MANAGING DISASTERS IN NEW ZEALAND FROM A CIVIL/STRUCTURAL ENGINEERING PERSPECTIVE

Dr Lusa Tuleasca ***Dr Wei Yuen Loo***

Presented at 2022 MIT/Unitec Te Pūkenga Research Symposium, Auckland - 8 December 2022

INTRODUCTION

- The International Federation of Red Cross and Red Crescent Societies (IFRC) define disasters as *“**serious disruptions to the functioning of a community that exceed its capacity to cope using its own resources**. Disasters can be caused by natural, man-made and technological hazards, as well as various factors that influence the exposure and vulnerability of a community”.* https://www.ifrc.org

- Risk is influenced by the decisions we make. From climate change to poor urban planning, it is critical to understand and address risk drivers to curb disaster risk. https://www.preventionweb.net

- Disaster risk is the consequence of the interaction between a hazard and the characteristics that make people and places vulnerable and exposed.

- From this perspective, two ways the structural/earthquake engineer makes his or her contribution through evaluating structures through:
  - *Seismic assessment of existing structures.*
  - *Reducing the risk to lives and injury through providing earthquake resistant ductile structures.*
  - *Reducing the cost of post-disaster repair through providing damage avoidance structures.*

INTRODUCTION – TYPE OF DISASTERS

Natural disaster: earthquake, tornado, cyclone, tsunami, flood, volcanic eruption, conflagration, landslides, wildfires, pandemic

Christchurch earthquake: before and after

Aftermath of **Cyclone Larry**

Aftermath of **Japan (Sendai) tsunami**

Flood

Drought

Volcanic eruption Mount Etna, Italy

http://creativecommons.org.au
Google - National Geographic

INTRODUCTION – ***TYPE OF DISASTERS***

Human-induced*:* war, famine, terrorism, chemical and gas contamination, nuclear accident, fire, environmental degradation

Bushfire

After **Bushfire**

Landslide

World War II

Chernobyl nuclear disaster

Norway Terrorist attack

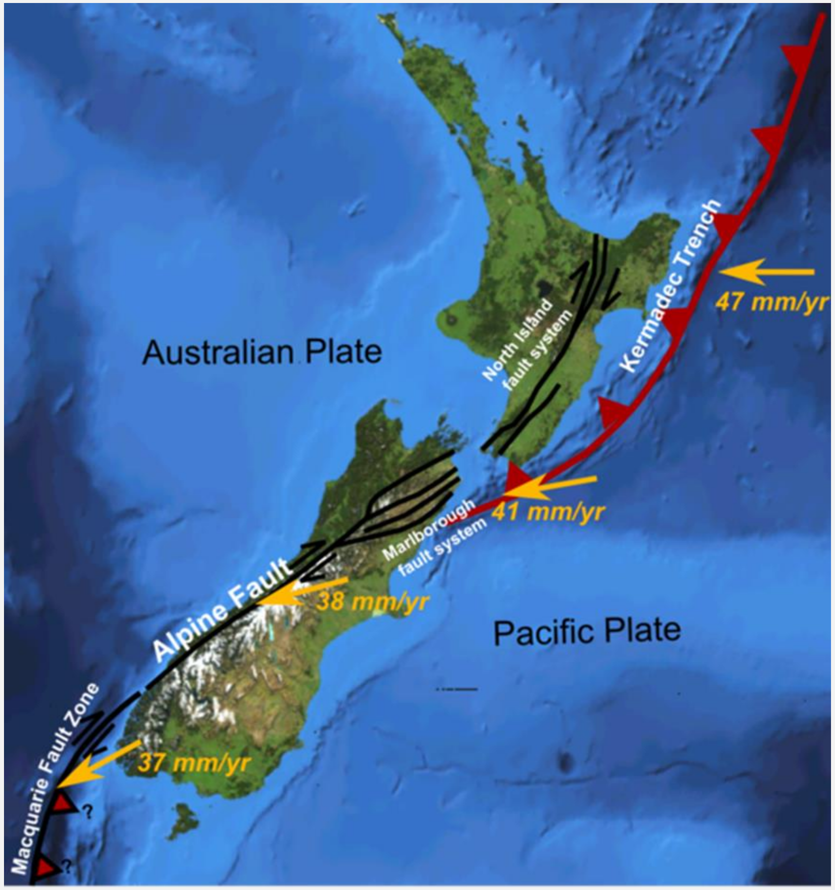
Google - National Geographic

INTRODUCTION - *EARTHQUAKE*

- Aristotle was one of the first to attempt an explanation of earthquakes based on natural phenomena. He postulated that winds within the earth whipped up the occasional shaking of the earth's surface https://projects.eri.ucsb.edu

- An **earthquake** (also known as a **quake**, **tremor** or **temblor**) is the shaking of the surface of the Earth resulting from a sudden release of energy in the Earth's lithosphere that creates seismic waves. Earthquakes can range in intensity, from those that are so weak that they cannot be felt, to those violent enough to propel objects and people into the air, damage critical infrastructure, and wreak destruction across entire cities. https://en.wikipedia.org/wiki/Earthquake

EARTHQUAKE IN NEW ZEALAND



https://en.wikipedia.org/wiki/File:NZ

New Zealand earthquakes 1960 to 2020	
Magnitude	Annual average
4.0–4.9	355.9
5.0–5.9	29.28
6.0–6.9	1.66
7.0–7.9	0.26
8.0 and over	0.01

EARTHQUAKE IN NEW ZEALAND

SEISMIC ASSESSMENT OF EXISTING BUILDINGS

- Scope of seismic assessment
- Expectation regarding expertise of engineers who undertake SA
  - Relevant experience in structural engineering - CPEng
  - Specific training
- Structures excluded: bridges, towers, masts and retaining walls
- Initial Seismic Assessment - ISA
- Detailed Seismic Assessment - DSA

EARTHQUAKE IN NEW ZEALAND

EFFECTS OF EARTHQUAKE ON EXISTING BUILDINGS

Collapsed Pyne Gould Guiness building Mark Mitchell/AFP/Getty Images

EARTHQUAKE IN NEW ZEALAND

EFFECTS OF EARTHQUAKE ON EXISTING BUILDINGS

Destroyed house in Central Christchurch AP Photo/Mark Baker

EARTHQUAKE IN NEW ZEALAND

SEISMIC ASSESSMENT OF EXISTING BUILDINGS

EARTHQUAKE IN NEW ZEALAND

SEISMIC ASSESSMENT OF EXISTING BUILDINGS

Building Description	Longitudinal NBS%	Transversal NBS%	Overall NBS%
Building A	21%	21%	21%
Building B	51%	41%	41%
Building C	41%	51%	41%

Element	Longitudinal NBS%	Transverse NBS%
BUILDING A – Wall bracing		
Second Floor	73%	63%
First floor	36%	25%
Subfloor	Not appropriate as this is combination of concrete slab-on-ground and subfloor framing	
SUMMARY Building A		
Lowest NBS% Building A	36%	25%
BUILDING B	46%	66.7%
BUILDING C	41%	51%

EARTHQUAKE IN NEW ZEALAND

SEISMIC ASSESSMENT OF EXISTING BUILDINGS

EARTHQUAKE IN NEW ZEALAND

SEISMIC ASSESSMENT OF EXISTING BUILDINGS

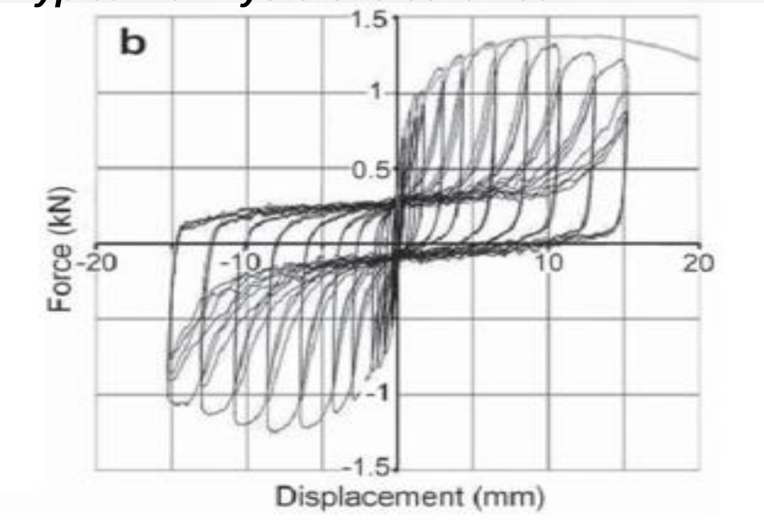
Building Description	Longitudinal NBS%	Transversal NBS%	Overall NBS%
Building A - masonry	68%	34%	34%
Building B	23%	17%	17%
Building C	51%	18%	18%

Element	Longitudinal NBS%	Transverse NBS%
BUILDING A		
Masonry Walls - In plane	68%	
- Out of Plane	34%	
Steel Frame	100%	100%
BUILDING B – Wall bracing for seismic only		
First Floor	35%	33%
Ground Floor	23%	17%
Final Building B	23%	17%
BUILDING C	51%	18%

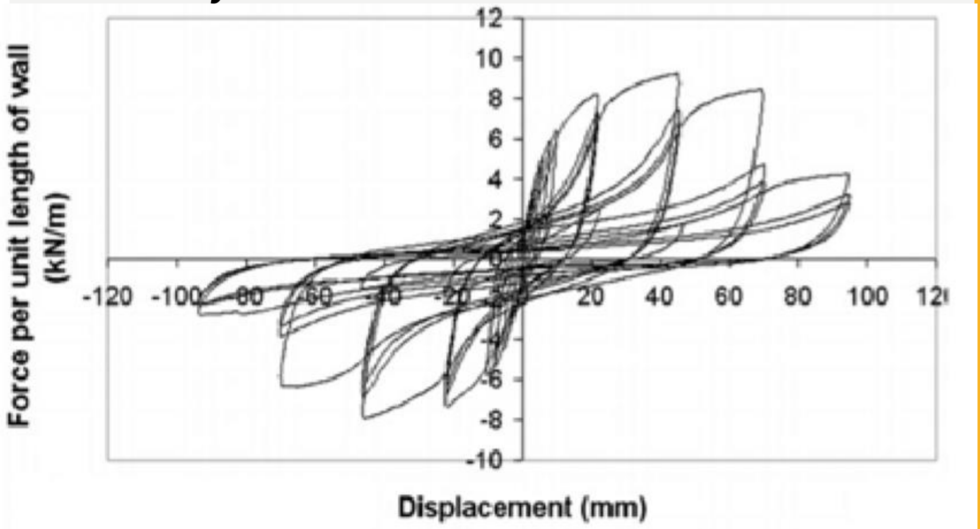
EARTHQUAKE IN NEW ZEALAND

DAMAGE PINCHED HYSTERETIC BEHAVIOR OF NAILS REFLECTED IN HYSTERETIC BEHAVIOR OF SHEAR WALLS

Typical nail hysteretic behaviour

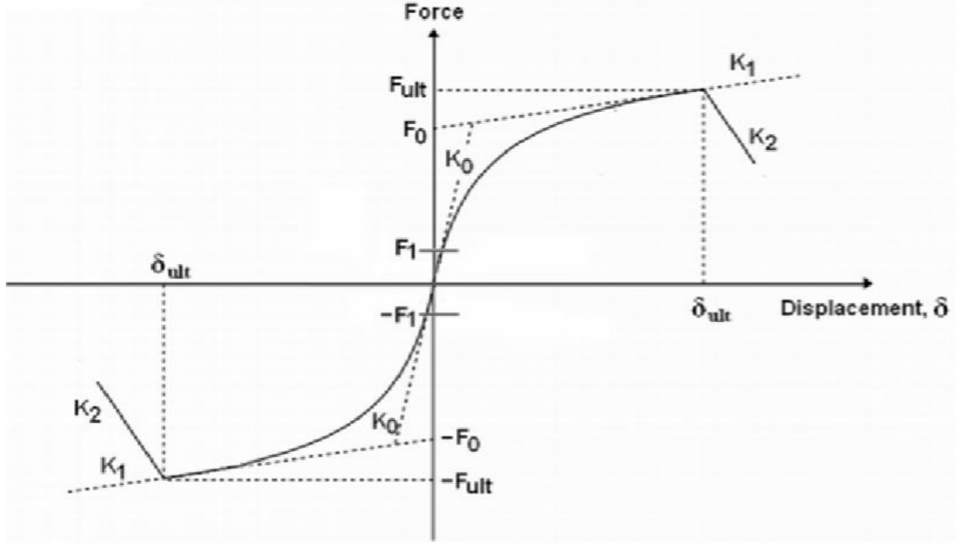


Shear wall hysteretic behaviour



EARTHQUAKE IN NEW ZEALAND

BACKBONE CURVE OF FASTENER THROUGH WOOD



The benchmark force-displacement relationship for modelling nails, will take the form of the well-known Foschi exponential curve (Dolan and Madsen 1992). Eq. (1) describes the curve between zero and ultimate displacement, δ_{ult}

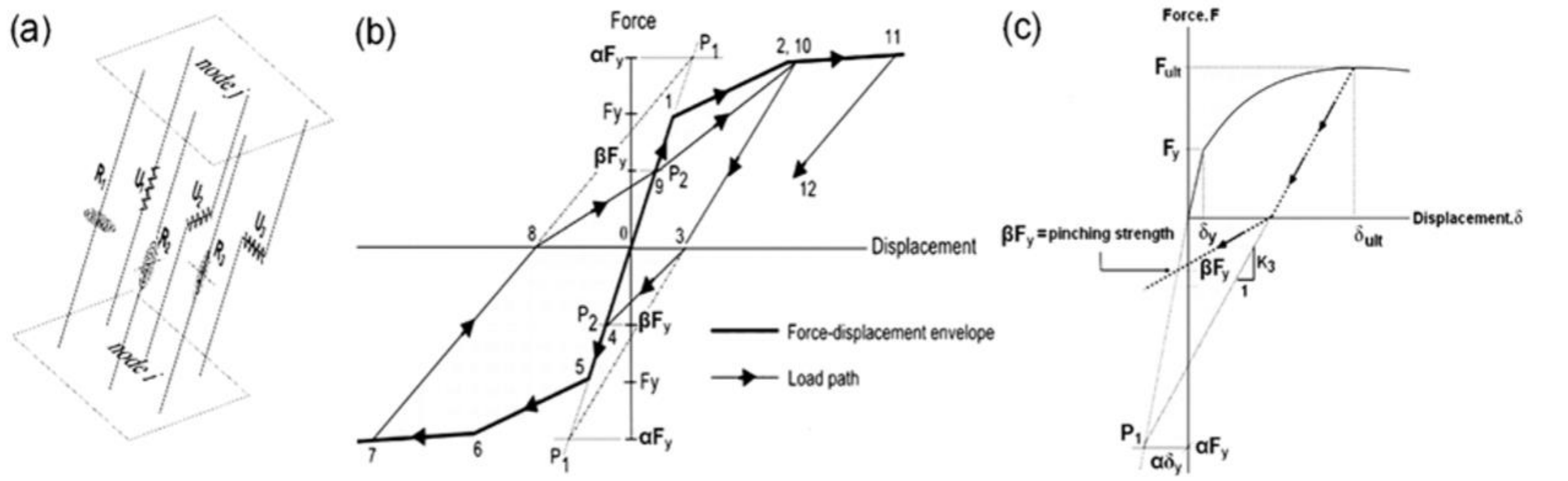
$$Force = (F_0 + K_1\delta) \cdot [1 - \exp(-K_0\delta/F_0)] \quad (1)$$

and Eq. (2) describes the relationship for displacements beyond δ_{ult}

$$Force = K_2\delta + (F_{ult} - K_2\delta_{ult}) \quad (2)$$

EARTHQUAKE IN NEW ZEALAND

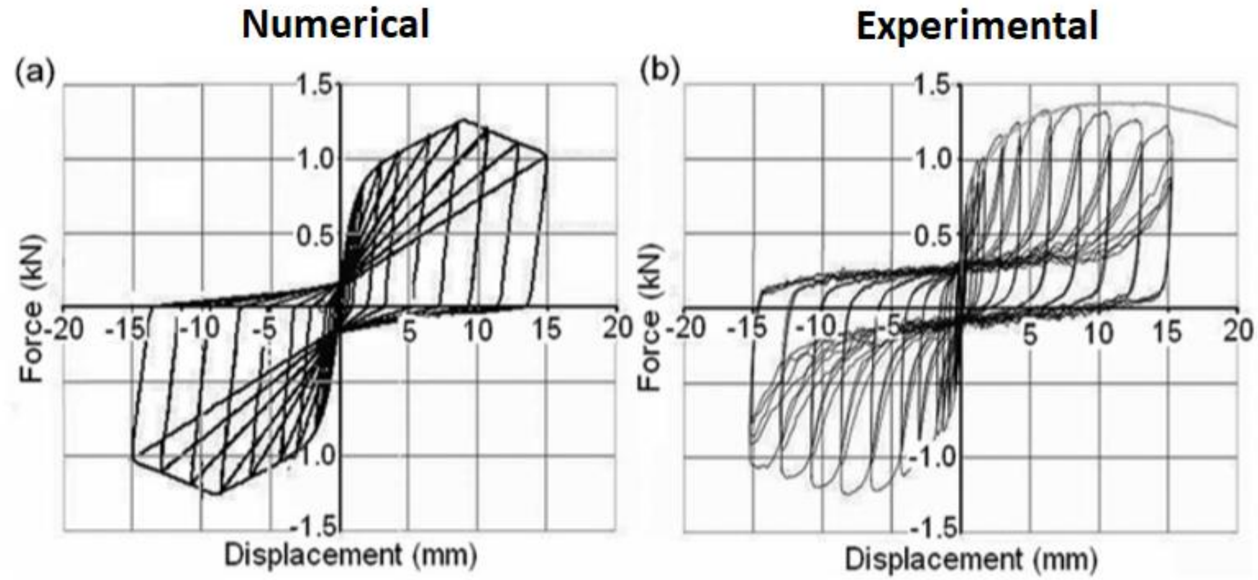
HYSTERETIC BEHAVIOR MODELLED BY SINGLE LINK ELEMENT



Nail connection (a) multilinear plastic link element adopted consists of translational and rotational springs (b) multi-linear plastic link –'pivot' hysteresis type, and (c) determination of hysteresis parameters α, and β

EARTHQUAKE IN NEW ZEALAND

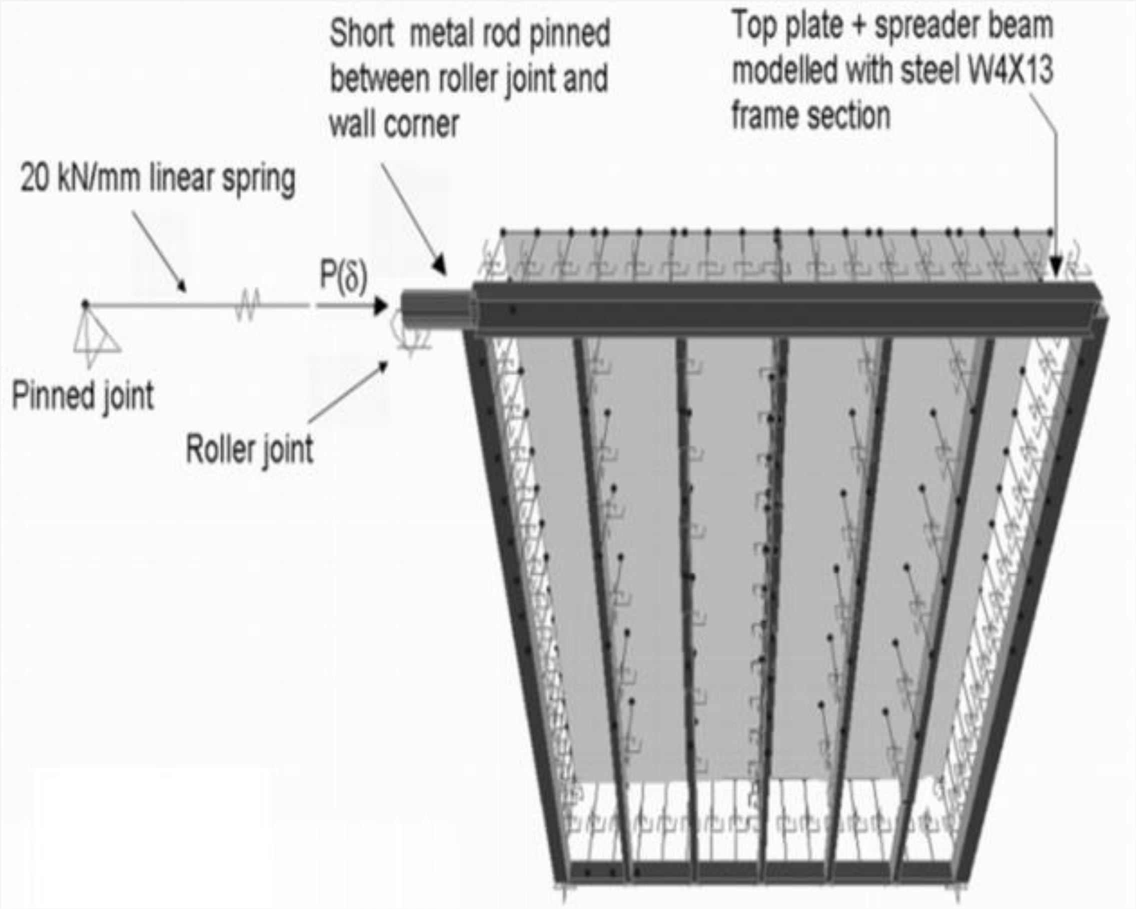
HYSTERETIC BEHAVIOR MODELLED BY SINGLE LINK ELEMENT



Force-displacement relationship for 3 mm nails attaching 11 mm thick OSB sheathing to SPF framing (a) Numerical simulation and (b) experimental result (courtesy of Dinehart *et al*. (2006))

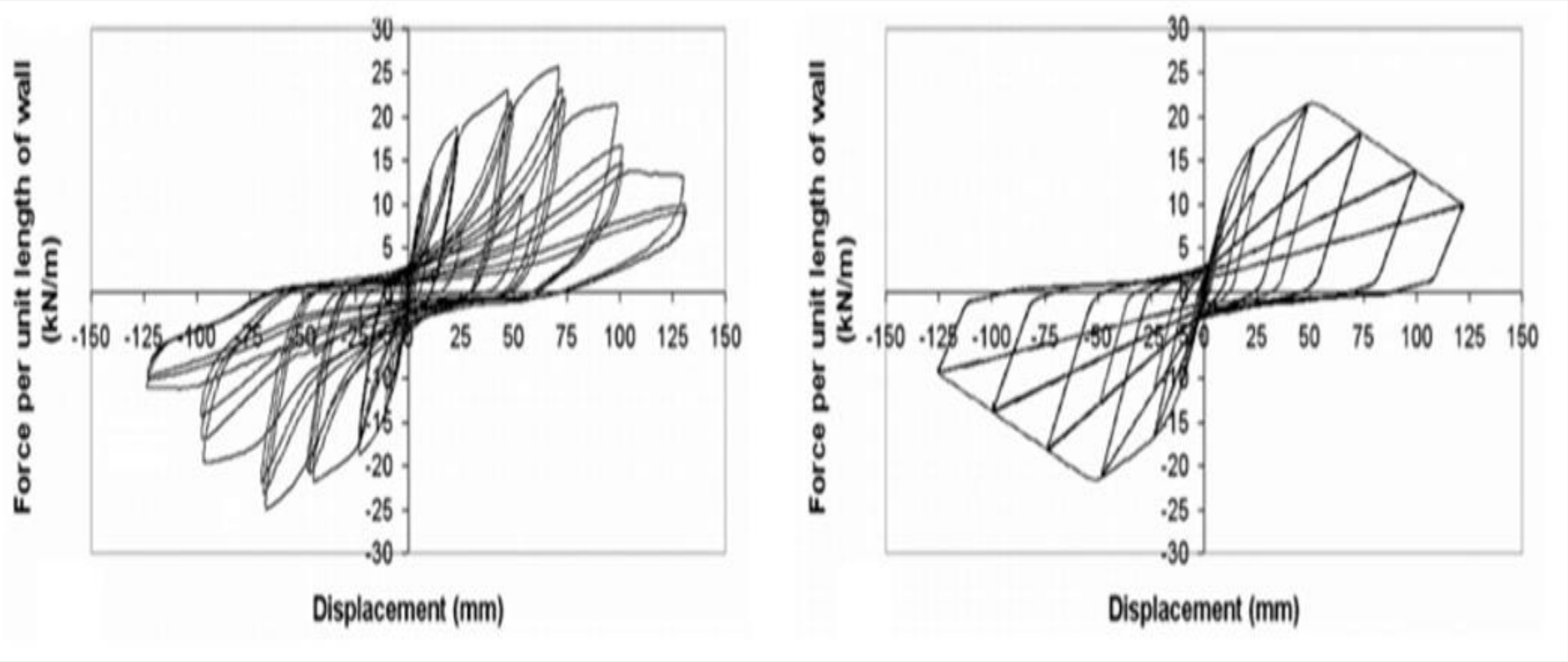
EARTHQUAKE IN NEW ZEALAND

ELEMENTS ARE IMPLEMENTED IN WALLS



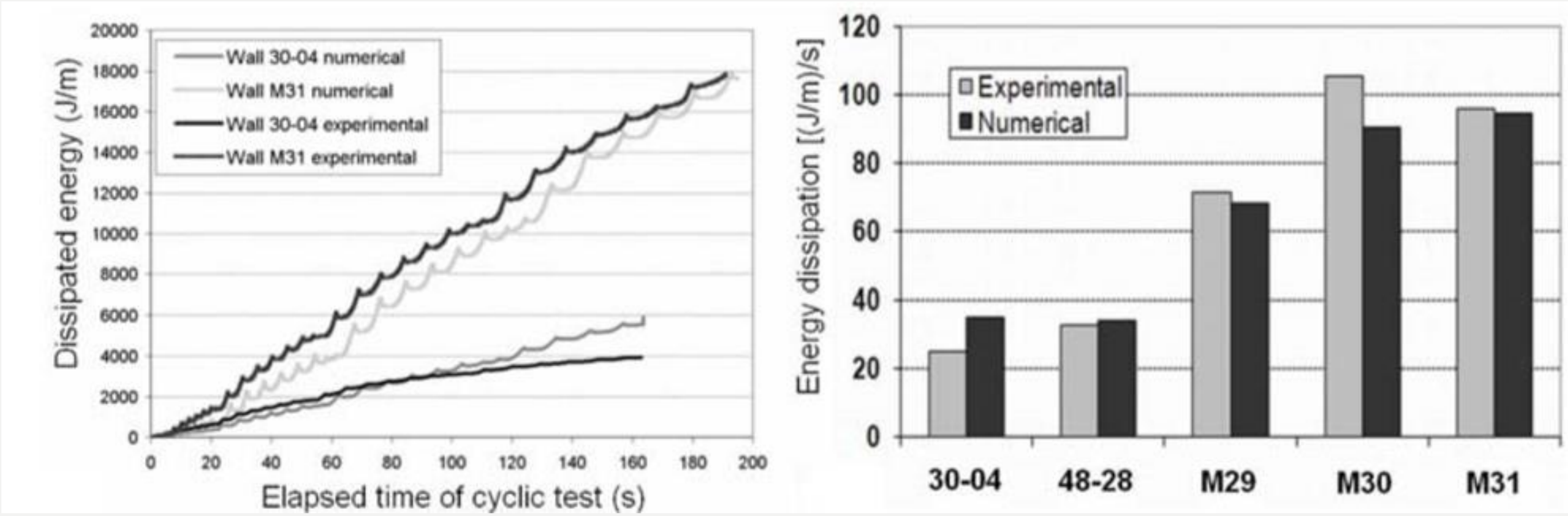
EARTHQUAKE IN NEW ZEALAND

GOOD MATCH BETWEEN NUMERICAL AND EXPERIMENTAL



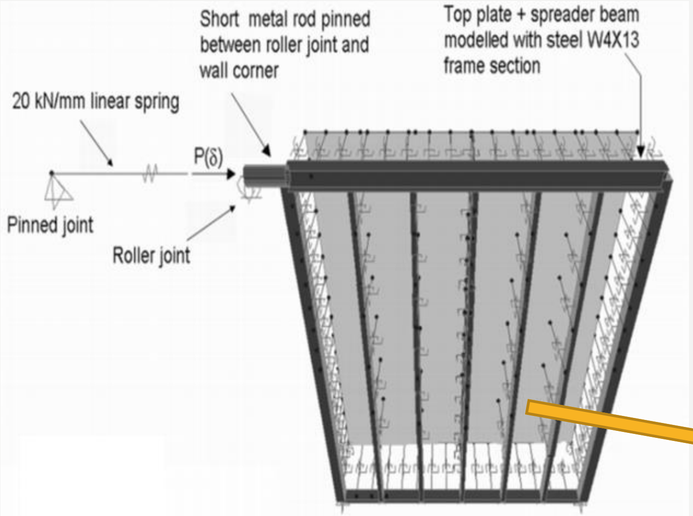
EARTHQUAKE IN NEW ZEALAND

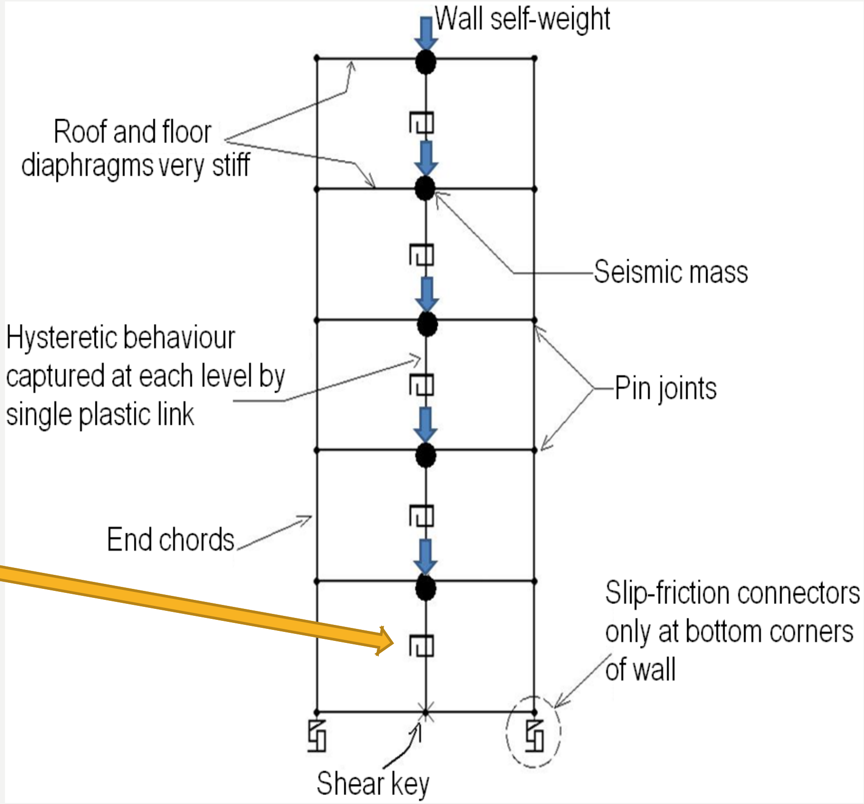
ENERGY DISSIPATION COMPARISON



EARTHQUAKE IN NEW ZEALAND

THE BEHAVIOR OF A WALL WITH MANY LINKS CAN BE CAPTURED BY A SINGLE LINK

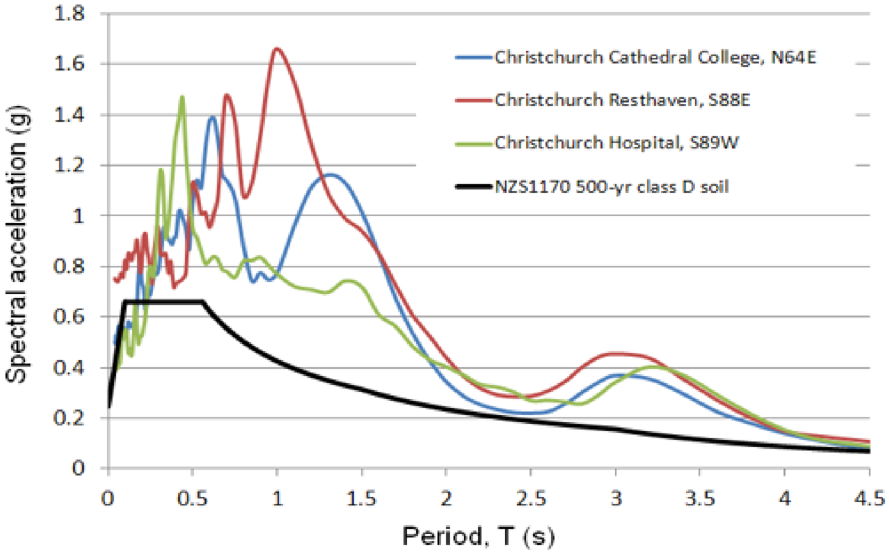




EARTHQUAKE IN NEW ZEALAND

CHRISTCHURCH, FEB 2011

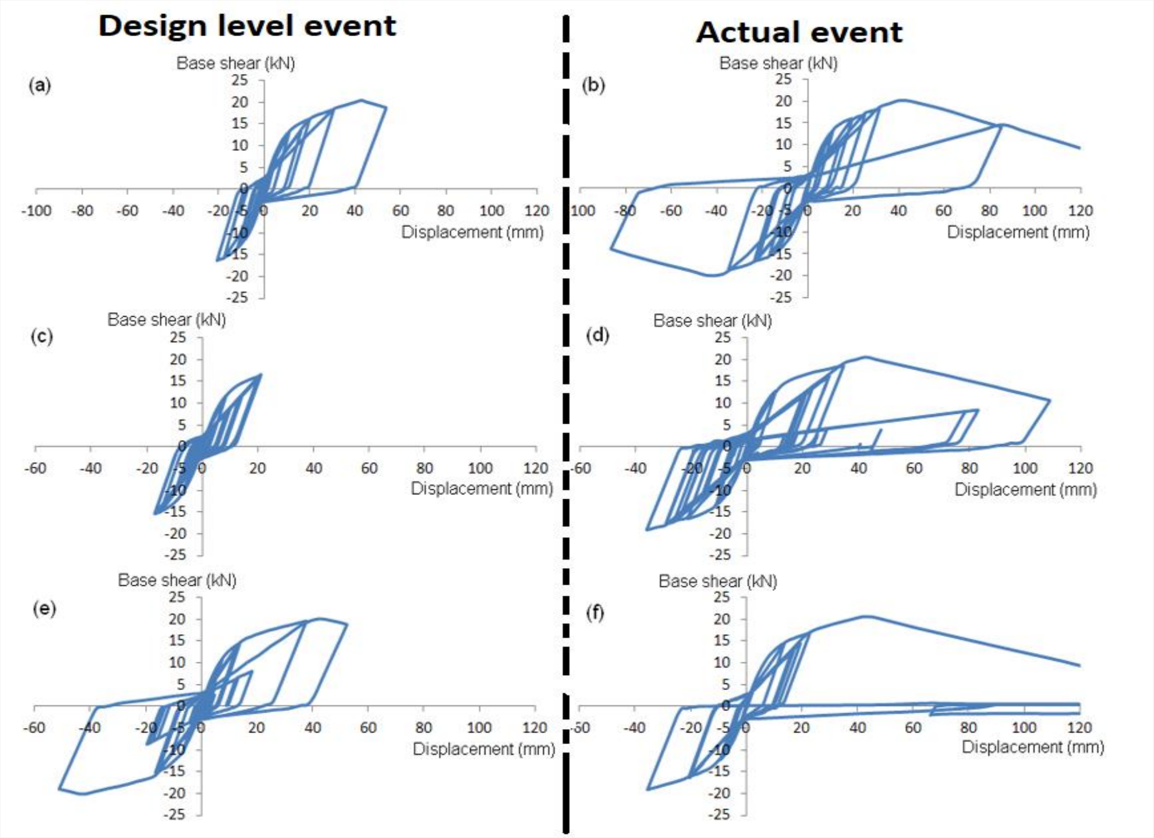
The authors modelled a shear wall using the methodology of the preceding section and subjected it to a sequence of simulated earthquake loadings. Earthquake motions from the destructive 22nd February 2011 Christchurch earthquake (magnitude 6.3 M_L) were applied. The data used were from three different sites in the Christchurch central business district: Christchurch Cathedral College, Christchurch Hospital, and Christchurch Resthaven (Note Zone factor for Christchurch was 0.22, is now 0.30



Spectral accelerations for the February 2011 Christchurch earthquake at three sites, and the ULS design spectrum (500 yr return period) for NZS1170.5 [16], Type D (soft) soils (Spectra produced from data provided by GeoNet NZ [17])

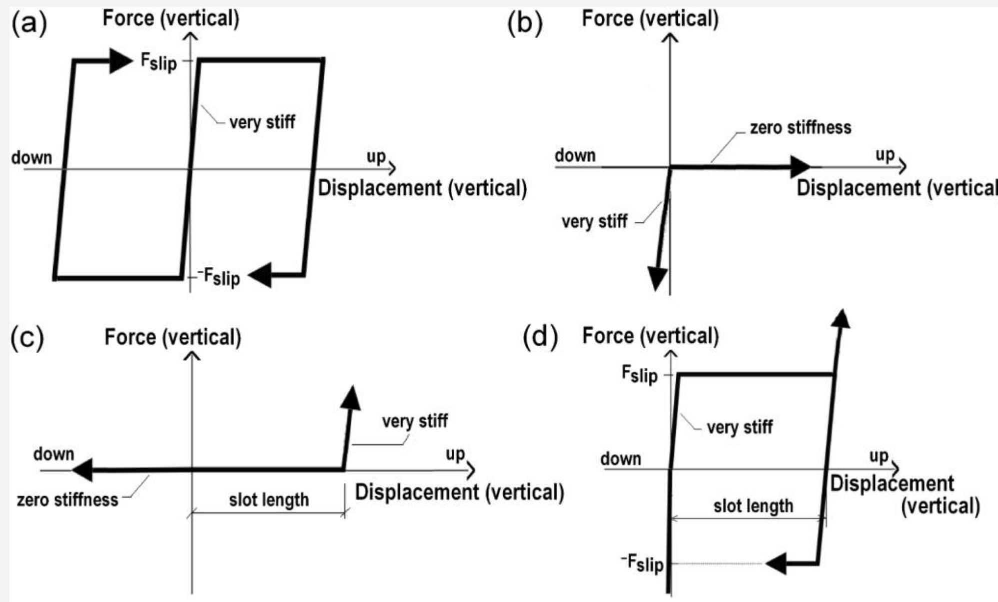
EARTHQUAKE IN NEW ZEALAND

CHRISTCHURCH: NUMERICAL COMPARISON BETWEEN ACTUAL AND DESIGN LEVEL (PREVIOUS) EVENTS, SINGLE STOREY WALL



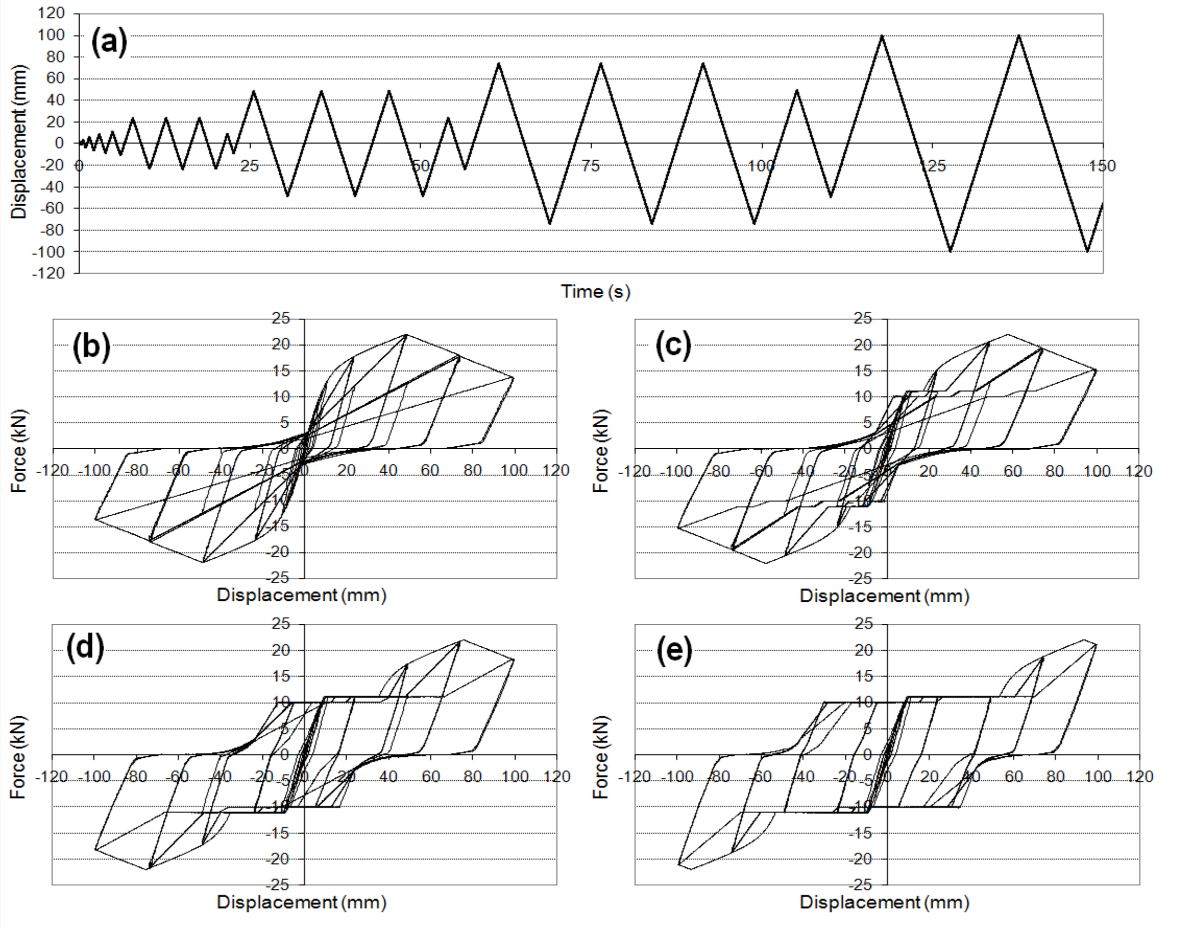
EARTHQUAKE IN NEW ZEALAND

OTHER APPLICATIONS: *COMBINED WITH PASSIVE ENERGY FRICTION DISSIPATERS MODELLED NUMERICALLY:*

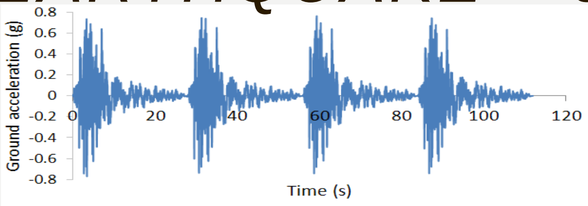


EARTHQUAKE IN NEW ZEALAND

OTHER APPLICATIONS: *COMBINED WITH PASSIVE ENERGY FRICTION DISSIPATERS MODELLED NUMERICALLY:*



EARTHQUAKE – SAN FERNANDO



San Fernando scaled events, 4 in succession, scale factor x 5

CONCLUSIONS

- While a country such as New Zealand, due to its geographic and geological setting is prone to a variety of extreme natural events
- However, proper engineering design and preparedness can not now only mitigate loss of life, but also cost to the repair of infrastructure.
- We have provided examples of some of the work done in civil engineering relating to earthquake risks in this country.
- Being prepared when a disaster strikes is the key to the survival of any person, family and community.

THANK YOU!

For details or any other questions relating to this presentation, please feel free to contact the authors

Dr Lusa Tuleasca: ltuleasc@unitec.ac.nz
Dr Wei Yuen Loo: wloo@unitec.ac.nz