Developing Procedures for the Prediction of Floor Response Spectra

FLAGSHIP 4

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OBJECTIVES

This study aims to develop a simple, accurate procedure for predicting floor response spectra.

This will facilitate industry adoption of a method to predict the acceleration demands on acceleration-sensitive secondary and nonstructural (NS) elements.

An evaluation of existing models to be used is presented here.

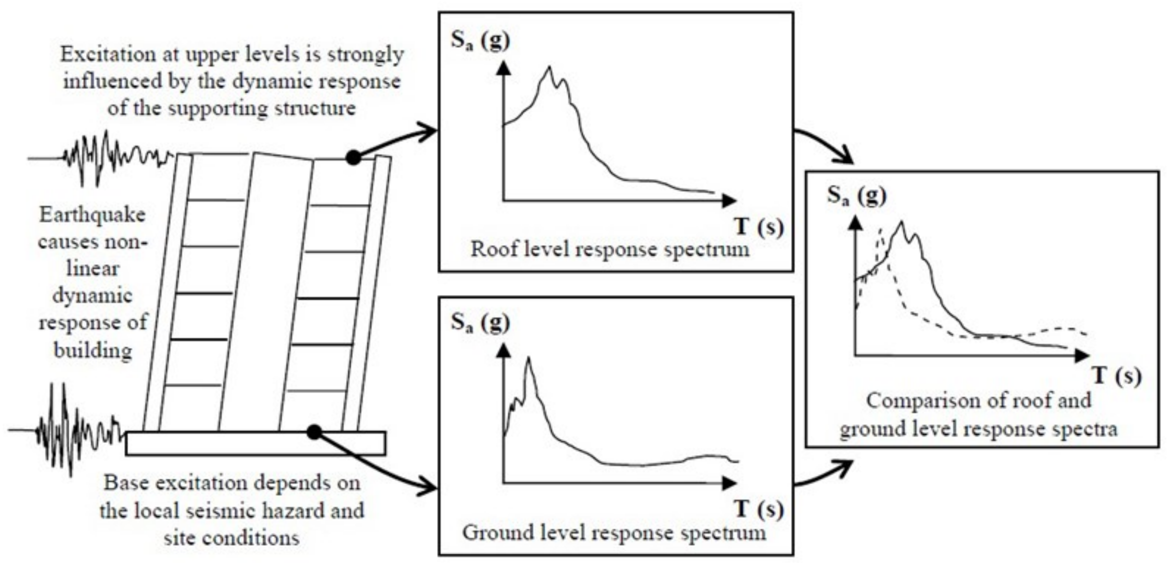


Illustration of floor spectra at roof at ground levels *From Sullivan, et al., 2013*

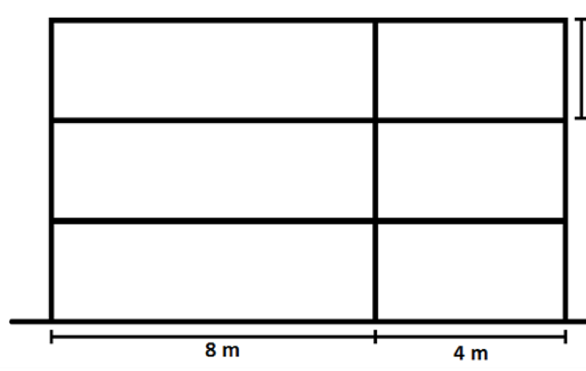
FACTORS AFFECTING FLOOR SPECTRA

- Ground motion
- Dynamic amplification
- Building typology
- Structural modal properties & combination
- Height of floor from ground NS element is fixed
- Inelastic structural / nonstructural behaviour
- NS element damping
- Structural damping

CASE STUDY STRUCTURE

A 3-storey RC structure was used to examine existing methods.

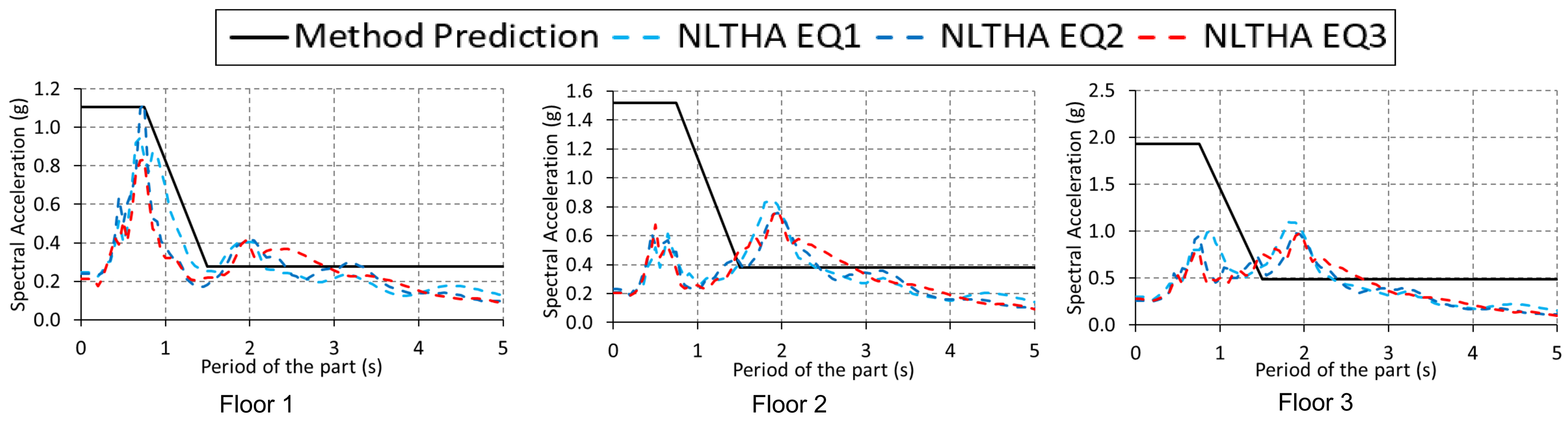
Nonlinear time history analyses were conducted for three earthquakes at 0.3 g PGA for comparison. Bilinear hysteretic properties were assumed for the plastic hinges.



Elevation of Case Study Structure

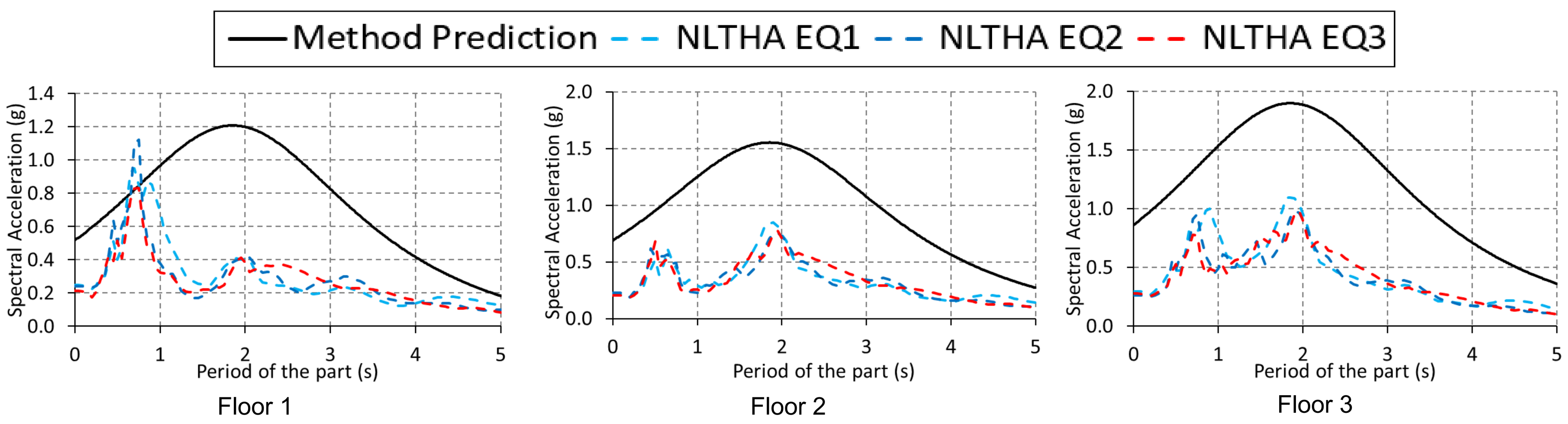
NZS1170.5

The NZ standard uses a trilinear function, giving its distinctive shape. Height and ground shaking intensity is accounted for. This method often envelopes the higher mode responses at lower periods, but misses the peak of the first mode. NS damping amplification and inelastic behaviour is not accounted for.



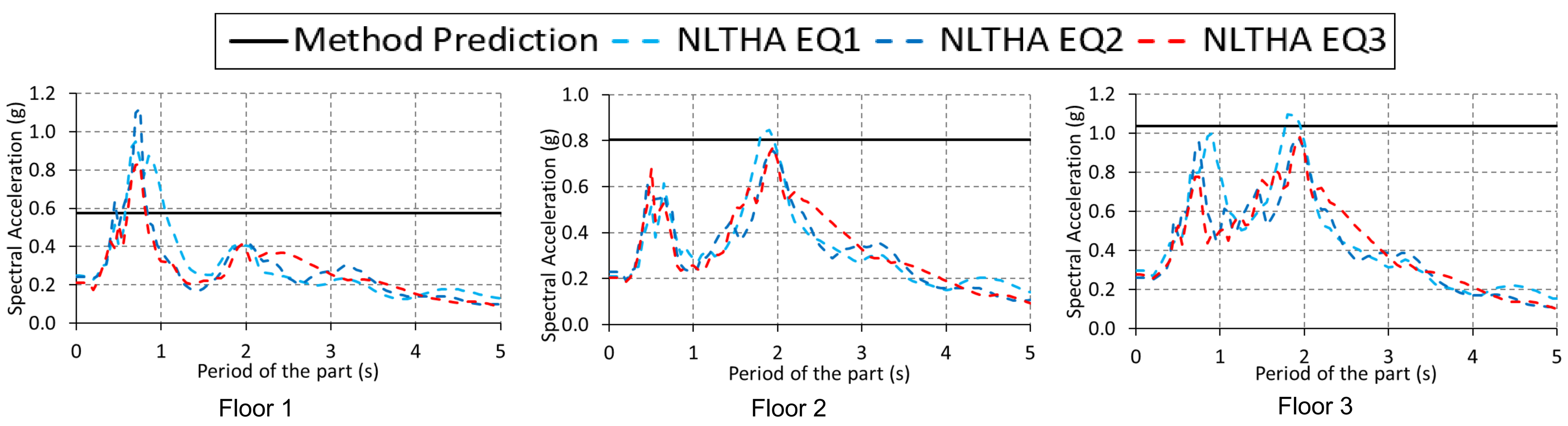
EUROCODE 8

The European method uses a curve centred on the fundamental mode. This method is overly conservative, but in some cases can under-predict floor spectra. Higher modes can be significant, and Eurocode 8 does not capture this well. It does not consider NS damping and inelastic behaviour.



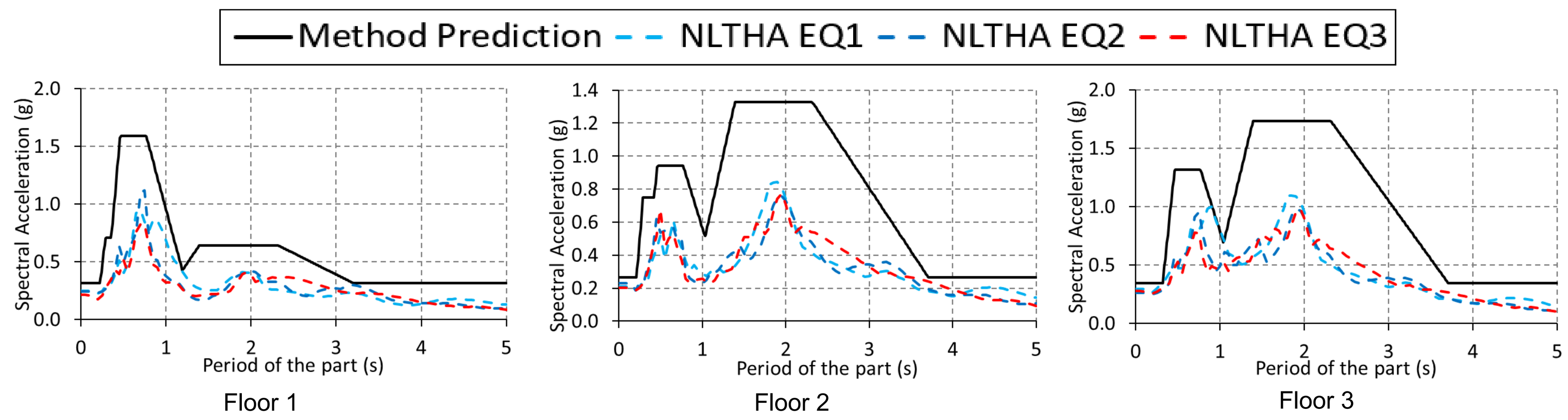
ASCE 7-16

The American ASCE 7-16 method uses factors based on the properties of the NS element. This produces a flat spectrum which appears to be conservative for Floors 2 & 3. As NS damping has not be accounted for, this prediction may be exceeded. Other than at the peaks, this method over-predicts significantly.



ASCE 7-16 ALTERNATE METHOD

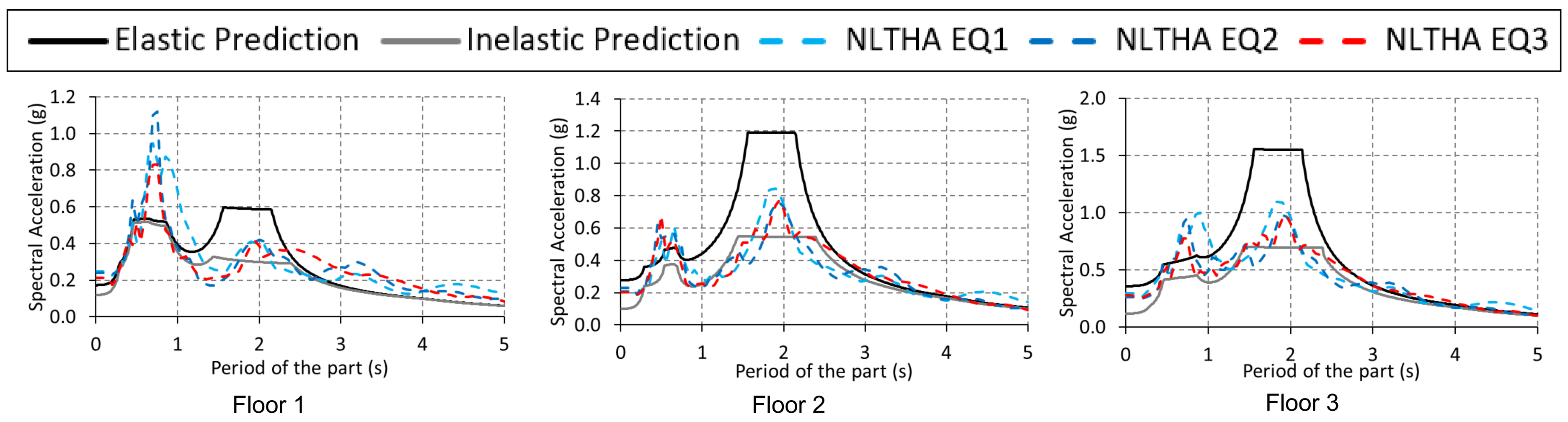
New in the 2016 publication, the alternate method uses modal properties, a ground response acceleration spectrum, and the Dynamic Amplification Factor. This appears promising, but as it does not vary with inelastic behaviour or NS damping, it will be interesting to examine under various conditions in further research.



VUKOBRATOVIC & FAJFAR (2017)

This method, to be simplified for practice, uses modal properties and a response acceleration spectrum as a basis. A Dynamic Amplification Factor based on NS damping for 3 NS period ranges is used. Inelastic behaviour is found using Eurocode's pushover N2 method, using a ductility-based reduction factor. Plateaus are used.

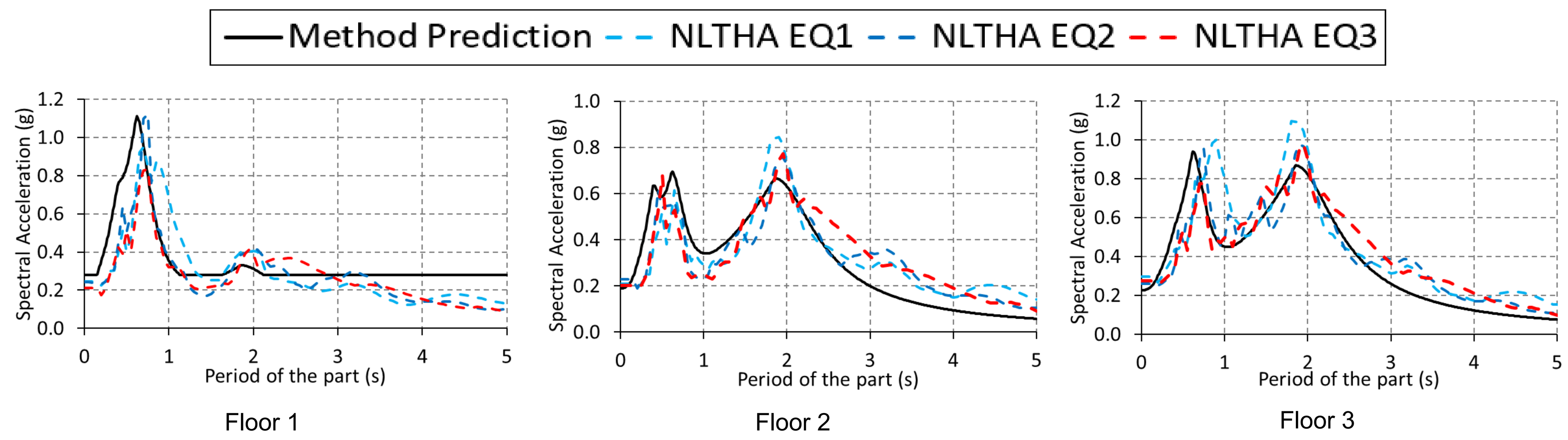
Modes for each floor are combined using SRSS or CQC up to the end of the 1st mode plateau, when an algebraic summation of the contributions with signs is used. Both elastic and inelastic curves are found. In this example at 5% NS damping, some higher mode responses exceed the envelope.



WELCH & SULLIVAN (2017)

The Welch & Sullivan method uses modal properties and a response acceleration spectrum as a basis. This approach would be simplified for practice. An empirically-derived Dynamic Amplification Factor based on structural and NS damping is used.

Inelastic behaviour is accounted for using ductility-based reduction factors for different typologies. Period elongation and rigid-body modes at lower levels considered. Curves found here are close to NLTHA, but do not envelope them.



FUTURE WORK

A. BNZ Wellington Building
From Chandramohan, et al., 2017

Methods will be applied to 2 existing structures subjected to EQs *(A & B)*, and 2 shake table structures *(C & D)*.

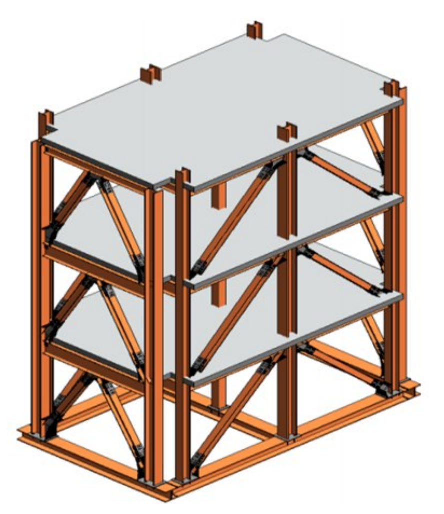
Results will be verified using accelerometer data.

B. UC Physics Building *From McHattie, 2013*

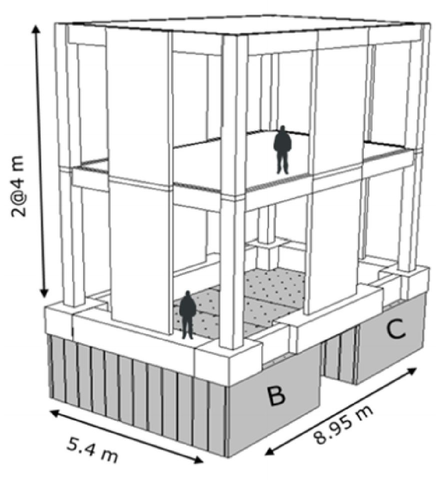
Simplifications will be applied and assessed for impact on accuracy and simplicity.

A method for predicting floor spectra which balances accuracy and simplicity will be formulated.

Meetings with industry will take place to ensure the method is suitable for widespread adoption.



C. ILEE 3 Storey Steel Building
From Dhakal, 2018



D. ILEE 2-Storey RC Building
From Dhakal, 2018

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REFERENCES:

Chandramohan, Reagan Ma, Q., Wotherspoon, L. M., Bradley, B. A., Nayyerloo, M., Uma, S. R., & Stephens, M. T. (2017). Response of instrumented buildings under the 2016 Kaikōura earthquake. Bulletin of the New Zealand Society for Earthquake Engineering, 50(2).

Dhakal, R. (2018). ILEE - QuakeCoRE Collaborative Projects. University of Canterbury.

McHattie, S. (2013). Seismic Response of the UC Physics Building in the Canterbury Earthquakes. University of Canterbury.

Sullivan, T. J., Calvi, P. M., & Nascimbene, R. (2013). Towards improved floor spectra estimates for seismic design. Earthquakes and Structures, 4(1), 109–132. https://doi.org/10.12989/eas.2013.4.1.109

Vukobratović, V., & Fajfar, P. (2017). Code-oriented floor acceleration spectra for building structures. Bulletin of Earthquake Engineering, 15(7), 3013–3026. https://doi.org/10.1007/s10518-016-0076-4

Welch, D. P., & Sullivan, T. J. (2017). Illustrating a new possibility for the estimation of floor spectra in nonlinear multi-degree of freedom systems. In 16th World Conference on Earthquake Engineering. Santiago, Chile.