to the loss of amenity. This damage will arise from the ingress of rain-water with a pressure difference across the envelope (i.e. net positive pressure across the roof or wall), and also from the envelope being damaged by flying debris or failure of cladding elements (i.e. soffits, gutters or fascia).

Due to low design (test) requirements for windows/doors (e.g. AS 2047) water ingress and associated damage to the house can be expected when heavy rain occurs with wind speeds greater than about 120 km/h (Henderson and Ginger 2008). This is due to the wind load pressures exceeding the test pressures specified. Water ingress in areas other than windows is also possible, although the wind speed at which this might occur is less understood for the other elements such as valley gutters or eaves vents.

Damage investigations in many parts of the world (Sheffield 1994, Sparks et al 1994, Henderson et al 2006, Van De Lindt et al 2007, Franco et al 2010, Boughton et al 2011, Gurley and Masters 2011) have shown that unmanaged water ingress has become a critical and recurring problem in residential constructions. The result is increased insurance losses due to interior damage (Sparks et al 1994, Pita et al 2012). Sparks et al (1994) suggested that insurance losses in buildings due to rain entering can be magnified by a factor ranging from two, at lower wind speeds, to nine at higher speeds. They recommended that building envelopes be designed for the same probability of failure as the main structural system.

The CTS conducted a study for the Insurance Council of Australia on insured losses in strata properties suffered during Cyclone Yasi (Henderson 2013). The study found 80% of claims noted damage resulting from water ingress (Figure 29). This result is strikingly similar to that of a survey following Cyclone Larry (Melita 2007) showing 75% of contemporary houses having envelope damage and water ingress. All this damage was from wind speeds far less than the structural design wind speeds as set out in the National Construction Code. From analysing the available strata claims and ratios of losses to sum insured (LR/SI) it can be inferred that approximately one quarter of the claims were associated with wind driven rain entering via the building envelope (roof space, windows, doors, etc) without mention of structural or other damage to breaching the envelope. These claims account for 20% of the total losses – just from wind driven rain ingress via "undamaged/code compliant" building envelope (Henderson 2013).

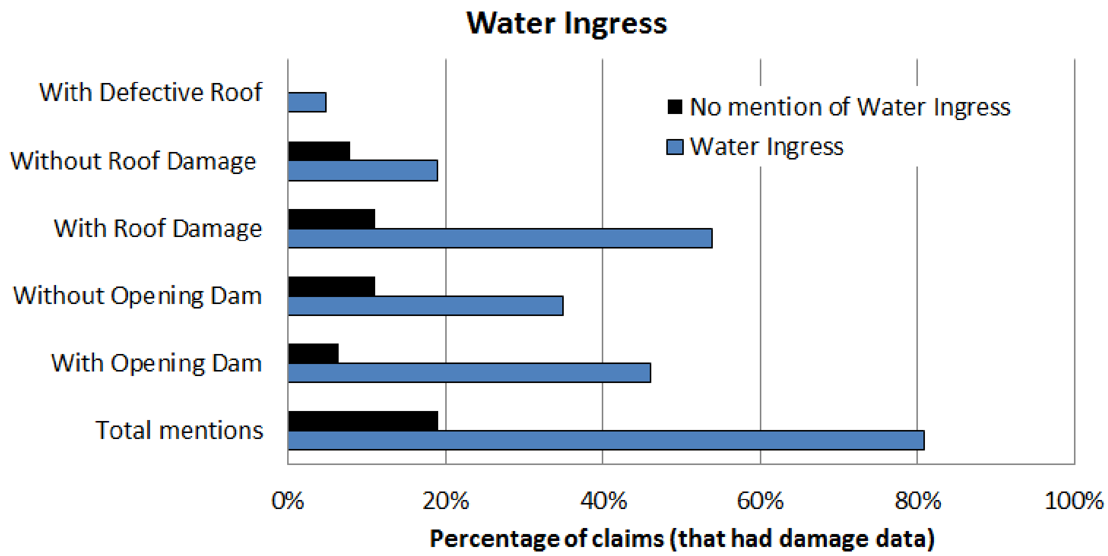


Figure 27. Wind driven rain water ingress damage from insurance claims data (Henderson 2013)

6.6.1. Observations for Australian Housing

The damage surveys by Boughton et al (2011) and Henderson et al (2006) from tropical cyclones Yasi and Larry, and Leitch et al (2010) from the Brisbane Thunderstorms of 2008 describe that wind-driven rain passed through the building envelope at openings such as windows and doors (even if closed), around flashings, through linings, or where the envelope has been damaged.

Boughton et al (2011) noted that high differential pressure between the inside and the outside of the building can be established in strong winds. This differential pressure can force water through gaps and spaces that it would otherwise not penetrate (Pringle 2003). The air flow around and over a building in an extreme wind event can drag water upwards over the building envelope. Flashings that are meant to channel downward-moving water away from the envelope, direct the upward-moving water into the building.

The following points of water entry into buildings were observed during the investigation of Cyclone Yasi (Boughton et al 2011):

- *Through ventilators.* Ventilators in gables, soffits or in the roof surface normally keep out driven rain that has a significant downward component to its motion. However in extreme winds, the upward component in the driven rain means that water was driven upwards through the soffit ventilators or between the slats in gable ventilators.

- *Around doors and windows.* The high differential pressure across the building envelope drove water through the small spaces around doors and windows and upwards through window weep holes. Some occupants reported a steady spray of water from the base of windows into rooms on the windward side of the house.
- *Under flashings.* Wind-driven rain moving upwards against the building envelope was pushed under flashings and into the building. This effect was particularly noticeable at the top of valley gutters. Water was driven up the valley gutter by wind where the direction of the gutter was aligned with the wind direction, entering the building near the top of the gutter and causing damage to the ceiling.
- *Through perforations of the envelope.* Water ingress was observed in buildings with a perfect structural performance, but where the building envelope had been damaged through either impact of debris or structural loss of cladding, significant quantities of water were able to bypass all of the normal water-tightness features of the building and enter the building (Figure 30).

Figure 28. Damage to ceiling and fittings from wind driven rain via in part debris damage to gable end (TC Larry)

As described by Boughton et al (2011), Leitch et al (2010) and Henderson et al (2006), regardless of the cladding material, roof complexity adds to the potential for water ingress. Valley gutters, box gutters, and parapets all require additional flashings and therefore create more potential locations for water to be driven into the roof space.

Damage from windborne debris also provides a means of water ingress into buildings (Walker 1975, Reardon et al 1986, Henderson et al 2006, Henderson et al 2010, Leitch et al

2010, Boughton et al 2011). Debris mainly impacts windward walls (including doors and windows) and the upwind slope of steep pitch roofs. Investigations have shown that building envelopes constructed from fibre cement or metal sheeting, glass windows, roof tiles etc. are especially susceptible to debris impact damage and hence have higher likelihood of water ingress.

Appendix B: Analysis Regions

Northern Queensland Coastal Region

In order to isolate regions that were predominantly impacted by wind during Cyclone Yasi, the coastal region of North Queensland extending from Bowen to Port Douglas was selected for analysis. In the first instance, this area was to be selected by post-codes located along the coast (Figure 31). However, it was discovered that several post-codes include multiple non-continuous geographic regions (e.g. see post code 4816), with some regions located in coastal areas and others located farther inland. These multi-region postal codes were removed from the Northern Queensland Coastal Region analysis for simplicity and alignment with the range of estimated wind speeds by region that the Cyclone Testing Station developed after Cyclone Yasi. The selected analysis region is shown in Figure 32.

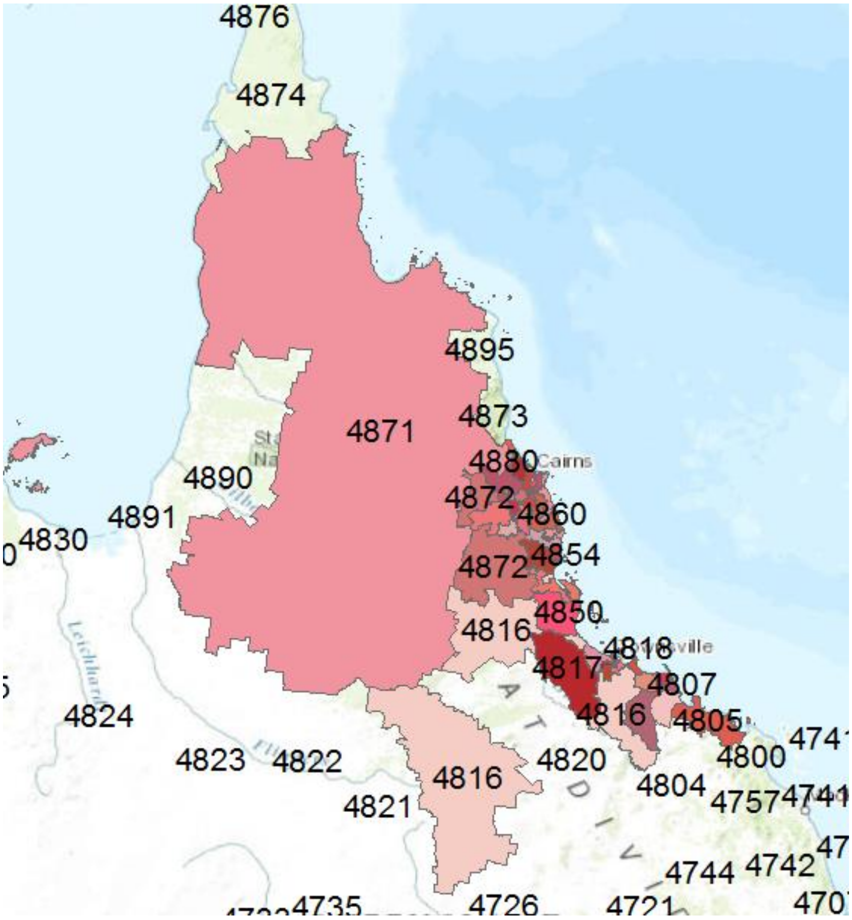


Figure 29. Geographic postal code regions in North Queensland

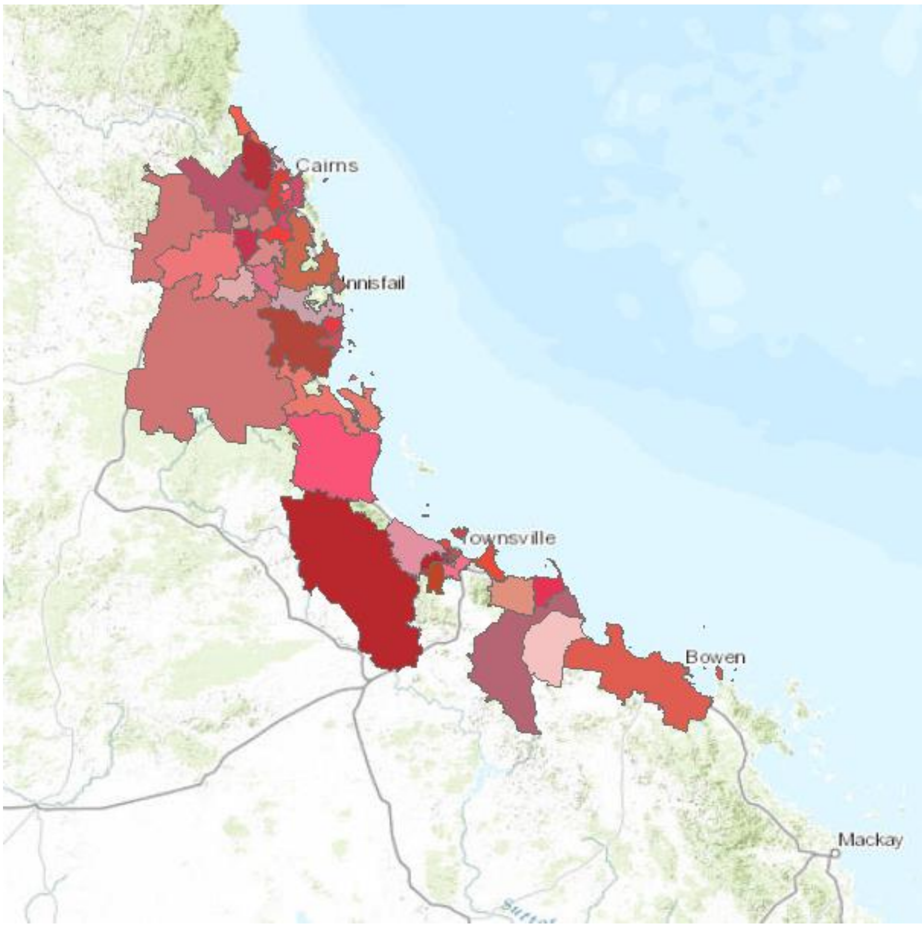


Figure 30. Postal code regions in the Northern Queensland Coastal Region of analysis which represents the bulk area affected by Cyclone Yasi.

Townsville Region (low wind speed area)

Due to the relatively large wind bands generated by Cyclone Yasi, the entire Townsville area in broad brush terms can be assumed for this study to have been subjected to a similar range of relatively low wind speeds, wind directions, and rain fall intensity. Hence, analysis of Townsville Region allowed performance comparisons between housing of various construction ages while limiting the uncertainty associated with variations in wind speed. Figure 33 defines the Townsville region by post-code, which extends from Alligator Creek to Bushland Beach. Of the policies within the Townsville Region, 30% filed a claim associated with Cyclone Yasi for a wind event which was about half of the wind load structural design criteria.

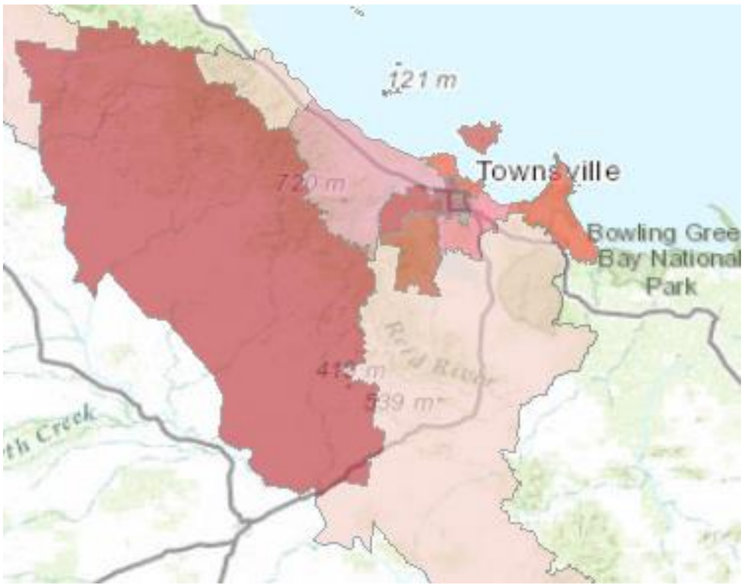


Figure 31. Postcodes in the Townsville study area

Tully/Mission Beach Region (high wind speed area)

The Tully/Mission Beach Region, which extends from Cardwell to Gordonvale, was selected for analysis due to the similar range of relatively high wind speeds, wind directions, and rain fall intensity. Hence, analysis of Tully/Mission Beach Region allowed performance comparisons between housing of various construction ages and provided a broad brush basis for comparing claim trends between high- and low-wind (i.e. Townsville) regions.