Seismic Performance of Flanged Timber Core-Wall Systems

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Introduction

Trail, BC Canada → Vancouver, BC Canada

StructureCraft

University of Canterbury, New Zealand

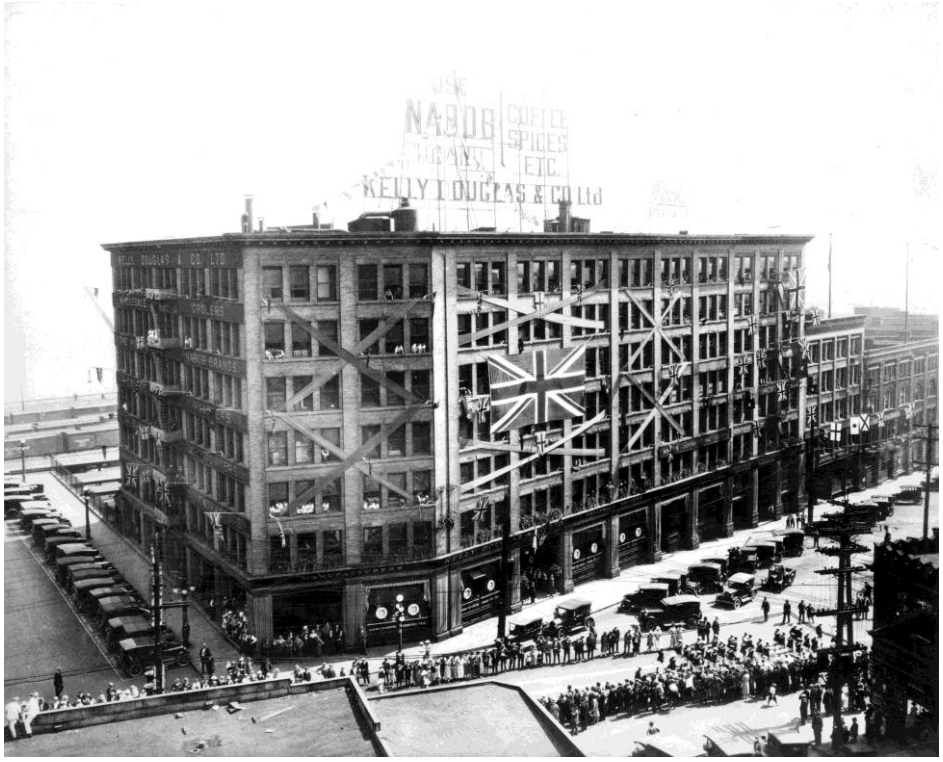
Presentation Outline

- Research Motivations
  - History of timber construction
  - Development of engineered wood products
  - Current construction practice
- Past Relevant Research
  - System behaviour
  - Connection level behaviour
- Scope and Objectives
  - Task 0 – State of the art research
  - Task 1 – Component level testing
  - Task 3 – Large scale timber core-wall test

Research Motivations

History of Timber Construction

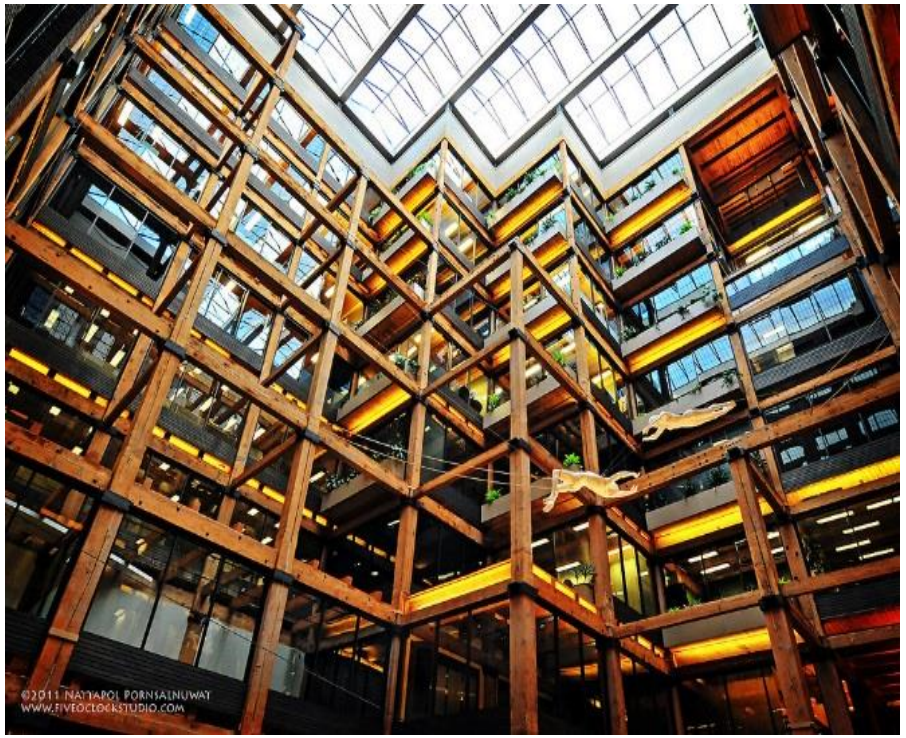
Pacific Northwest Douglas Fir Log



Kelly Douglas & Co. Warehouse
(McGlynn, J.P., 2013)

History of Timber Construction

Butler Building Minneapolis
(Butler Square, n.d.)



Butler Building Minneapolis
(Butler Square, n.d.)

History of Timber Construction

Logging Truck
(Alamy, n.d.)

Six Storey Light Timber Frame Construction
(On-Site, 2015)

Engineered Wood Products

Glulam

Laminated Veneer Lumber

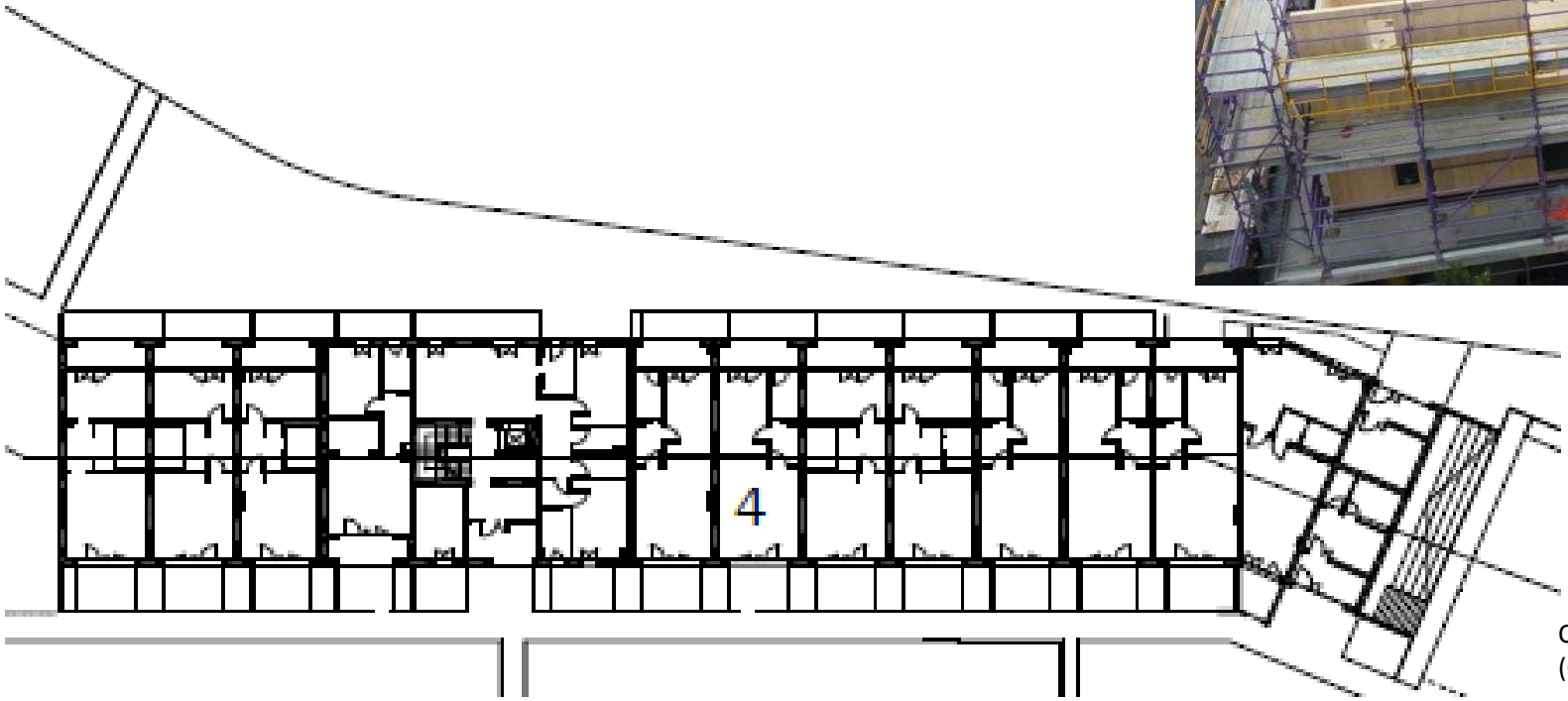
Cross Laminated Timber

(StructureCraft, n.d.)

Panel Systems

- Prefabricated Construction
- Fast on-site installation
- Suitable for residential construction

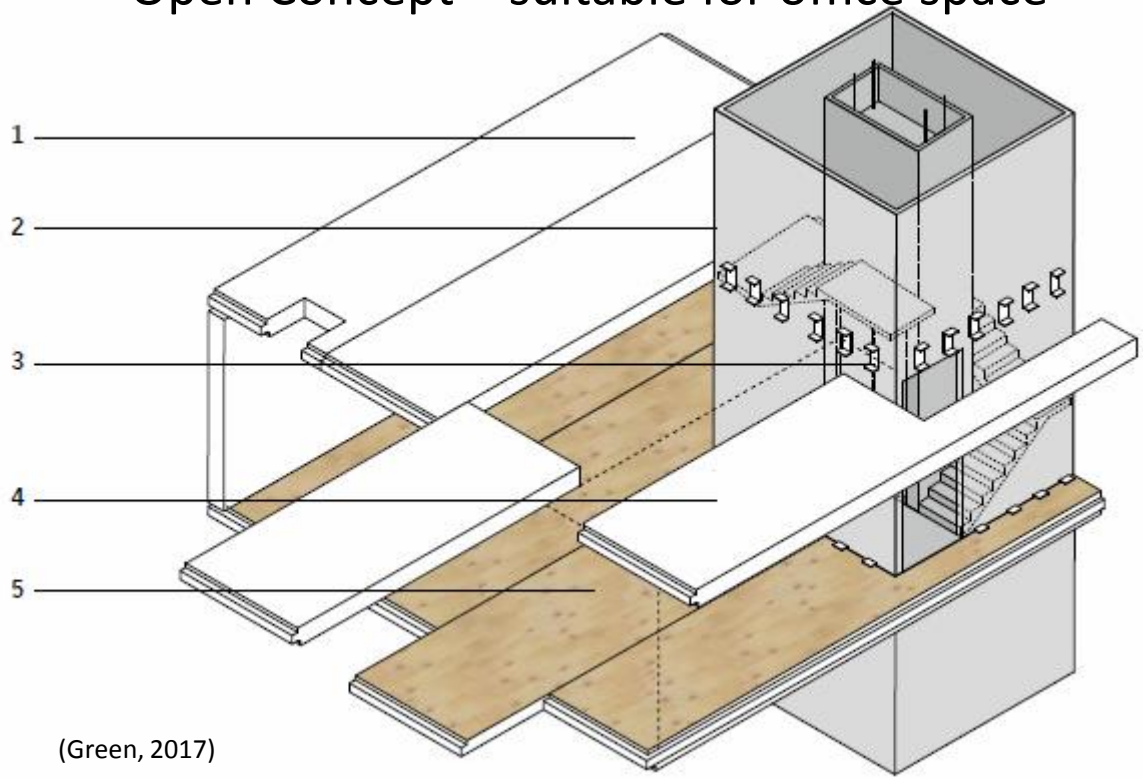
Forte Building, Australia
(Built Offsite, n.d.)



Cenni di Cambiamento Building, Italy
(Green, 2017)

Hybrid Systems

- Concrete core constructed On-Site
  - Core acts as primary lateral force resisting system against Wind and Earthquake
- Open Concept – suitable for office space



(Green, 2017)

Wood Cube, Germany
(Green, 2017)

Hybrid Systems

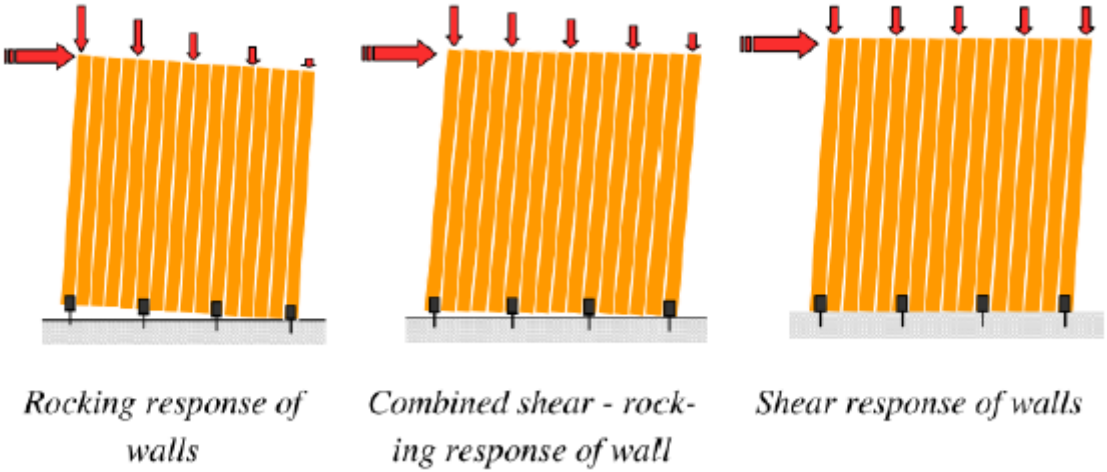
UBC Brock Commons
(Seagate Structure, n.d.)

Can these “concrete cores” be replaced with “timber cores”?

Past Relevant Research

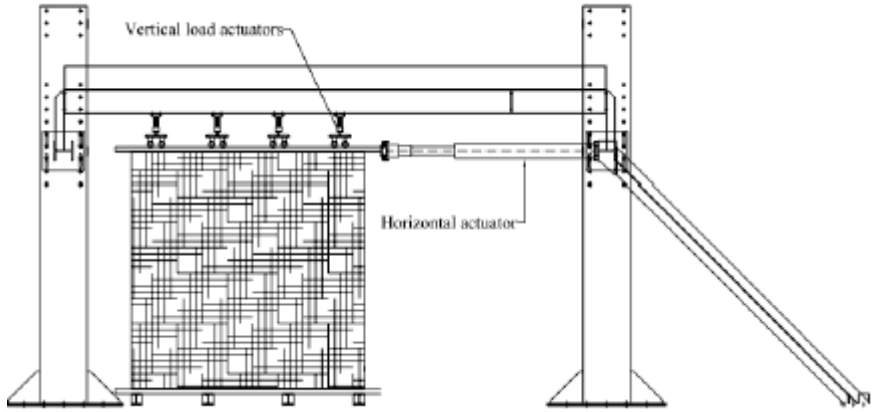
System Behaviour

- Dujic et al., (2005) found CLT walls respond mainly in rocking
  - Highly dependent on anchoring systems



Typical Responses of CLT Walls (Dujic et al., 2005)

- Ceccotti (2006) confirmed that connections have strong influence on behaviour



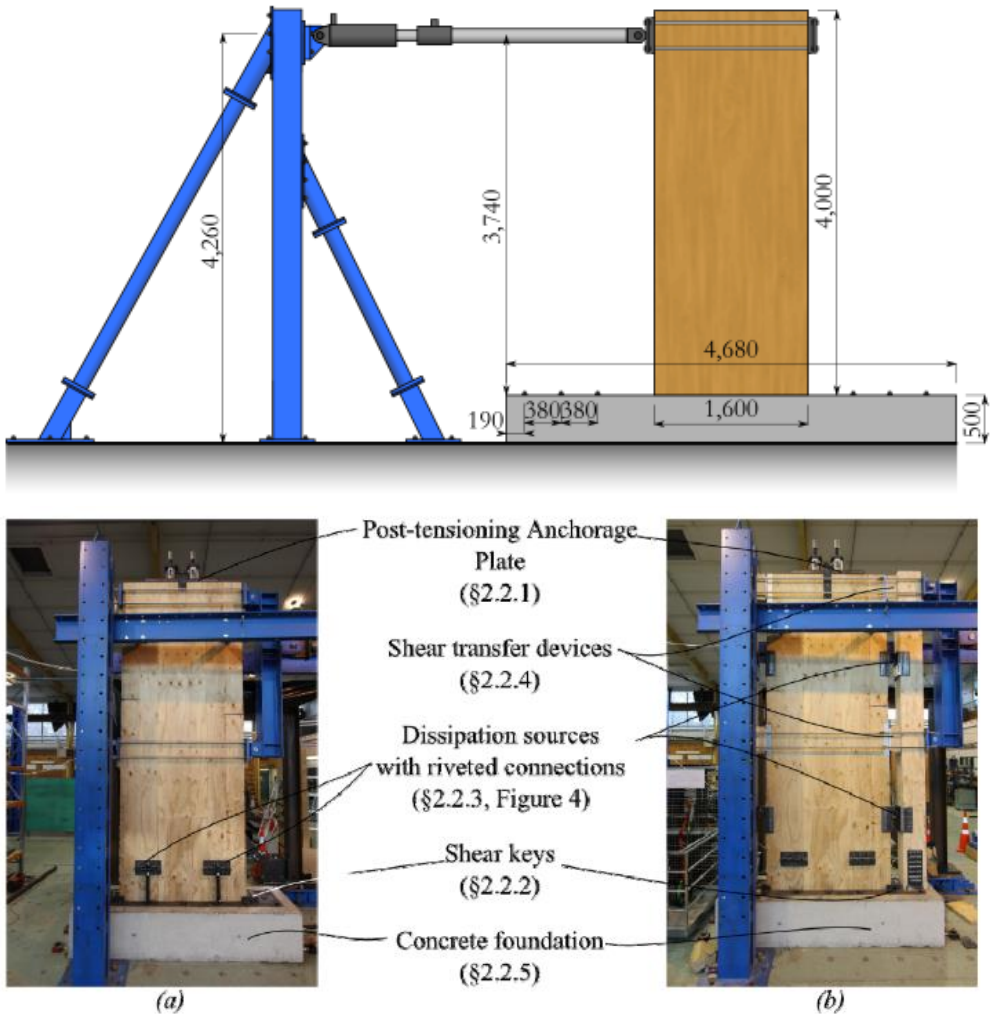
Single Panel Tests (Ceccotti et al., 2006)

System Behaviour

Pres-Lam System

- Research commenced in 2005

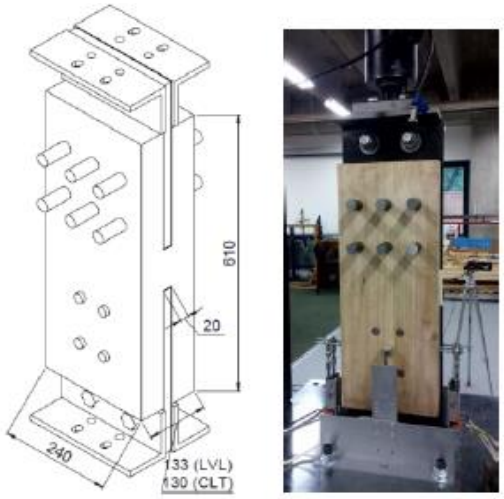
- Sarti (2015) most recently refined in-plane wall behaviour



Pres-Lam LVL In-Plane LVL Wall Test Setup (Sarti, 2015)

Connection Behaviour

Hold-down



Hold-down Connection (Ottenhaus, Li, Smith, et al., 2017)

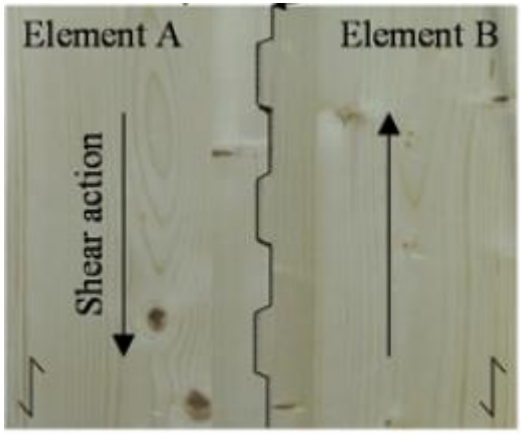
- Analytical overstrength models developed

Self-tapping Screws

Screw Testing in CLT (Gavric et.al., 2015)

- Orthogonal CLT panel connections

Castellated Joints



Castellated Joint Testing in CLT (Schmidt & Blass, 2016)

- Connection vs. CLT wall capacity assessed for various in-plane connections

Summary

System Level Behaviour

- Shear wall research has focussed on in-plane behaviour

Connection Level Behaviour

- There has been relevant connection level research
  - Hold—down connections: proposed analytical overstrength models
  - Screwed connections: large focus in glulam, further research required for CLT
  - Castellated shear connections: preliminary investigations explored

Scope and Objectives

Scope and Objectives

To investigate the performance of flanged timber core-walls

Tasks

Task 0 – State of the art research
Task 1 – Component level testing
Task 2 – Archetype building analysis and numerical modelling development
Task 3 – Large scale timber core-wall test
Task 4 – Analytical and numerical parametric studies
Task 5 – Guidelines for the design of timber core-wall systems

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Industry – Cathedral Hill II

Figure 4. *Architectural rendering of the building*

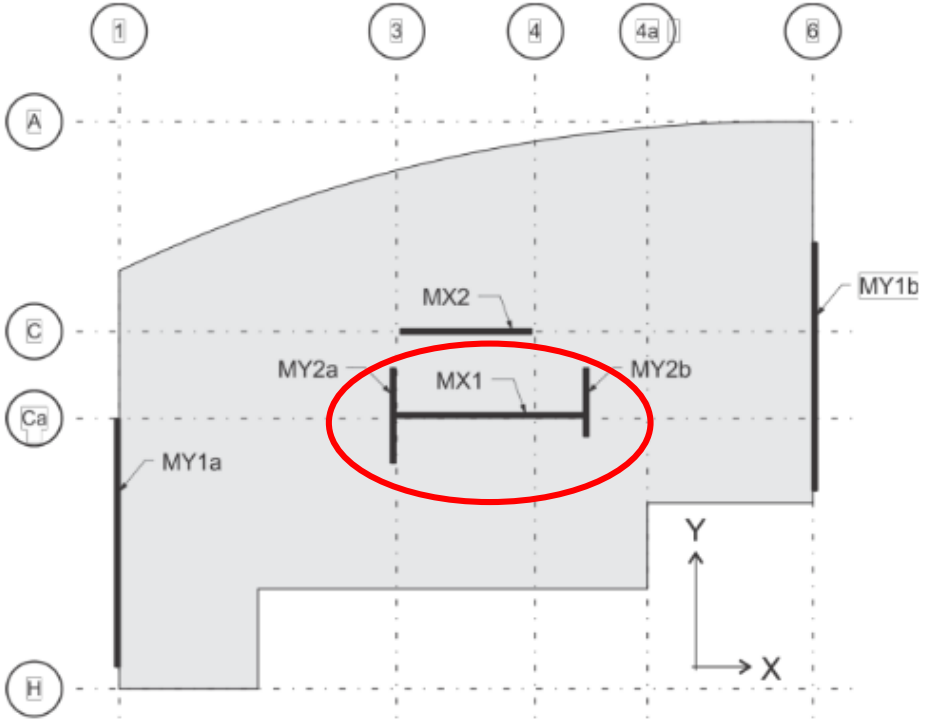
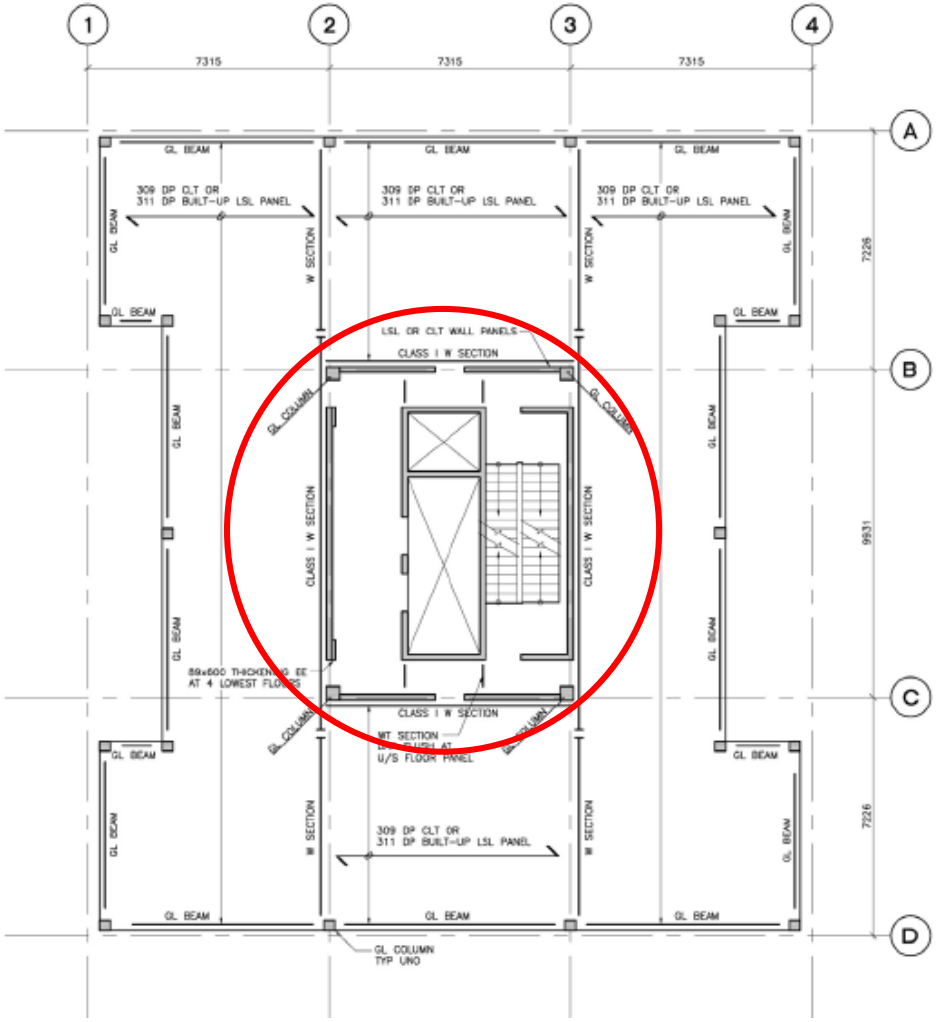


Figure 6. *Typical plan view showing the shear walls of the lateral-load resisting system.*

Cathedral Hill II (Below & Sarti, 2016)

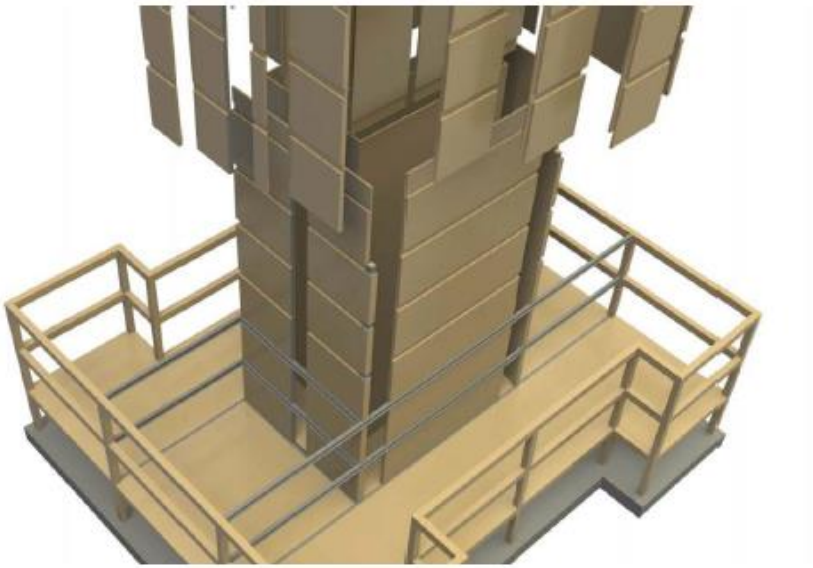
Industry & Research – FFTT System



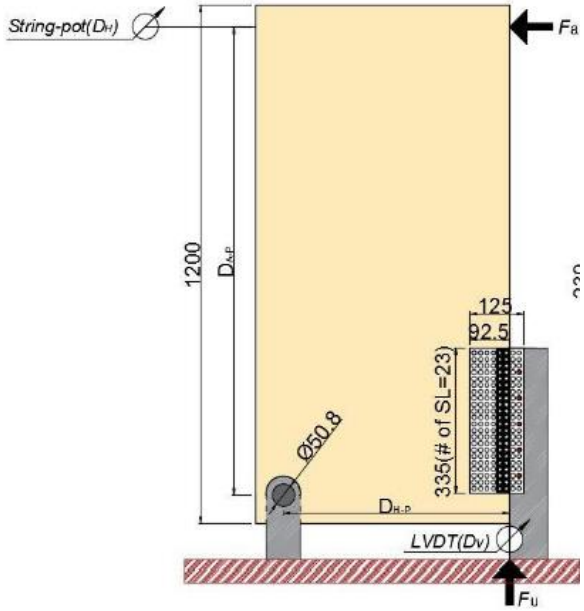
(Green, 2017)

Research – FFTT System

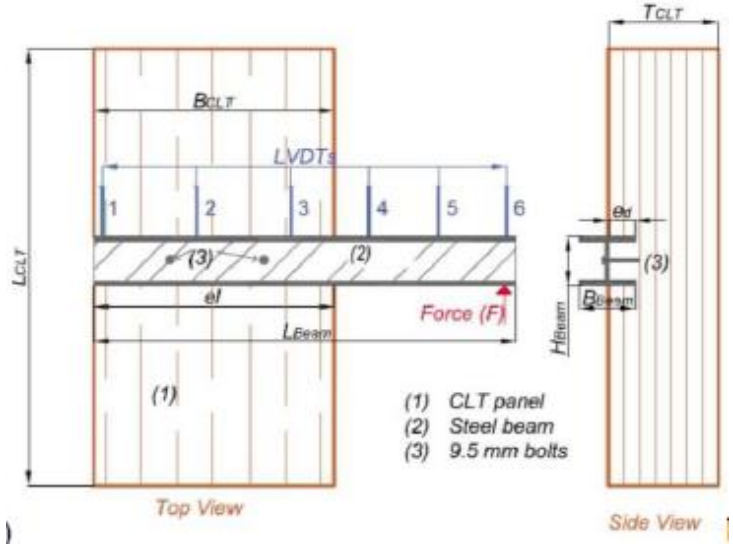
- Key connection testing (Azim, 2014; Bhat, 2013; Zhang et. al., 2017)
- System level numerical analysis by Zhang (2017)



(Green, 2017)



FFTT Hold-down Connection (Zhang, 2017)



FFTT Embedded Steel Beam Connection (Zhang, 2017)

Reinforced Concrete U-Shaped Walls

- Investigated failure mechanisms, stiffness degradation and torsional stiffness

- Experimental work confirmed diagonal direction is most critical in U-shaped walls

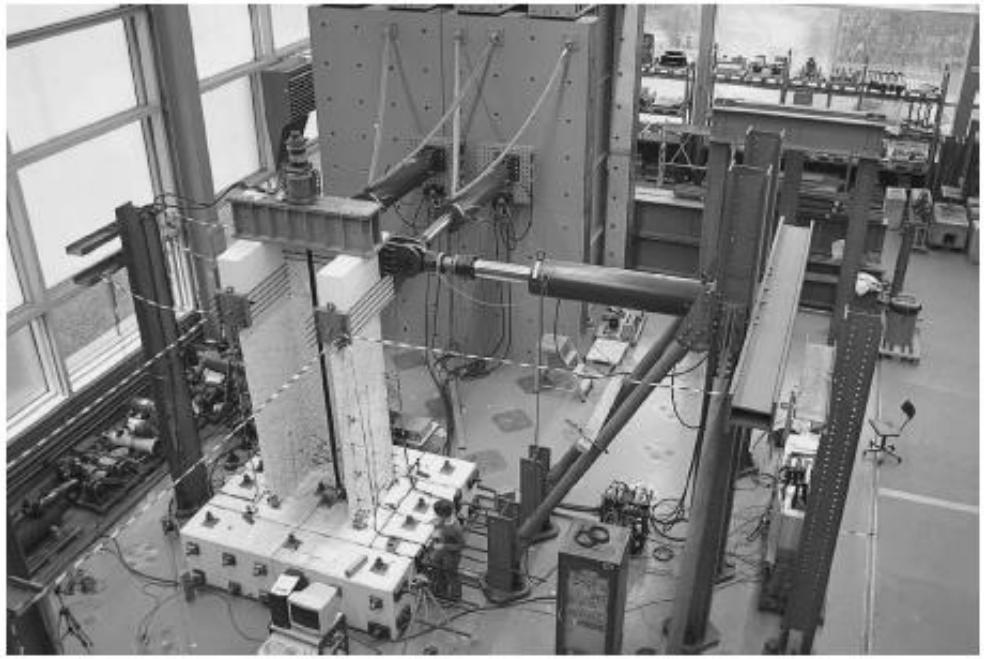


FIGURE 7 Photo of the test setup.

Beyer, K., Dazio, A., & Priestley, M. J. N. (2008). Quasi-Static Cyclic Tests of Two U-Shaped Reinforced Concrete Walls. *Journal of Earthquake Engineering, 12*(7), 1023-1053. doi: 10.1080/13632460802003272

CLT Core-wall System

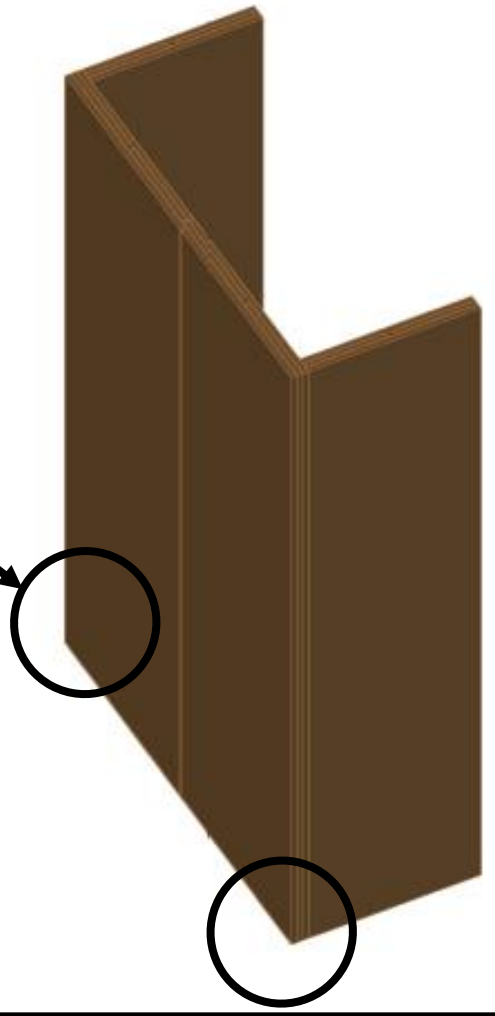
a)

Dunbar, A. J. M. (2014). *Seismic design of core-wall systems for multi-storey timber buildings: a thesis submitted in partial fulfilment of the requirements for the degree of Master of Engineering in Earthquake Engineering, Department of Civil and Natural Resources Engineering, University of Canterbury . Christchurch, New Zealand*.

Research Gap

Connection Testing → Large Scale Test

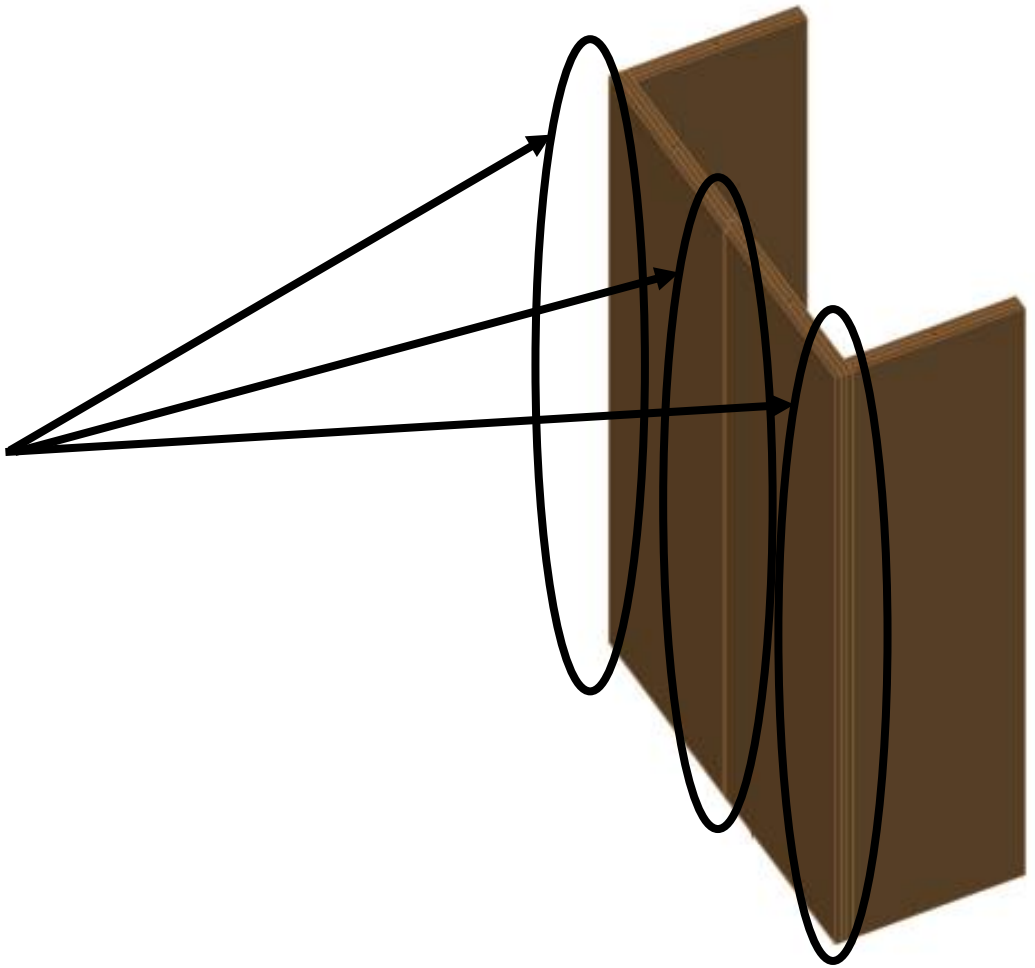
- Hold-down Connections



Research Gap

Connection Testing → Large Scale Test

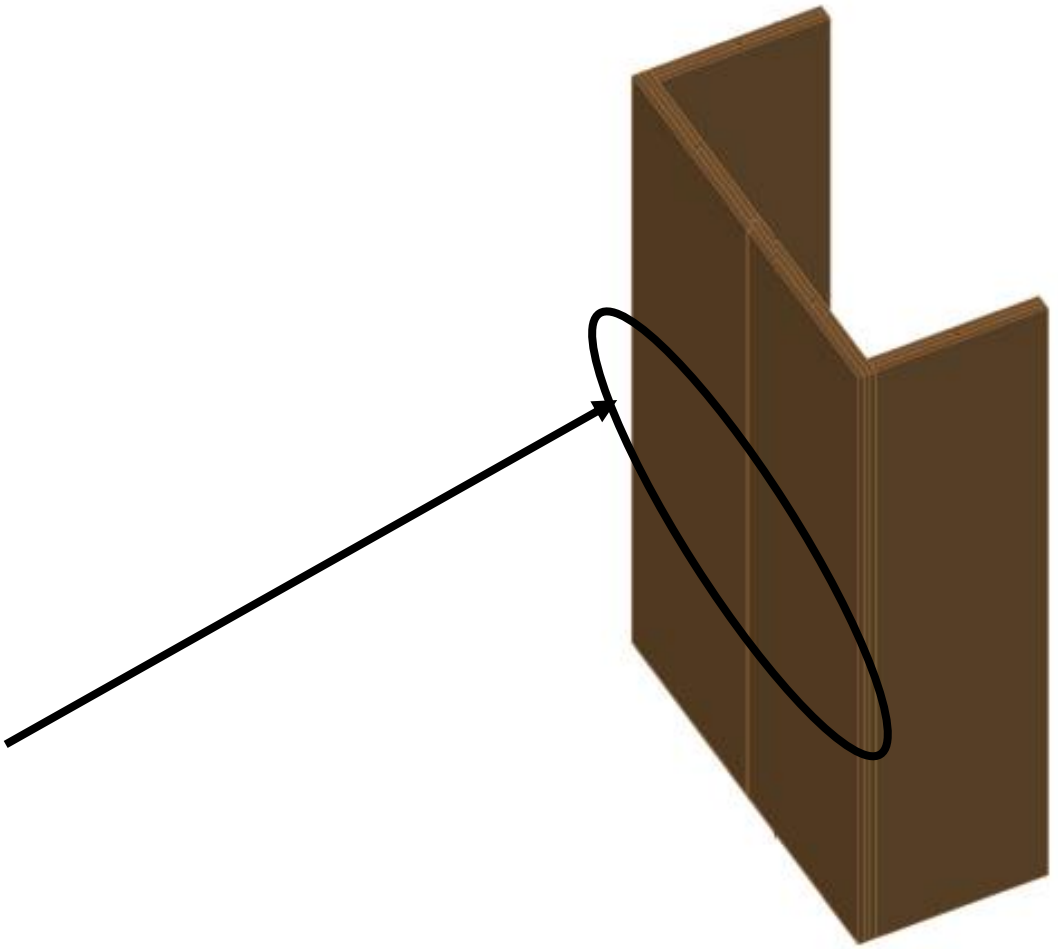
- Hold-down Connections
- Screw Connections



Research Gap

Connection Testing → Large Scale Test

- Hold-down Connections
- Screw Connections
- Castellated Connections



Research Gap

Connection Testing → Large Scale Test

- Hold-down Connections
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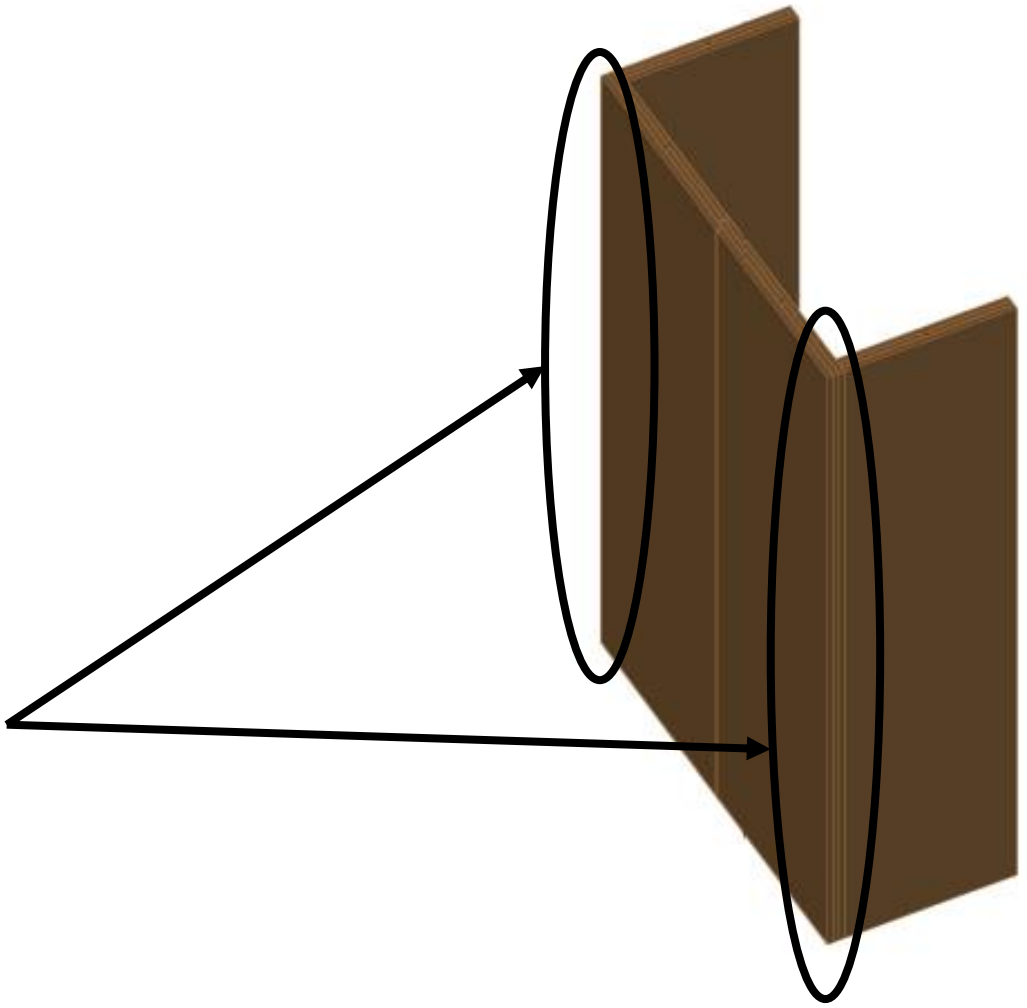
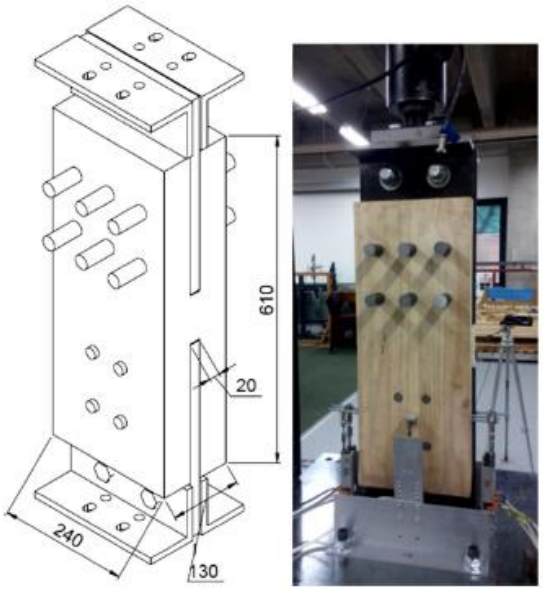


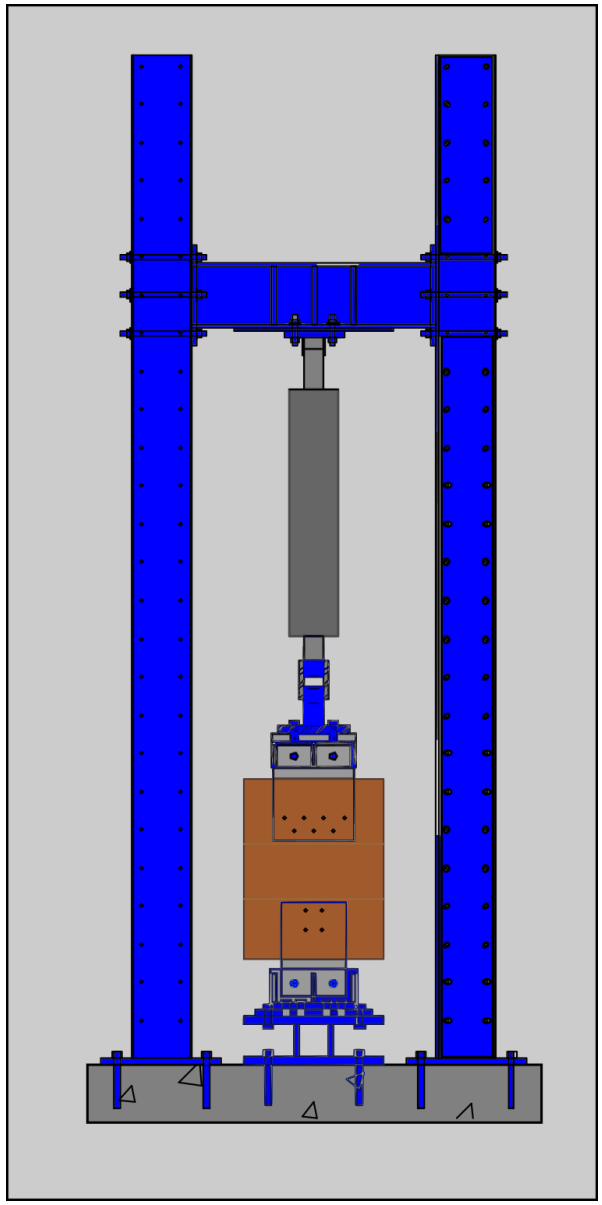
Dowelled Hold-down Connections

- Axial force connection at horizontal joint
- Validating and extending research

  by Ottenhaus (2017)
- Strong connection with ductility

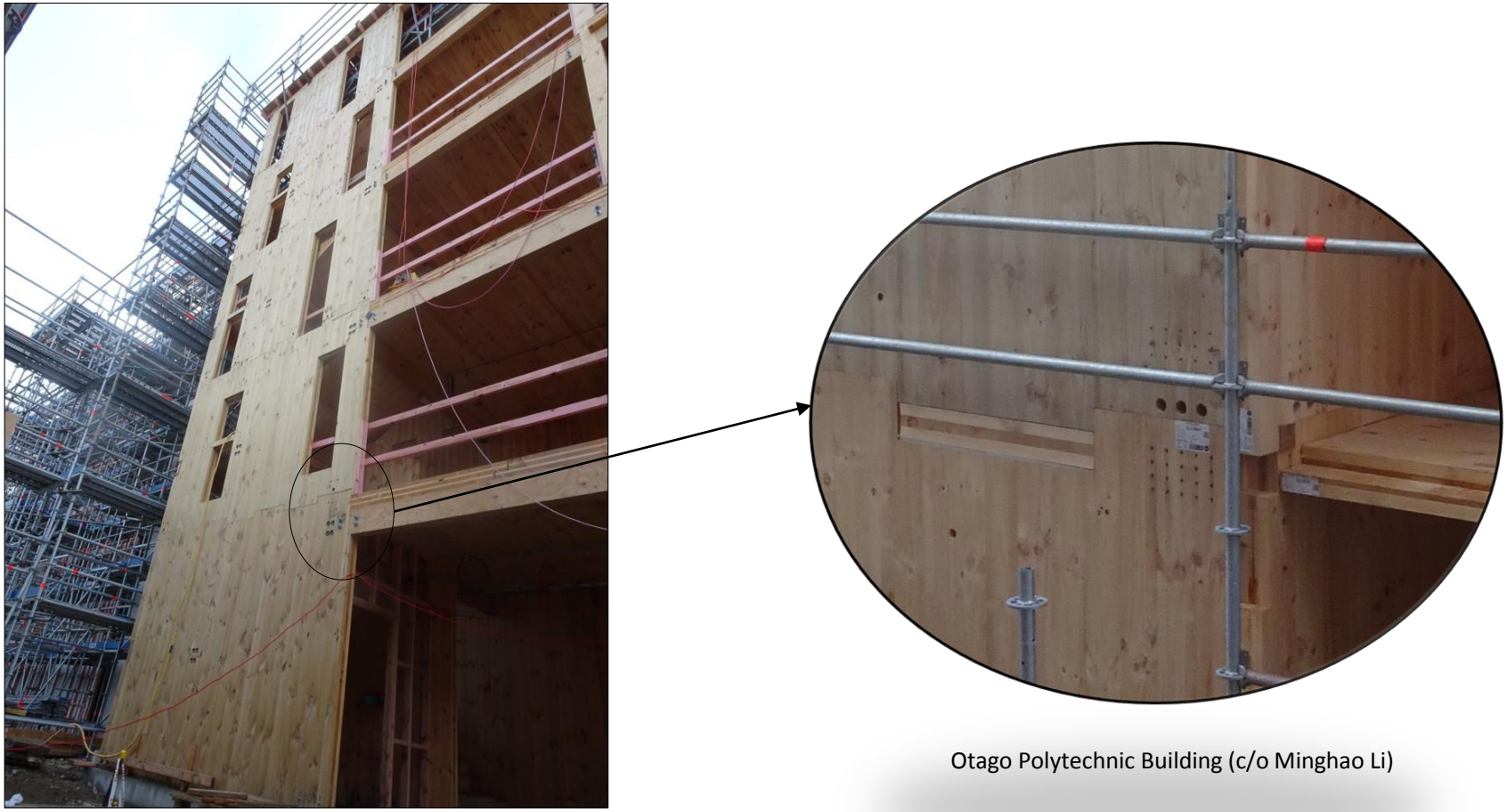


Hold-down Connection (Ottenhaus, Li, Smith, et al., 2017)



Dowelled Hold-down Connections

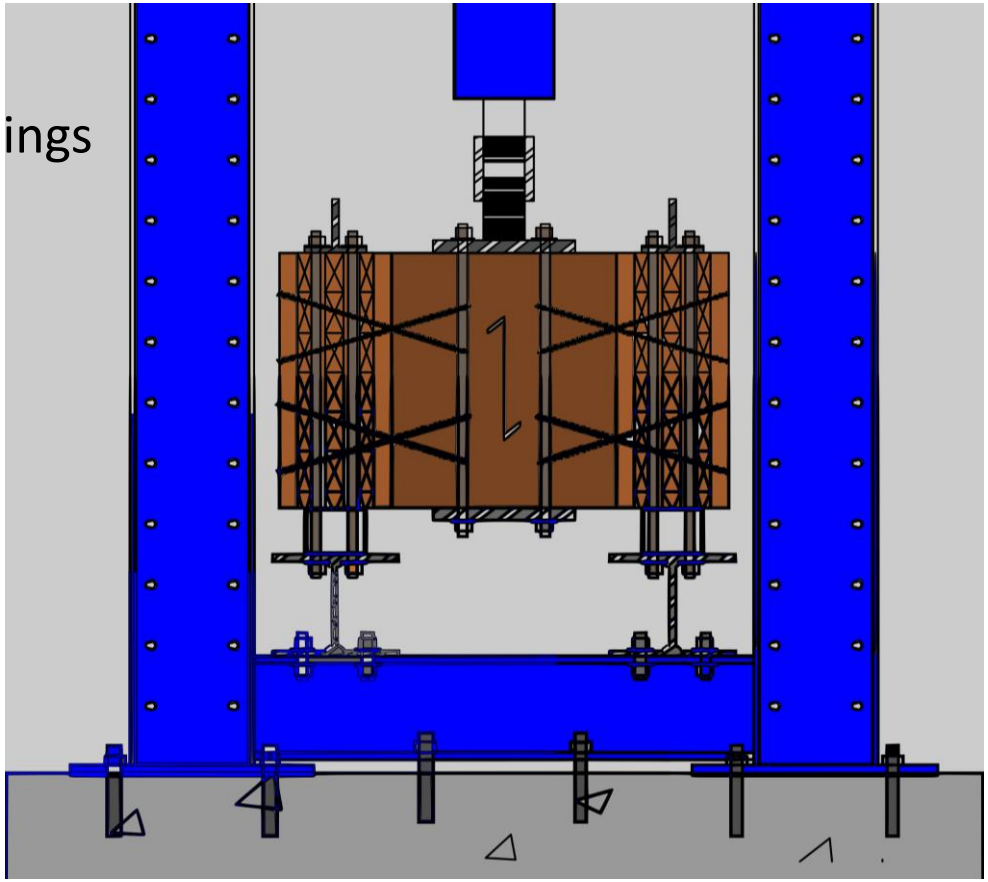
- In Industry



Otago Polytechnic Building (c/o Minghao Li)

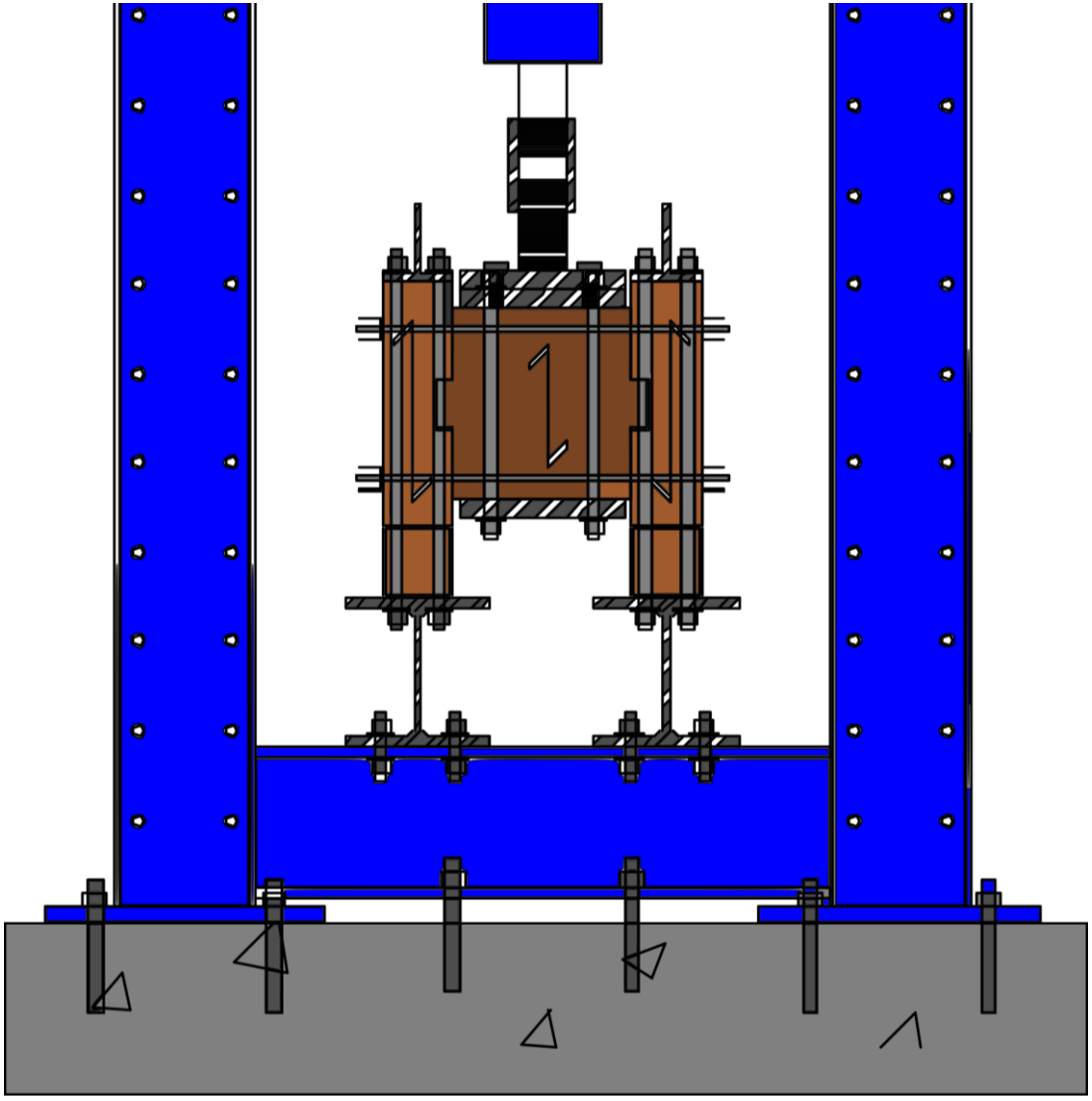
Screwed Connections

- Used in horizontal and vertical joint
- Most typical connection technique for CLT buildings
- Can perform well both axially and in shear



Castellated Joint Connections

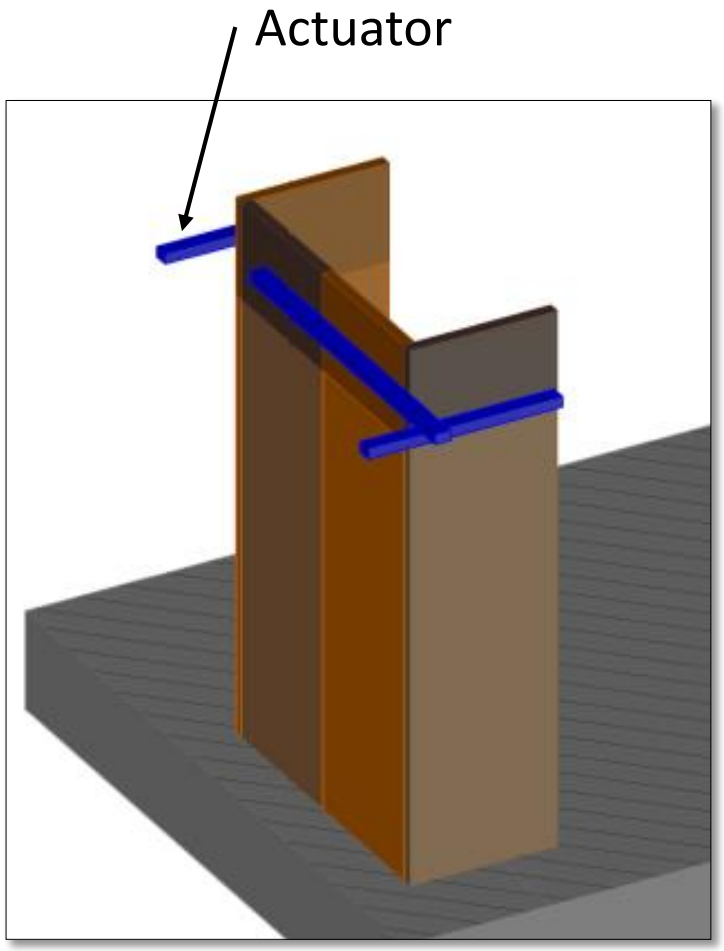
- Used in horizontal and vertical joint
- Shear force transfer between CLT panels



Castellated Joint Connections

Otago Polytechnic Building (c/o Minghao Li)

C-shaped core-wall test



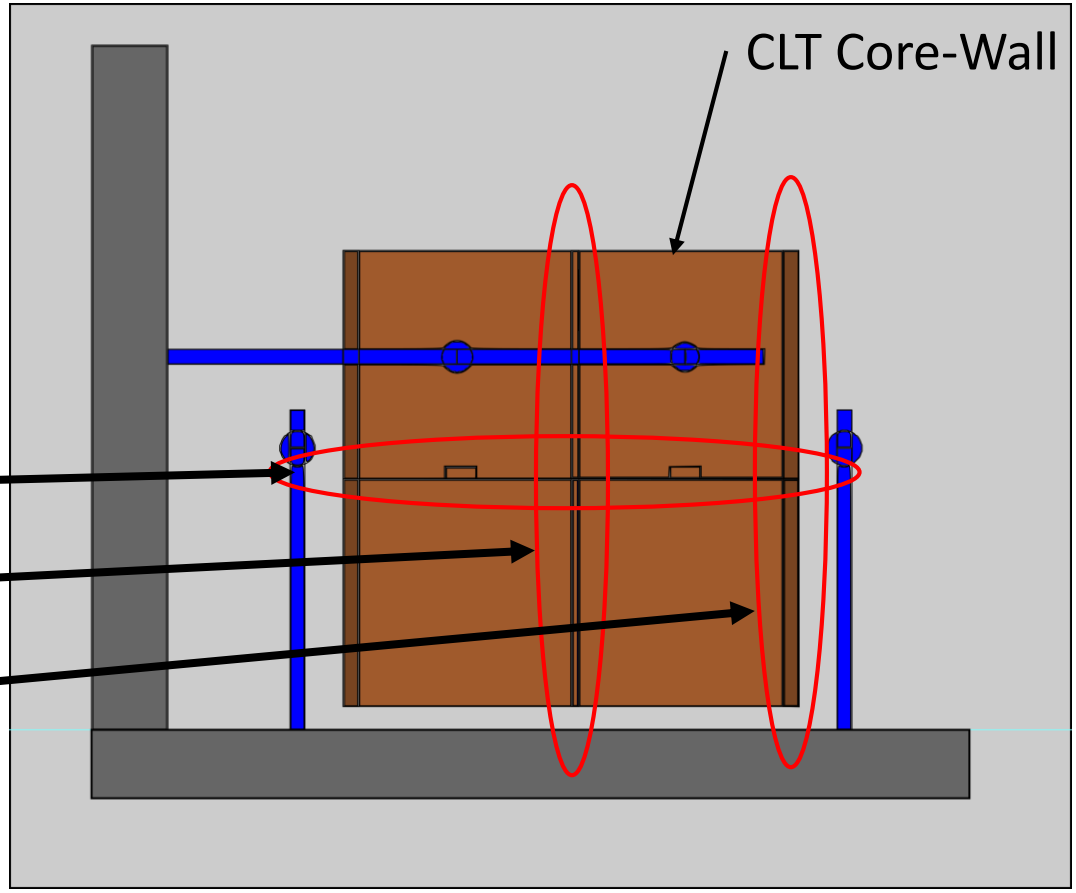
Key Considerations:

- Bi-directional cloverleaf test pattern
- Implement horizontal and vertical joints in test
- High-performance (Pres-Lam) and conventional systems will be tested

Large-scale core wall tests

Test Sequencing:

- Baseline in-plane test first (no flanges)
- Vary connection joints
  - Horizontal
  - Vertical in-plane
  - Vertical orthogonal



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- Scholarship New Zealand (New Zealand Commonwealth Scholarship Fellowship Plan)

Thank you

Justin Brown

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Civil & Natural Resources Engineering

University of Canterbury