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RETROFITTING OF A HIGH-SET QUEENSLAND HOUSE FOR WIND LOADING

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Cover: Cyclone Yasi roof damage. Source: Cyclone Testing Station, James Cook University

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INTRODUCTION

This report presents a preliminary study on the retrofitting/upgrading of roofing connections in an older Australian house type to improve its performance under wind loading. The house type selected is a rectangular plan high-set house with a low pitched gable roof. These houses are common in North Queensland and have been the subject of previous vulnerability studies by the Cyclone Testing Station. In previous studies this house type is also known as the 'Group-4 House'.

Vulnerability to wind loads of a population of these houses will be estimated using the Vulnerability and Wind Simulation (VAWS) software that is currently under development by the Cyclone Testing Station and Geoscience Australia. The changes to vulnerability functions for four connection upgrading scenarios are investigated. These preliminary analyses are used to inform initial cost benefit estimates for retrofitting older Australian houses.

1.1 STRUCTURAL SYSTEM

The house is a high set timber framed structure with metal roof cladding and fibre cement wall cladding, an example is shown in Figure 1. The dimensions and structural system were determined from survey data and the resulting representative house was originally described by Henderson and Harper (2003).

The house is 12.6 m long, 7.3 m wide and 4.4 m tall including 2.0 m stumps. The roof structure consists of rafters at 10 degree pitch at 900 mm centres supporting battens at 900 mm centres that in turn support corrugated metal cladding. The existing battens to rafter connections and roof to wall connections have capacities of 1.5 kN and 5 kN respectively. A schematic of the roof structure is shown in Figure 2.

FIGURE 1 PHOTO OF GROUP 4 HOUSE

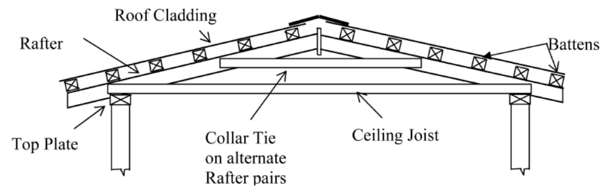

FIGURE 2 ROOF STRUCTURE OF THE GROUP 4 HOUSE

1.2 VAWS SIMULATION AND RETROFITTING MEASURES

The VAWS software program, as described by Parackal, Wehner et al. (2019), uses a Monte Carlo process to determine the vulnerability of a house through simulating hundreds of realisations of a structural model under wind loads. Using the VAWS software the vulnerability of a population of Group 4 houses is estimated for a control case and four upgrading scenarios, these include:

1. Retrofitting only edge, corner and ridge battens with the addition of a screw (3 kN)
2. Retrofitting all battens with the addition of a screw
3. Scenario 2 + strengthening end rafters with a hold down strap (10 kN)
4. Scenario 2 + strengthening all rafters with a hold down strap (10 kN)

Sheeting strengths specified for this model are those of new roof sheeting, as these types of houses have often had their sheeting replaced without the upgrade underlying roof connections. During retrofits, new sheeting is installed and the sheeting strengths are assumed not to change.

One hundred realisations of the Group 4 house are run for each of the scenarios. Vulnerability is quantified as a damage index given as a function of the gust wind speed at 10 m height at the site. The damage index is defined as the ratio of the cost of damage to the replacement cost of the house.

For this study, the damage index calculated is for the roof structure alone and does not include the costs of damage to other parts of the structure or damage due to water ingress. Additionally, the VAWS wind-borne debris simulation is run to simulate internal pressurisation and subsequent roof failures that would occur due to debris impacts.

RESULTS

Scenario 1 where edge batten to rafter connections were strengthened showed little change in performance compared to the control case, as seen when comparing Figure 3 and Figure 4. As loads are higher on batten to rafter connections that are on the second row from the edge due to larger tributary areas it is these connections that fail first. From research by Parackal (2018), retrofitting first and second internal batten rows is recommended to delay the onset of damage and a progressive failure of batten-rafter connections. However, due to the one-way load redistribution process used in VAWS failure propagation may not be arrested by the strengthened connections once failure initiates in other batten rows and further investigation is required.

Scenario 2 indicated that retrofitting all battens improved building performance significantly, increasing the onset damage wind speed from 45 to 55m/s as shown in Figure 5. Generally, it is not recommended to retrofit only one level of hold down in a structure. However, with further investigation it may be possible that significant improvements in performance can be made by retrofitting batten to rafter connections only. In terms of cost benefit of retrofitting it is still best to retrofit all levels of connections as the roof sheeting and construction access are already provided.

Scenario 3 involved retrofitting only end rafters (roof to wall connections and ridge connections) with strapping in addition to retrofitting all batten to rafter connections. No significant change in performance was noted as shown in Figure 6.

Scenario 4 includes the retrofit of all battens and all rafters, a significant improvement in performance is made as shown in Figure 7.

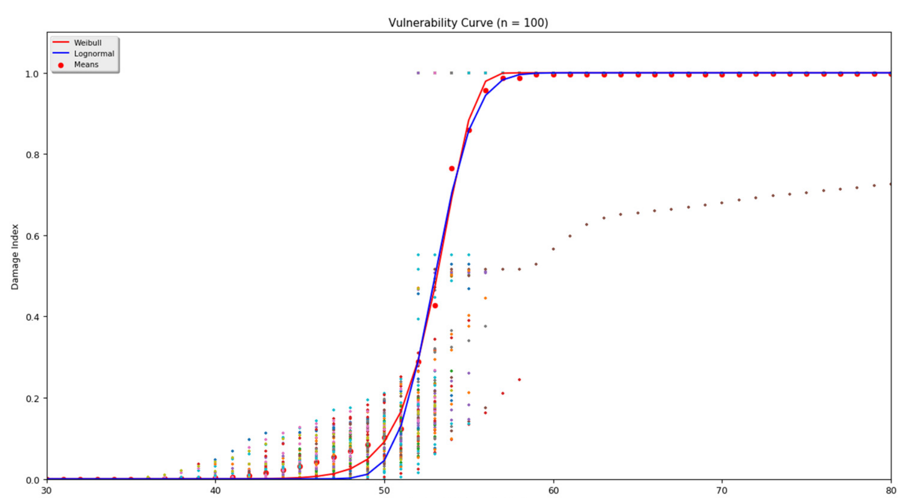

FIGURE 3 THE CONTROL CASE WITHOUT RETROFITTED CONNECTIONS

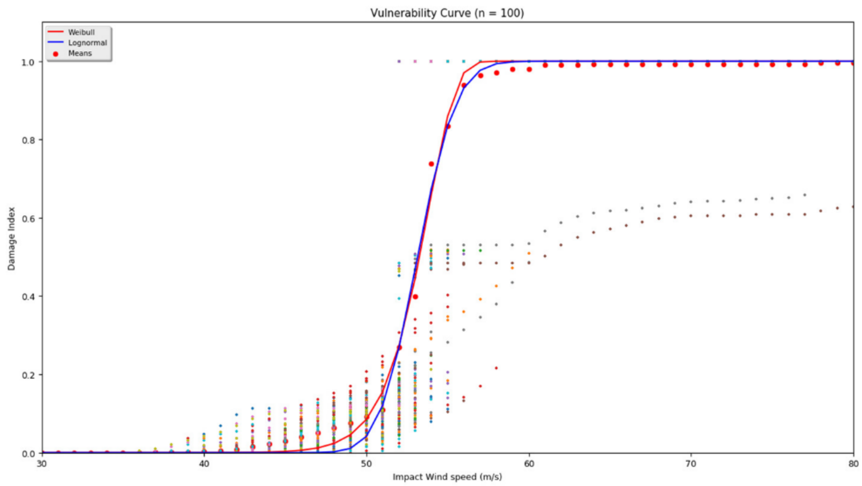

FIGURE 4: SCENARIO 1 - EDGE BATTEN TO RAFTER CONNECTIONS RETROFITTED WITH AN ADDITIONAL SCREW (3KN)

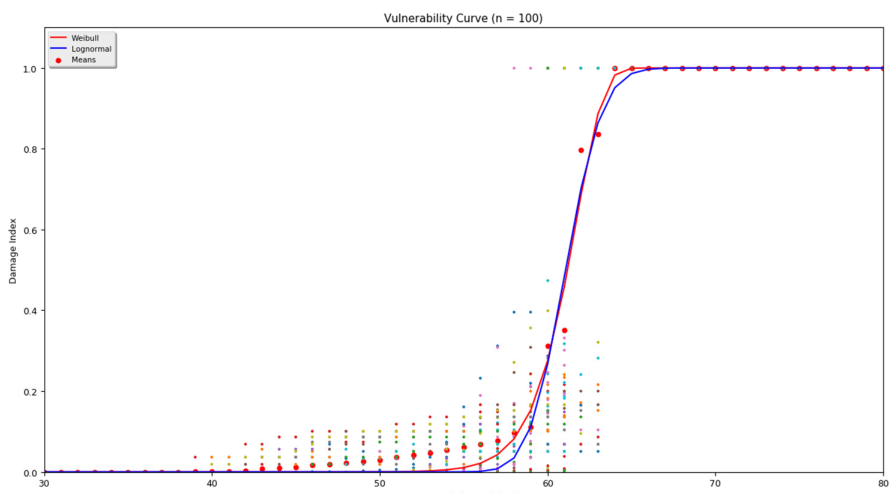

FIGURE 5: SCENARIO 2 - ALL BATTEN TO RAFTER CONNECTIONS RETROFITTED WITH AN ADDITIONAL SCREW (3KN)

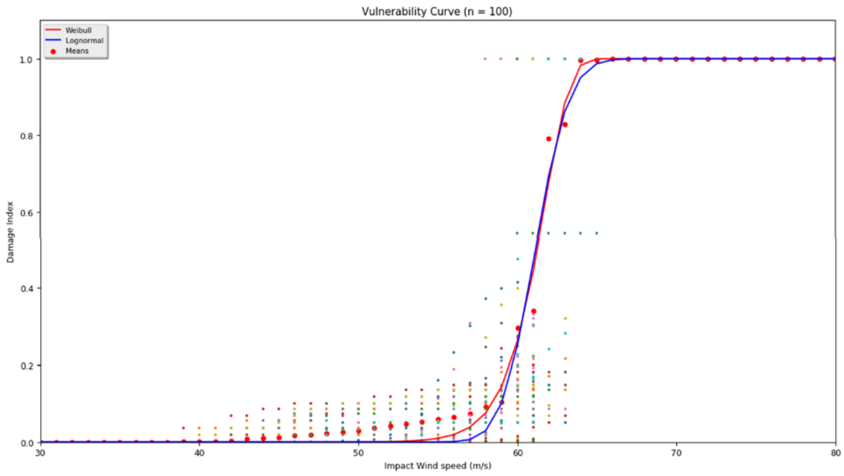

FIGURE 6: SCENARIO 3 - ALL BATTENS TO RAFTER CONNECTIONS RETROFITTED WITH 3KN SCREW CONNECTION + 10KN STRAP FOR END RAFTER TO WALL CONNECTIONS

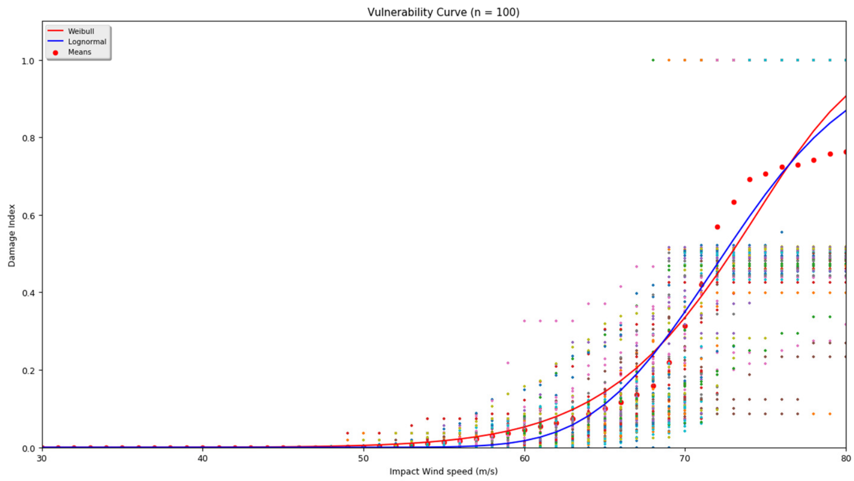

FIGURE 7: SCENARIO 4 - ALL BATTENS TO RAFTER CONNECTIONS RETROFITTED WITH 3KN SCREW CONNECTION + 10KN STRAP FOR ALL RAFTER TO WALL CONNECTIONS

DISCUSSION AND CONCLUSIONS

A preliminary retrofitting study of a high-set Queensland house using the VAWS vulnerability modelling software was presented. Four retrofitting scenarios with different extents of roof connection upgrades were studied.

The improvements in building performance under wind loading could clearly be seen in the changes to the vulnerability functions for certain scenarios. However, targeted retrofitting of a single row of connections in edge regions of the roof was not effective for reducing vulnerability. Further investigation is recommended to study the effects of strengthening multiple rows of connections in these edge regions where failures often initiate.

REFERENCES

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