

Seismic isolation of light-frame wood buildings in New Zealand

Background and Motivation

- Widespread and costly damage was observed in the residential sector in previous earthquakes.
 - Christchurch 2011: \$16 billion in residential building damage out of a total \$40 billion building and infrastructure losses.
 - Northridge 1994: \$12.7 billion (US\$) out of a total \$25.7 billion recovery and reconstruction funds were associated with residential building reconstruction.
- Drift control of wood structures is the key parameter for minimising seismic related damage (Filiatrault and Folz, 2002). Seismic isolation is very effective at minimising superstructure drifts.
- Research has shown significant secondary impacts of earthquakes on well-being and work place stress in 1/3rd of the population (Potter et al., 2015). This includes effects due to stress from dealing with insurance for private home owners.

Objectives

- Show seismic isolation is effective for reducing seismic vulnerability for light-frame wood buildings (residential buildings) in New Zealand by comparing expected annual loss (EAL) to fixed-base buildings.
- Generate a 3D model of light-frame wood buildings to assess performance.
- Undertake testing of a proposed system that deals with issues of isolating light weight buildings such as the effect of wind loading.

Methodology

- Determine suitable combinations of weight and isolator coefficients of friction that will give high performance while preventing movement during strong wind gusts.

$$\mu = F_{wind} / W_{isolated} \quad (1)$$

- Use cyclic testing data of a light-frame wood building to generate fixed-base and isolated SDOF building models in Ruaumoko.

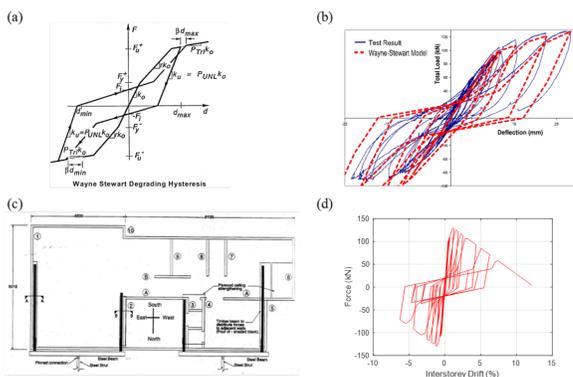


Figure 1. (a) Visual representation of the Wayne-Stewart hysteresis loop and its parameters from Ruaumoko, (b) a comparison of the Wayne-Stewart degrading hysteresis model to the cyclic testing results of a typical New Zealand light-frame wood house, (c) the floor plan of the cyclic test building, and (d) the CUREE cyclic analysis results for the Wayne-Stewart model.

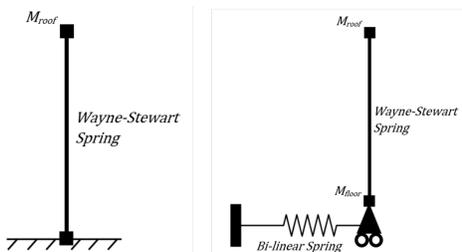


Figure 2. SDOF models used in Ruaumoko comparing the fixed-base (left) and seismically isolated (right) configurations.

- Using vulnerability functions already determined for fixed-base light-frame wood buildings (Horspool et al., 2016), determine vulnerability functions for seismically isolated residential buildings through nonlinear time history (NLTH) analysis.
- Using these vulnerability functions, compare the EAL experienced by the current fixed-base building stock to the seismically isolated building stock.
- Assess performance of a proposed system using the Timber3D software and physical testing on a shake table.

Acknowledgements

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References

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Assessment of required friction coefficients for preventing sliding under wind loads

- Using Equation 1, required isolator coefficients of friction to prevent movement under strong wind gusts are determined.
- 18 different building configurations are considered which accounts for variances in house weights based on construction materials used.
- Wind loads are based on "High" wind loads from NZS 3604.
- Results show that with a 250 mm thick concrete floor most weight configurations are able to be protected with an isolator coefficient of 0.1 which is in the vicinity of a standard seismically isolated building. Therefore, significant performance benefits are expected (Francis et al., 2020).

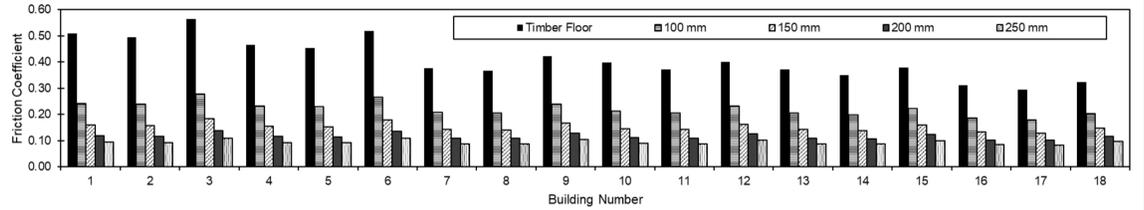
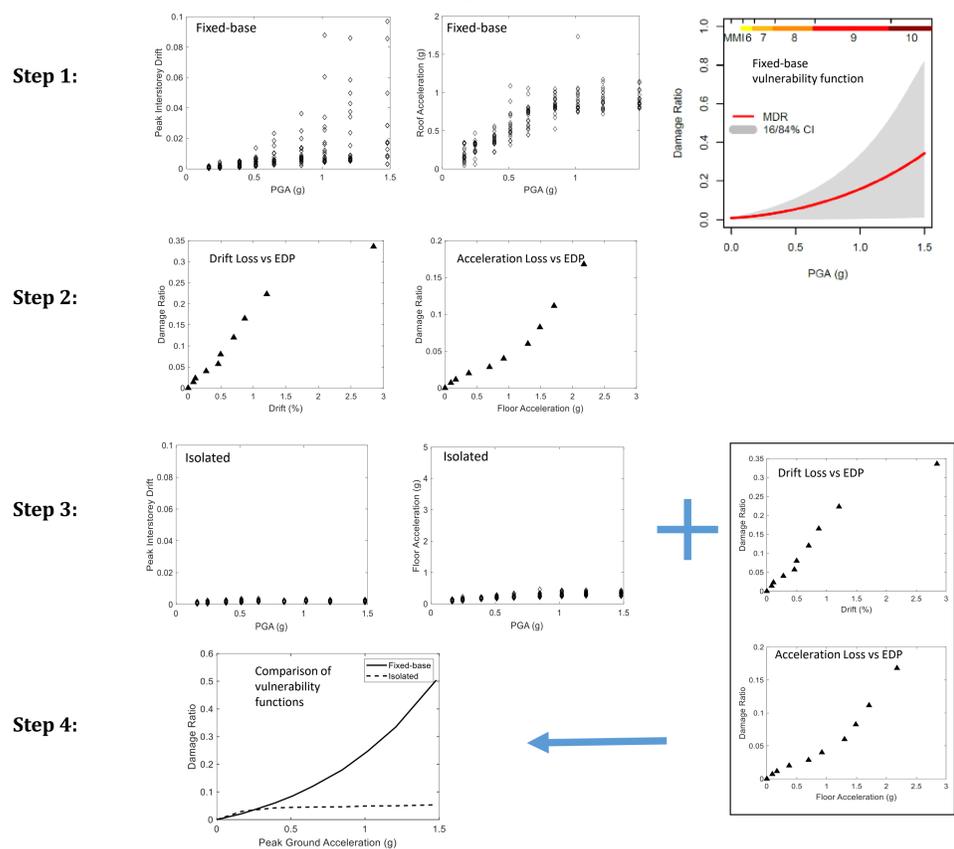


Figure 3. Required seismic isolator friction coefficient for 18 different building configurations with differing weights considering various cladding types, roof types, roof pitches and flooring system, for high wind zones.

Simplified vulnerability analysis to determine loss functions for seismically isolated light-frame wood buildings

- The following process outlines how vulnerability functions for the fixed base building model are determined. The process shown considers the calculation of vulnerability for a single intensity level. The process is completed for the remaining intensities (different values of PGA) to complete the seismically isolated vulnerability functions.
 - Step 1: Undertake NLTHA of fixed-base building model using selected ground motions.
 - Step 2: Determine loss vs EDP relationships for a fixed-base building based on acceleration to drift loss ratio of 1:2.
 - Step 3: Run NLTHA on seismically isolated model and determine vulnerability from loss vs EDP equations.
 - Step 4: Compare seismically isolated building vulnerability functions to the original and note the reduced vulnerability at each intensity level.



Timber3D building modelling

- Timber3D is used to model a light-frame wood building. The model is adapted from a kit-set home which is designed to resist wind and earthquake loading as specified in NZS 3604: Timber Framed Buildings.
- The modelling consists of three components:
 - Connection modelling information such as hysteretic behaviour of screws and hold-down bolts.
 - Component modelling to determine the cyclic behaviour of bracing wall components which combines connector behaviour with sheathing panel and wall framing behaviour.
 - A 3D modelling package which utilizes the component models to generate a 3D model for undertaking non-linear time history analysis.

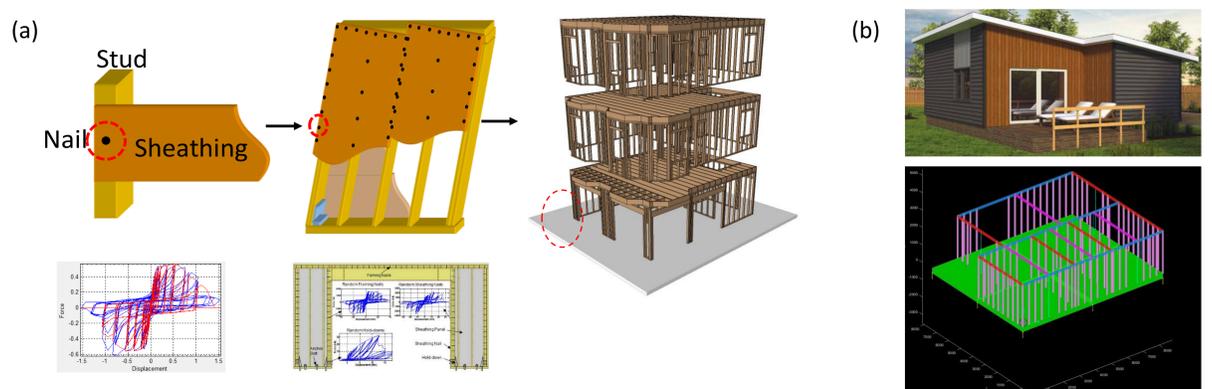


Figure 4. (a) Schematic from Weichiang Pang (2015) showing the connection, wall assembly, and finally, the 3D model components of Timber3D software and (b) the house modelled for consideration in this research.

Where to from here?

- Work is underway on testing of a seismic isolation solution which mitigates previous wind loading and cost issues. The testing is divided into two components:
 - Friction testing of various plastic-to-metal sliding surfaces to characterise sliding behaviour of the proposed seismic isolation devices.
 - Full-scale shake table testing of a light-frame wood wall representative of the type used in residential construction to verify the effectiveness of the proposed isolation system, test it's buildability and compare the performance to a standard fixed-base building.
- Results from the testing will be available mid 2021.