CANTERBURY EARTHQUAKES ROYAL COMMISSION

WEDNESDAY, MARCH 14TH 2012

New Technology to Mitigate Damage to Timber Structures in Earthquakes

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Outline

- Structural timber systems to resist earthquakes
- Connections
- Slip-friction connector (SFC)
- Behaviour of systems using SFC
- Future testing

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Structural Timber Systems to Resist Earthquakes

- Plywood shear walls and diaphragms
- Pres-Lam System
- Cross-Laminated Timber (CLT) panels

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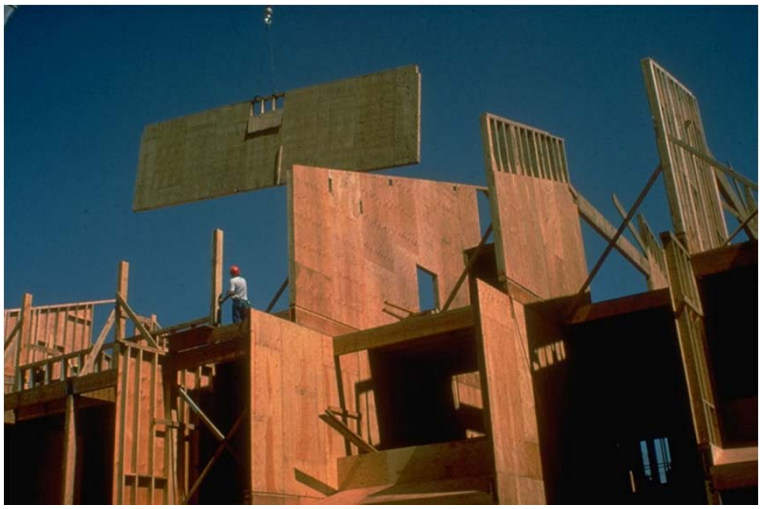
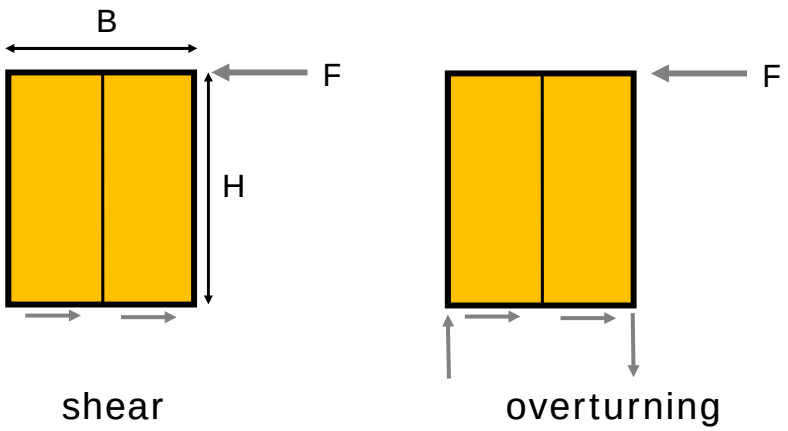
Plywood shear walls



Horizontal force resistance provided by two actions



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Pres-Lam System

- Developed by Buchanan, Pampanin and Palermo at UC
- Used in NMIT building in Nelson
- Uses post-tensioning and other devices to absorb energy and restore structural elements to their original position

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Pres-Lam System in NMIT

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CLT Panels

- Solid timber panel
- Allow for pre-fabrication and rapid erection
- Used extensively in Europe and growing in importance in other parts of the world

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CLT panels

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CLT used in residential construction

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In multi-unit residential construction

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7-storey bldg tested at Miki, Japan

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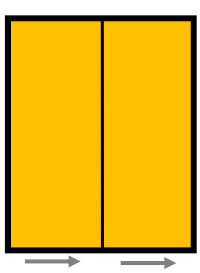
Connections

- For shear walls
- For CLT panels

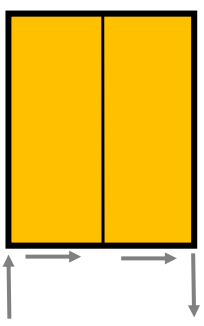
Shear wall shear resistance



Shear resistance increases:
- sheathing thickness
- number of nails
- framing density

the nails are the critical part to absorb the energy…

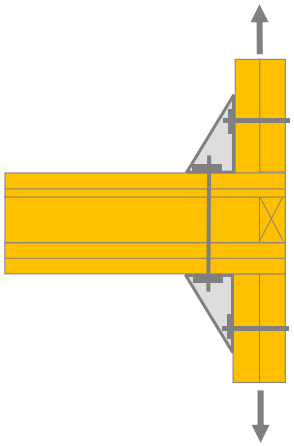
Shear wall overturning resistance



Resisted by chords
- end framing member
- hold-down connections
- anchor bolt in concrete

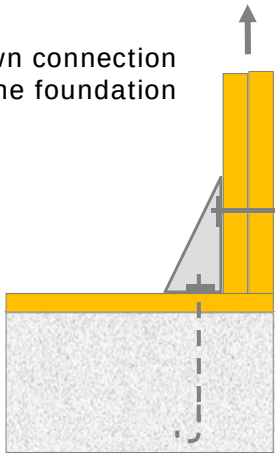
The hold-down connection is designed as rigid…

Hold-down connections



hold-down connection between floors

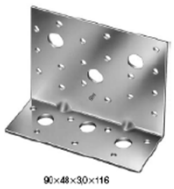
hold-down connection to the foundation



Example of plywood shear walls with hold-downs

CLT Panel Connections

- Steel brackets nailed, screwed or bolted to the panels



NEW TECHNOLOGY TO MITIGATE DAMAGE TO TIMBER STRUCTURES IN EARTHQUAKES

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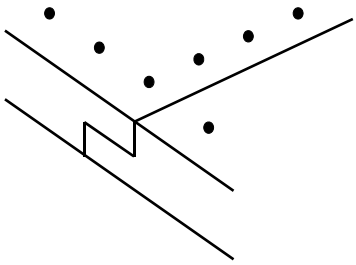
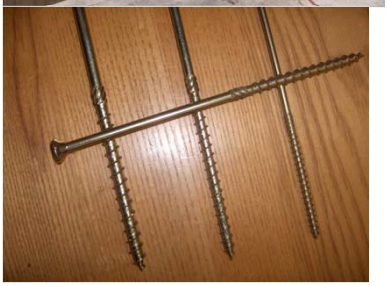
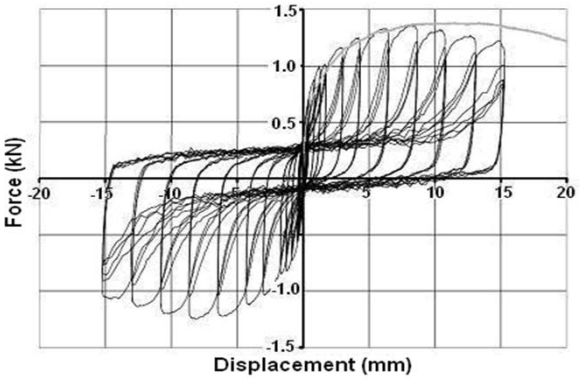




- For shear wall and CLT panel connections, absorption of energy is mainly due to the inelastic behaviour of the nail, screw or bolted connection
- The wall may be permanently damaged at the connections



To mitigate damage of the timber structural elements and absorb energy, one should not rely on the timber connection

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Proposed:

To develop the concept of slip-friction hold-down connectors for traditional shear walls and timber panels.

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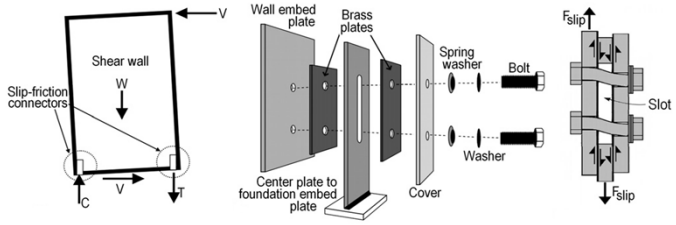
Replacing these …

With Slip-Friction Connectors (SFC)

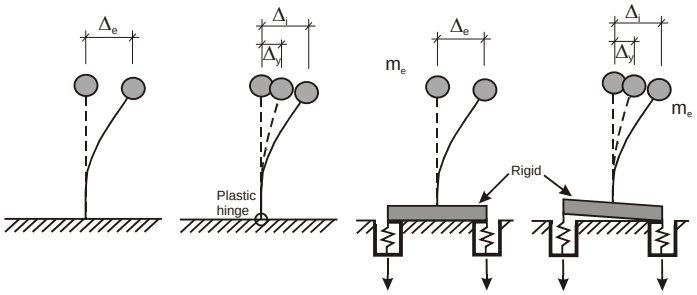


from Loo et al. (2012), middle figure courtesy of Precast/Prestressed Concrete Institute (Bora et al. 2007)

- Slip-friction connectors consist of steel plates bolted together
- Tension in bolts mobilises frictional forces between plates
- Sliding between connector plates limits forces on wall/panel
- Walls undergo controlled 'rocking' during seismic event

ROCKING MECHANISM

- The shear wall rocks but is not a 'pure' rocking structure
- The shear wall itself can be flexible
- The rocking behaviour is constrained by constant force slip-friction connectors (up and down)

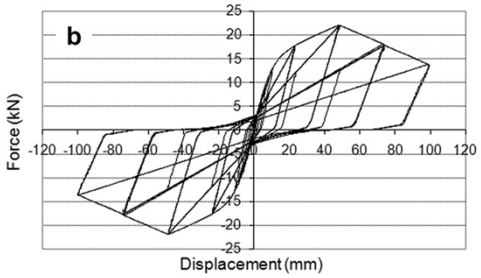


SFC main performance criteria

- Negligible inelastic damage after *ultimate limit state* event
- Maximum drifts remain within code limits under *maximum considered event*
- Connectors remain rigid during *serviceability limit state* loading
- Residual displacements after *ultimate limit state* event are negligible
- Minimal repair after *ultimate limit state* event (to both wall and connector)
- Improved energy dissipation characteristics

Typical shear wall behaviour

- The behaviour of timber shear walls with traditional connectors is governed by the sheathing-to-framing nail connections



from Loo et al. (2012)

- The pinching arises from severe inelastic damage to the wood and nails as these connections oscillate under a seismic event

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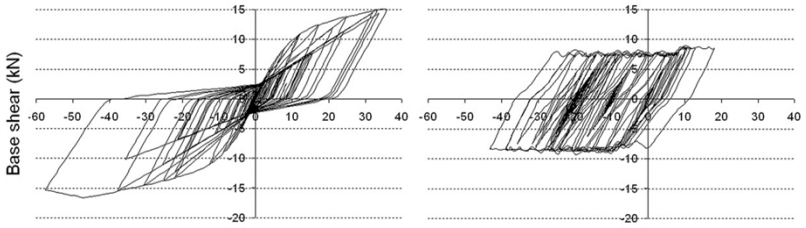
Example of damage limitation - 1

Load-displacement responses under earthquake loading

Traditional hold-down | With slip-friction connector



from Loo et al. (2012)

- The slip friction connector reduces nail deformations

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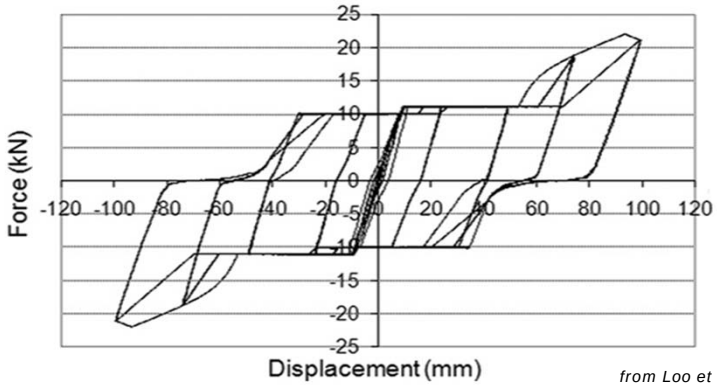
Example of damage limitation - 2

- Slip-friction connectors change the hysteretic behaviour of the wall



from Loo et al. (2012)

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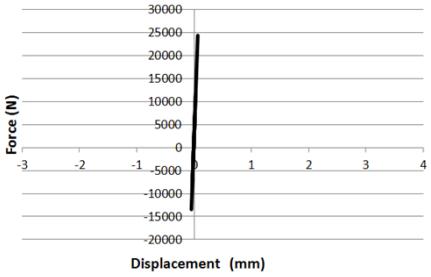
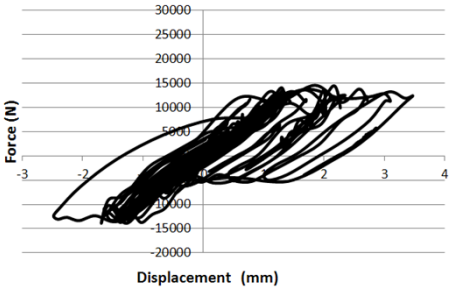
CLT wall with SFC



- CLT wall with traditional connectors remains elastic, with little energy dissipation

- With slip-friction connectors, wall behaviour completely changed. Highly ductile and excellent energy dissipation



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FUTURE RESEARCH

- Testing on connectors to optimize material use
- Numerical and analytical investigation of rocking shear wall with slip-friction connectors to investigate sensitivity to variation in live load and building period
- Shake table tests on timber walls with slip-friction connectors

THE SUPPORT OF THE MINISTRY OF AGRICULTURE AND FORESTRY FOR THIS RESEARCH THROUGH FUNDING FOR THE TIMBER CHAIR IS GRATEFULLY ACKNOWLEDGED

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