Wind effects on buildings

With the help of BRANZ data, the Riskscape joint project between NIWA and GNS aims to better predict the costs of damaging wind events on buildings.

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In the past, predicting the probable behaviour of building components under extreme winds has been difficult due to a lack of quantitative data. Predictions can only be made once we know the probability of a certain-sized wind event and the likely performance of the various elements of the building construction being exposed to it. The behaviour of these elements can be expressed in terms of their ‘fragilities’.

This means a probability can be established that a certain wind speed will cause the failure of an element or a joint between elements. To quantify the probabilities and thus determine the range of expected behaviour, we need to test replicates of representative constructions.

Roofs the first thing to go

Historic wind events have shown that the roof of a structure usually fails first (see Figure 1). Once even part of a roof has gone, the wind load on the elements of the remaining structure will change and other parts may fail.

For example, if a section of roof is removed by wind, the distribution of pressure inside the building will increase or decrease, depending on the location of the removed section. When this new distribution adds to the external pressures, further failure of the structure can occur.

It’s all about connections

Over the past year, BRANZ has been gathering strength data for a range of connections in the roof structures of both older and new low-rise buildings. Older roof cladding materials include concrete and clay tiles, corrugated steel and corrugated asbestos cement sheets. Newer roof cladding systems include clay tiles, corrugated steel sheets, pressed metal tiles and synthetic rubber membranes.

Concrete and clay tiles are heavy and also quite porous to air penetration. The major issue with these claddings is that the capping tiles can be dislodged if the mortar bedding between the capping tiles and the rest of the tiles has already failed over the years (see Figure 2).

Pressed metal tiles are generally well fixed to their supporting battens and don’t tend to dislodge. Similarly, the synthetic membranes don’t tend to rupture.

Focus on traditional fixing method

BRANZ tests concentrated on the traditional lead-head nail fixing of corrugated steel sheets to purlins and then the connections between purlins/battens and the rafters/truss top chords. The connections between the heels of trusses and rafters to the wall top plate were also investigated.

Lead-head nails are essentially steel flat head nails with a shaped ‘blob’ of lead cast around the head. As the nail is driven, the bottom skirt of the lead head deforms over the curve of the corrugated steel profile to provide weather resistance. Over time, the lead head tends to loosen on the nail head due to the weather and/or foot traffic on the roof. Sometimes, the lead heads pop off the steel
nail, allowing moisture to pass through the hole in the corrugated steel. Thus, the shafts of the nails will corrode over time, making the nail less resistant to any uplift forces.

Trying to source samples of corrugated steel roofing complete with the purlin substrate was impractical as lead-head nails are no longer manufactured, so old stocks of unused nails were obtained, and small single nail samples fixed into rimu and radiata pine purlins were subjected to withdrawal loads in the laboratory’s Dartec universal test machine (see Figure 3). The predominant failure mode was pull-out of the nail from the timber, although the corrugated sheet deformed locally in the process.

**Timber density affects nail performance**

Statistical analyses were conducted on the test results, and fragility curves were derived for both purlin species. Although the number of replicate tests for each type was small, they covered a range of timber densities – the parameter most affecting nail performance.

A sample fragility curve is shown in Figure 4. Curves have also been produced for connections between:
- rimu purlins and rimu rafters (straight nailed)
- rimu rafters and rimu top plates (skew nailed)
- radiata pine trusses and radiata pine top plates, fixed with skew nails only and fixed with skew nails plus wire dogs.

Using information on contributing areas to each joint, the fragility curves can be translated into wind uplift pressure curves and then 3-second gust wind speeds. The results will be entered into the NIWA model.

There is still some work to be done to establish fragility curves for batten to rafter/truss top chord connections.

![Figure 4: Example curve relating the probability of failure against load in a lead-head nail fastener.](image)

Over the next year, the study will consider the probabilities of wall cladding failure.

*The Riskscape project is funded by the Foundation for Research, Science and Technology. The BRANZ project is funded by the Building Research Levy.*