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Building resilience in volcanic eruptions

A local volcanic eruption is a substantial risk to the Auckland region. Research into the impact of multiple volcanic hazards on the roofs of buildings showed that they generally deal well with volcanic ash and flying rocks landing on them.

AUCKLAND SITS ON an active volcanic field with 53 known volcanoes (Figure 1) and a 5–15% probability of an eruption occurring within a typical lifetime.

Although this probability is quite small, the human and infrastructure exposure in Auckland is huge. If an eruption were to occur, many people could be displaced and significant infrastructure such as the Auckland Harbour Bridge could be damaged or destroyed.

Complex hazard risk in Auckland

Volcanic eruptions are complex events with many different hazards occurring at the same time in the area. Hazards such as volcanic ash (or tephra) fall, flying rocks (known as volcanic ballistic projectiles) and lava flows can have cumulative effects or interact in more complicated ways.

The complex hazard interaction and risk in Auckland makes understanding and preparing for an eruption a research priority.

Figure 1: Maungawhau/Mt Eden scoria cone with Auckland CBD in the background.

Developing an impact framework

University of Canterbury research, carried out for a doctoral thesis, developed a framework calculating the cumulative impacts from volcanic hazards, using eruption scenarios. By considering exposed buildings and their vulnerability to potential volcanic hazards, the framework assigns every building an impact state. The framework changes over time for each new hazard, depending on the new hazard and the previous hazard the building has been impacted by.

Figure 2: Tephra load during experiment (left) and the structural damage (right).

This provides a cumulative impact state for each building exposed to volcanic hazards, describing the generalised damage to each building at the end of the eruptive sequence. This can be used to estimate potential damage and loss in a volcanic eruption as well as other impact or risk metrics, including building habitability or clean-up requirements.

Experiments of ash fall and rock projectiles

To strengthen our understanding of multi-volcanic hazard impacts, laboratory experimentation on the impacts of ash fall and volcanic ballistic projectiles was conducted.

The means of assessing multi-volcanic hazard impacts in a laboratory is still in its infancy, and the University of Canterbury is at the forefront of the science. This was the first time the experimental ash lab and full-scale ballistic canon laboratories were combined to test the impacts of ash load on roofs and the interaction of ash load and volcanic ballistic projectile impacts.

NZS 3604:2011 roof structure

Timber-framed experimental roof structures with sheet metal roofs were developed according to NZS 3604:2011 *Timber-framed buildings*. While there is no provision for tephra load in this standard, it has been estimated that New Zealand buildings could withstand large tephra loads.

The experimental structure exceeded expectations of collapse load and endured almost 17 kPa of tephra load (Figure 2). The mechanism of collapse was failure at the ridge-rafter fixings. This is not commonly seen in worldwide post-eruption impact assessments that generally find mid-beam component failure. However, New Zealand has different component and building standards to those where post-eruption impact assessments have been conducted.

Metal roofing stood up well

Tephra fall and ballistic impact multi-hazard experimentation included applying a tephra load to an experimental roof structure and then firing a volcanic ballistic projectile at the structure in order to simulate the concurrent hazards. Four tephra loads, all 2 kPa (12 cm) or less, and two ballistics, 3.5 kg and 0.9 kg, were used in the experiments.

The volcanic ballistic projectiles were fired using an air cannon that could propel the ballistics at up to 50 m/s (180 km/h).

The results showed that an increasing tephra load led to a decrease in the likelihood of sheet-metal perforation by ballistic projections with perforation only occurring at tephra load less than 1 kPa (6 cm). Although the resistance to perforation increased, structural damage of roof purlins still occurred.

Further understanding of multi-volcanic hazard impacts and development of multi-hazard vulnerability functions is required to improve the impact assessment process. The multi-hazard impact results from the research provide a snapshot of localised damage that could be expected from tephra fall and volcanic ballistic projectiles.

Research findings

Insights from the research include:

- tephra loading has the potential to cause fixing failure when strong timber components are used
- tephra loading can increase roof resistance to ballistic perforation
- ballistics can cause structural damage to timber components when not directly impacting them.

The framework developed for cumulative impact states can be used and further developed to improve disaster, risk and resilience strategies. These include helping insurers like EQC to better forecast potential damage, helping local authorities refine their plans to mitigate the impact of an eruption and predicting whether houses will be habitable.

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