MODELLING CYCLONE LOSS MITIGATION USING CLAIMS ANALYSIS

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ABSTRACT

This paper follows from a series of recent studies conducted by the authors and Suncorp Group Limited which analysed insurance claims from Tropical Cyclone (TC) Yasi (Queensland, 2011) to determine typical drivers of insured loss (i.e. roofing failures, etc.) for residential housing. Using the claims data from TC Yasi, the benefits of mitigation were broadly estimated by reducing claim values based on survey results from builders and assessors on expected loss reduction in properties with mitigation features. This information was provided to Urbis (project consultant to Suncorp) for cost-benefit analysis of the projected benefits of mitigation over the next 50 years in Queensland. In this paper, the claims manipulation approach to modelling loss mitigation is presented and the results for TC Yasi are briefly discussed.

KEYWORDS

Structural retrofitting, legacy housing, insurance, claims analysis, wind resistance, Cyclone Yasi.

INTRODUCTION

Damage investigations carried out by the Cyclone Testing Station (CTS) following severe wind storms have typically shown that Australian houses built prior to the mid-1980s do not offer the same level of performance and protection during windstorms as houses constructed to contemporary building standards (Boughton and Falck, 2007, Boughton et al, 2011, Henderson et al, 2006, Henderson and Leitch, 2005, Henderson et al, 2010, Reardon et al, 1986, Reardon et al, 1999). A significant decrease in wind-induced damage to housing can be achieved if these legacy homes are upgraded to the current construction minimum. In the wake of recent severe wind events (i.e. 2014 Brisbane Thunderstorms, 2015 TC Marcia, etc.), there is a renewed vision for large-scale wind damage mitigation programs in Australia. A practical and economical retrofit program to reduce wind-related damages has the potential to dramatically reduce losses from future wind events. To inform the selection of upgrading techniques for various Australia construction types, rational modelling of the benefits is required.

METHODOLOGY

Claims data were used to estimate proportions of housing population expected to incur a certain level of loss for range of wind speeds (i.e. fragilities). Based on construction age, the policies were grouped into three "generic" house types. The analysis used the policy and claims data from TC Yasi (policies with and without claims). The use of such data for modelling does not account for ongoing incremental improvements to new buildings (i.e. changes to garage door standards, roofing tile standard, etc.) that should result in reduced damage to new housing with these components.

Approach Overview

A program was developed to perform the fragility analysis. Proportions of homes expected to incur varying levels of loss for a given wind speed were estimated for four mitigation scenarios: a) structural roof upgrading (applies to pre-60s and 1960-80s housing), b) opening protection for windows and roller doors (applies to all housing ages), c) community preparedness upgrades (applies to all housing ages), d) no mitigation upgrading.

The program was written based on five variables from the claims data including: sum insured value, claim value ($, includes null claims), loss ratio (computed as claim value / sum insured value), age of construction (in three bins: pre-1960, 1960-80s, post-1980), and estimated wind speed during TC Yasi.

From the unaltered claims data, a baseline performance case for non-mitigated structures (item d above) was generated by assuming all policies had not been upgraded (by the methods above) prior to TC Yasi. This baseline case was established by quantifying the proportion of homes falling within four loss ratio groups (0, 0-0.1, 0.1-0.5, >0.5) for each of the three housing age groups and wind speeds ranging from 22-70 m/s.

The effects of mitigation were simulated by reducing claim values in the original data set, and re-evaluating proportions of homes falling into the various loss ratio groups. The criteria for modifying claim values were dependent on the type of mitigation action, age of construction, estimated wind speed, and loss ratio (as an indication of more/less extreme damage modes). The amount of reduction for each mitigation action was estimated from survey of builders and assessors in Queensland. The criteria and assumptions used for applying modifications are detailed in the following sections.

Statistical assumptions for the proportions of claims modified by (e.g., the proportions of policies with avoided damage) were estimated based on damage modes extracted from assessors' reports (Table 1) from Cyclones Yasi and Larry (Smith and Henderson, 2015). The number of available reports on claims with high loss ratios was limited, and is noted as a source of uncertainty in the extrapolation of statistics from these samples to larger claim sets in the fragility analysis. All adjustments that result in claim values below zero were assumed equal to zero. Storm tide damaged properties were not considered.

Table 1. Damage modes (by word mention) from claim assessor's reports for Cyclones Yasi and Larry grouped by loss ratio and analysis region (Smith and Henderson, 2015).

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%

Structural Roof Upgrades

Damage to the roofing structure is a well-known driver of loss during cyclones and other high-wind events (Figure 1). In addition to direct loss, roofing damage often leads to water ingress and additional wind-borne debris. The basic engineering design principles for wind loads on roofing structures require that each element of the system (i.e. cladding, battens, and rafters) be connected to each other and to the foundation of the structure through supports in the wall system. Roofing failures generally occur when one or more of the connections in the system fails. Contemporary housing is constructed with stronger connections than legacy housing (pre-1980s) due to enhanced building standards. Therefore, modelling for structural roof upgrades was focused on pre-1960s and 1960-80s housing as follows: a) strapping at batten/rafter and ridge connections (pre-1960s and 1960-80s), b) collar ties between rafters (pre-1960s), and c) vertical tension members between rafters and ceiling joists (1960-80s).

Figure 1. Wind-induced roofing failure due to poor framing connections in Yeppoon, Australia following Cyclone Marcia (2015)

In order to quantify basic estimates for the performance increase achieved by structural roof upgrading, simple structural analysis models were generated for pre-1960s and 1960-80s typical roofing shapes using a structural engineering software package (SPACE GASS). Using SPACE GASS, before and after upgrade versions of a simple two-dimensional roof systems were subjected to wind uplift loads based on approximations from AS/NZS 1170.2 (Standards Australia, 2011). As severe roofing failures typically occur due to failed connections (e.g., batten/rafter, ridge, etc.), the upgrades were designed to disperse loading throughout the roofing structure and down to the foundation supports, thus reducing the concentrated loads at critical connections. The upgrades also strengthen the load capacity of critical connections (via strapping). The combination of these effects creates a situation where the strength of connections are increased and the load they are required to resist is decreased.

Pre-1960s roofing structures (Figure 2) generally consist of high-slope, pitched frame hip construction. The mitigation upgrades selected for this roofing type include additional strapping at batten/rafter and ridge connections as well as collar ties to join rafters. Roofing structures from the 1960-80s generally consist of low-slope, pitched frame gable construction (Figure 2). The mitigation upgrades selected for this roofing type include additional strapping at batten/rafter and ridge connections as well as tension members to join rafters down to ceiling joists.

Figure 2. Typical Pre-1960s (left) and 1960-1980s (right) residential structures in Queensland, Australia

To estimate the performance benefits of upgrading, the loads at the rafter/batten interface (a critical connection for wind uplift) were estimated for a range of wind speeds (10 m height, suburban terrain) both before and after the upgrades using SPACE GASS.

In order to simulate the effects of these upgrades during TC Yasi, assumptions were made about the likelihood of roofing failure and severity of loss, based on the wind speed and loss ratio of policies in the data set. These assumptions were used to form criteria for modifying policy claim values based on the estimated loss mitigation resulting from the upgrade. From Table 1, the following statistical assumptions were made for claims with pre-1960s and 1960-80s housing:

- 30% in the 22-40 m/s wind band and the <10% loss ratio band had minor roofing damage

- 40% in the 40-47 m/s wind band and the <10% loss ratio band had minor roofing damage
- 50% in the >47 m/s wind band and the <10% loss ratio band had minor roofing damage
- 90% in the 22-47 m/s wind speed bands and the 10-50% loss ratio band had moderate roofing damage
- 100% in >50% loss ratio band had severe roofing damage

From these assumptions, and correspondence with claims assessors in Queensland, the criteria for reducing claim values in the data set were established. Specifically, the claim reduction value ($) and the proportion of policies it applies to were estimated for various combinations of wind speed and loss ratio (Table 2). For example, if the wind speed and loss ratio associated with a claim was 45 m/s and 30% respectively, the claim would be reduced by $30,000. This adjustment would have been made to 90% of claims that fit these criteria. Building code changes in the 1980s emphasized a continuous load path from the roof structure to the foundation, significantly decreasing the risk of severe roofing failures. Therefore structural roofing upgrades were applied only to homes constructed prior to 1980.

Table 2. Applied criteria for reducing claim values based on structural roofing mitigation upgrades

Wind Speed (m/s)	Loss Ratio (%)	Mitigated Loss ($)	Proportion of Claims Modified
22-40	<10	2,000	0.30
	10-50	25,000	0.90
	>50	70,000	1.00
40-47	<10	2,000	0.40
	10-50	30,000	0.90
	>50	100,000	1.00
>47	<10	2,000	0.50
	10-50	70,000	0.90
	>50	150,000	1.00

The roofing upgrade solution was presented in “scenario” format to assessors, builders and engineers in Queensland to provide cost estimates for implementation in an undamaged structure (i.e. prior to a severe wind event). The upgrade scenario included replacement of the metal cladding and then strapping of the rafter to top plates. A rectangular housing plan of 12 m x 8 m was assumed with a hip roof 22.5 degree slope. The costing scenario included battens to be strapped or screwed to rafters, collar ties installed for each rafter pair, strapping at rafter to top plate connections, and strapping struts at ridge to hip beams down to ceiling joists. The estimated cost varied from $30,000 to $53,200.

Opening Protection

Damage to openings in the external shell of a building (e.g., windows, roller doors, etc.) during cyclonic or severe storm events often exposes the interior of the home to both wind and water ingress. Wind flow into the building can create positive internal pressure, adding to the overall loads on cladding elements (i.e. roofing, etc.) and increasing the likelihood of roofing or other failures.

Water ingress into the building can cause extensive damage to building contents and is well-known to increase insured losses. Opening protection is focused on reducing the likelihood of these damages by protecting vulnerable openings (i.e. windows, roller doors) from wind-borne debris impact and pressurized water ingress. The types of upgrades that can be used to protect windows differ from those of garage doors and thus the two upgrades are discussed separately below.

Garage door upgrades

Garage door failures generally occur due to loads generated by wind-induced pressures (Figure 3). At lower wind speeds, damage is typically limited to buckling failure. However, at higher wind speeds buckled doors can become dislodged from tracks, causing additional damage to the surrounding structure and becoming wind-borne debris in some cases. To mitigate these damages, the upgrade model for garage doors includes aftermarket bracing to restrain the door from buckling in either the inward or outward direction.

Figure 3. Wind-induced garage door failure due to poor bracing in Yeppoon, Australia following Cyclone Marcia (2015)

Based on consultation with representatives from the building industry in Queensland, it was estimated that ~20% of pre-1960s and 1960-80s housing is equipped with a roller door. Alternatively, ~90% of post-1980s housing are equipped with a roller door. Therefore, the benefits of garage door upgrades were applied to these proportions of claims for each age group. For example, of all the claims for post-1980s housing, a random subset including 90% of those claims was selected, to which the mitigation criteria in Table 3 were applied. From Table 1, the following statistical assumptions were made to form the loss reduction criteria:

- 2% in the low loss ratio band (0-10%) had roller door damage
- 15% in the medium loss ratio band (10-50%) had roller door damage
- 30% in the high loss ratio band (>50%) had roller door damage

Table 3. Applied criteria for reducing claim values based on roller door mitigation upgrade

Wind Speed (m/s)	Loss Ratio (%)	Mitigated Loss ($)	Proportion of Claims Modified
22-40	<10	1500	0.02
	10-50	1500	0.15
	>50	1500	0.30
40-47	<10	3000	0.02
	10-50	5000	0.15
	>50	5000	0.30
>47	<10	3000	0.02
	10-50	8000	0.15
	>50	10000	0.30

The costs associated with roller door upgrading were estimated at $300 for aftermarket supports (on a per house basis) from discussions with product manufacturers.

Fenestration upgrades

Fenestration-related damage modes may include direct damage from wind-borne debris (Figure 4), which can also increase the likelihood of roofing failure from internal pressure increases, and water ingress damage to the building walls and contents from poor window casing or sealing performance. The primary damage mode varies by wind speed, the amount of wind-borne debris or rain, etc.

Figure 4. Wind-borne debris failure of fenestration without opening protection in Yeppoon, Australia following Cyclone Marcia (2015)

For modelling, the fenestration mitigation upgrade was assumed to effectively reduce the loss associated with each of these damage modes, the positive benefits of which increase with wind speed. The upgrades include plywood covering (homeowner installation) and commercially available shuttering systems. Table 4 shows the applied criteria for fenestration upgrades in the model. These upgrades were applied to housing of all ages. From the Table 1, the following statistical assumptions were made to form the loss reduction criteria:

- 15% in the 0-10% loss ratio band had fenestration related damage
- 50% in the 10-50% loss ratio band had fenestration related damage
- 80% in the >50% loss ratio band had fenestration related damage

Table 4. Applied criteria for reducing claim values based on fenestration mitigation upgrades

Wind Speed (m/s)	Loss Ratio (%)	Mitigated Loss ($)	Proportion of Claims Modified
22-40	<10	1,000	0.15
	10-50	2,000	0.50
	>50	5,000	0.80
40-47	<10	2,000	0.15
	10-50	5,000	0.50
	>50	10,000	0.80
>47	<10	5,000	0.15
	10-50	10,000	0.50
	>50	15,000	0.80

The costs associated with window upgrading were estimated (on a per house basis) from correspondence with building contractors in Queensland. To establish a single costing value, each home was assumed to have eight windows with upgrades being applied to all windows. It was assumed that the number of windows, window performance, and cost of upgrading were independent of the building age or construction type. The two upgrading scenarios (plywood vs commercial systems) were assumed to have the same performance benefits once installed. The costing estimates were $1360 for plywood shutters and $3200 for commercial window protection shutters/screens.

Community Preparedness

From the Smith and Henderson (2015), minor claims represent 86% of the total number of filed claims for Cyclone Yasi in the North Queensland Coastal Region. These minor claims typically include damage shade sails, minor water ingress, minor debris damage, etc.

Community education/awareness campaigns, with emphasis on cyclone preparation (e.g., removing shade sails, pruning trees, removing debris and unsecured items from the yard, etc.), may be an effective method of reducing the frequency of claims of this size. Past experience suggests that 100% implementation of these "preparation upgrades" is unlikely, and actual implementation rates will be much lower, depending on the method of dissemination adopted by the community outreach campaign. Therefore, for modelling purposes, it was assumed that the positive benefits of these upgrades were realized in only 30% of claims. The magnitude of benefit was determined by consultation with builders and assessors in Queensland and assumed to increase with loss ratio as $2000, $3000, and $5000 for <10%, 10-50%, and >50% respectively. The cost estimate for a community awareness campaign was assumed at $1 million annually over the 50 year projection period used by Urbis.

RESULTS

The outputs of fragility modelling for simulated mitigation were based exclusively on claims data from TC Yasi and are likely to vary significantly for future events. The fragilities for this event and the estimated cost of selected upgrades were provided to Urbis for cost-benefit modelling of the projected impacts of mitigation over the next 50 years in Queensland. The authors refer readers to the Urbis report (Hutley and Batchen, 2015) for results of the cost-benefit analysis. The results for TC Yasi are discussed briefly in this section. Figure 5 shows the effect of TC Yasi claims data modification for simulated structural roof upgrading in pre-1960s housing. The effect of this modification was most significant in claims with higher loss ratios as expected with the criteria in Table 2. There were 8,089 homes constructed prior to 1960 in the data set, 1,911 of which filed a claim. The true net loss for this group of policies was $45.5 million after TC Yasi. The simulated roof upgrades produced a 47% reduction, yielding net loss of $24.1 million.

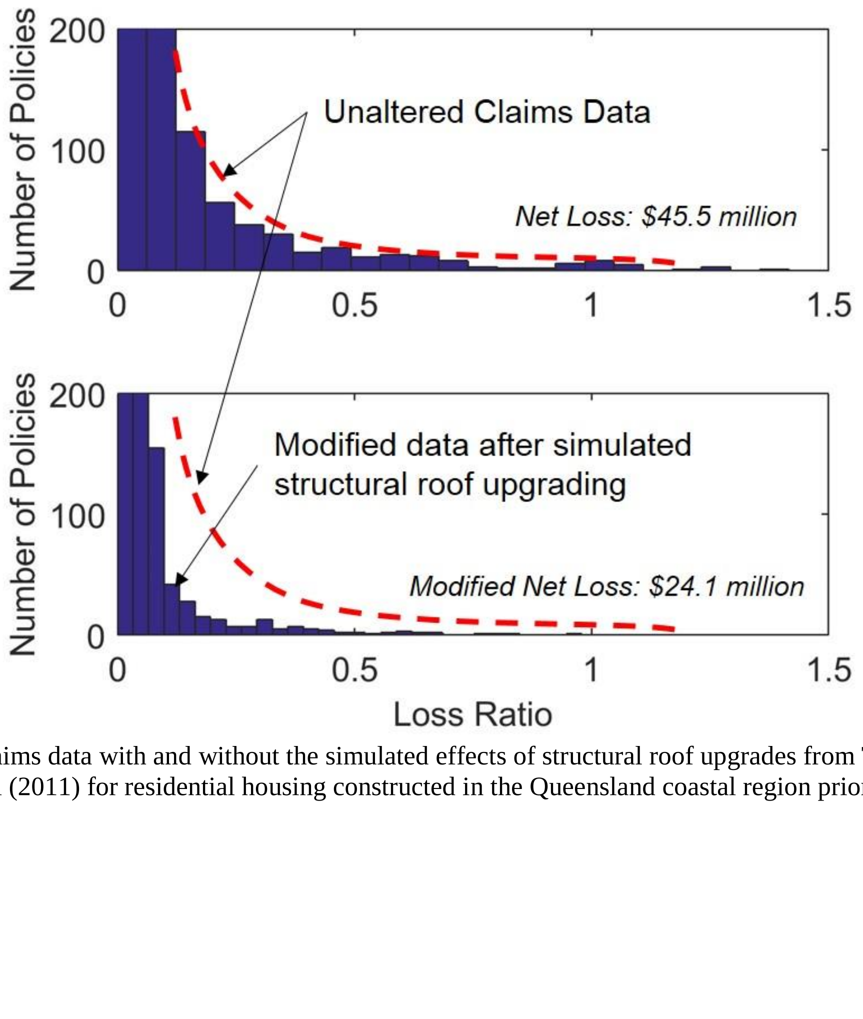

Figure 5. Claims data with and without the simulated effects of structural roof upgrades from Tropical Cyclone Yasi (2011) for residential housing constructed in the Queensland coastal region prior to 1960

There were 14,315 homes constructed between 1960 and 1980 in the data set, 3,967 of which filed a claim. Figure 6 shows the effect of structural roof upgrades on these policies. The trend is very similar to that of pre-1960s housing. As expected, the effects the simulation are most significant in claims with higher loss ratios. The net loss for these policies was reduced from $81.5 million to $44.5 million, a 45% decrease.

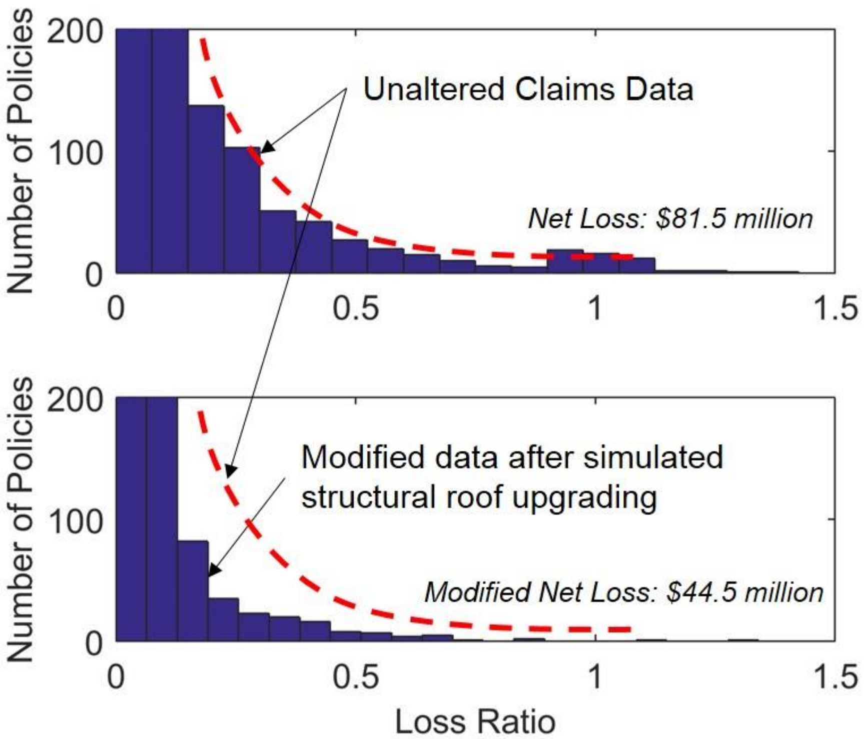

Figure 6. Claims data with and without the simulated effects of structural roof upgrades from Tropical Cyclone Yasi (2011) for residential housing constructed in the Queensland coastal region from 1960 to 1980

In addition to roof upgrades, the effects of opening protection and a community preparedness campaign were also simulated. These simulations were applied to all ages of housing in the data set. For all housing constructed prior to 1980, opening protection and community engagement yielded net reductions in loss of 7% and 3% respectively. There were 32,478 homes constructed after 1980 in the data set, 7,292 of these filed a claim. Despite damage severity being significantly lower for these contemporary homes, the net contribution to loss was $115 million. This loss was reduced by 5% and 3% in the simulations for opening protection and community engagement respectively.

DISCUSSION

Mitigation pricing and associated reductions in loss for cyclone intensities were estimated from claims data and estimates from assessors, builders and manufacturers. The considered upgrades included:

- Retrofitting to roof structure for pre 1980s houses (upgrading roof framing connections)
- Protection of windows and doors to reduce wind driven rain ingress and reduce likelihood of a windward dominant opening
- Community awareness measures (effective ongoing maintenance of house, dismantle for shade cloth awnings, cleared gutters, pruned trees, appropriate tie down for garden sheds, etc.)

The fragility models be developed further to include probabilistic components for wind speed, component capacities, and damage/loss of building elements. The resultant models should validated with other cyclone loss data and include other loss reduction measures such as ongoing improvements in building codes (e.g. changes to garage door standard following Cyclone Yasi).

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