10.1071_ISSN0311-4546EC106p36

Modelling the forces of nature

The research team at CSIRO Building Construction and Engineering built a house in their laboratory to gauge its response to loading scenarios caused by natural disasters. The results form the basis of a model that can be used to optimise the strength of buildings.

In the United States, home of Tornado Alley and the restless San Andreas Fault, strong winds and earthquakes regularly devastate buildings and communities. Designing more resilient houses for such locations requires understanding how the typical suburban home responds to nature's fury.

To gather this information, the American National Association of Home Builders Research Centre, turned to Dr Greg Foliente and his team at CSIRO Building Construction and Engineering in Melbourne.

'We're the only laboratory with the combined capability to test, measure and model the behaviour of a house under stress. So the association asked us to model the response of a representative house to simulated wind and earthquake loads,' Foliente says.

To do this, the group built a 10-square, timber frame, L-shaped house in their laboratory. A unique system of CSIRO-designed 'load sensors' was then placed underneath the house, to measure the forces unleashed by a simulated disaster in three dimensions –- horizontal forces from north to south and east to west, and a vertical force. A mechanical device was then used to simulate an earthquake and a cyclone.

'In an earthquake, the ground moves left and right and the contortions in the house mean the base and the roof are not in the same place at the same time. Instead of moving the ground, we used a mechanical device to push and pull the roof,' Foliente says. 'We also used the device to push the house in one direction, simulating the effect of a strong wind.'

Using information relayed from the load sensors to a computer, the scientists were able to develop a computer model, detailing how the house and its individual components (down to the nails) behaved. This model can now be used to simulate historical earthquake or wind loading records and test the design of new building materials and products.

'A full-size physical experiment gives us only one chance to study the response of a given house under a specific loading event. The computer model is a powerful tool because we can repeatedly assess house response and performance under any natural disaster loading scenarios in a virtual environment,' Foliente says.

'And because we can look at specific parts of the house, we can look at the performance "demand" or requirement on a particular product.'

Understanding the demand on a product – like a nail or bolt – will help manufacturers improve the product while keeping costs down. For example, using the model, scientists can determine exactly how much strength and/or flexibility a product needs. Then, once the product is made, the model can be used to determine its optimal placement in the house.

'We can use the model to simulate a scenario with the new product in place, to see whether the improved product, and its position in the house, works,' Foliente says.

The research promises to open the door to the use of new building materials in suburban homes, such as carbon fibres, waste plastic or straw, and the development of new products that help dissipate stress.

'Houses in disaster prone areas may have suspension, a bit like a car, to ride out severe winds or earthquakes with less damage and reduced injury to occupants,' Foliente says.

CSIRO's computer modelling and testing capability will also enable products to be tested against the safety requirements of Japanese and American building codes, paving the way for the export of Australian products to these markets.

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Wendy Pyper

Destructive elements

HOUSES are destroyed for a number of reasons in an earthquake or severe wind event. In an earthquake, damage occurs because:

- Connections or 'anchorage' points, between the wall and the floor for example, fail.
- The house may be unable to resist a lateral force. For example, if one side of a box is removed, the other sides collapse under pressure. This is known as 'lack of bracing'.
- A small room or porch may become separated from the main building.
- 'Soil or site problems', such as a landslide, soil liquefaction (when soil temporarily becomes like quicksand) or the rupture of the land surface underneath the house, may occur.

In a cyclone or other wind event, damage occurs through connection or anchorage failure; lack of bracing, and 'breach of building envelope', in which the outer shell of the house is damaged. This causes a change in air pressure inside the house and the walls begin to peel away.