International Wood Symposium

23 January 2014 – Vancouver BC

Post-tensioned Multi-storey Timber Buildings

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University of Canterbury, New Zealand
Summary

Cost effective
Sustainable
High performance
Timber building systems
2010 & 2011 earthquakes

Movement of fault = 40mm per year
Christchurch earthquakes

Main quake: 4 September 2010, 4.30am. M 7.1
No deaths

Aftershock: 22 February 2011, 1 pm. M 6.3
182 deaths
Christchurch earthquakes

Dust rising after the quake
Masonry buildings
Masonry buildings
Building collapses. Loss of life

115 deaths in CTV. 18 deaths in PGC

42 deaths in other buildings (masonry)
7 deaths in rockfall etc.
182 total deaths
Liquefaction
Liquefaction damage
Vertical accelerations

Roof shaken off

Timber house structurally safe
Internal linings

Gypsum plasterboard

Provided bracing for most houses

Ceiling damage
Engineered timber buildings

No serious damage to any non-residential timber buildings

Shear cracks in column
Solid wood houses

Good performance despite differential slab movement
Wall bracing failures
Soft storey collapses

Before

After
Steel buildings
Reinforced concrete

Now demolished
## Why so many demolitions?

**Earthquake engineering philosophy**

<table>
<thead>
<tr>
<th>Earthquake Level</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor earthquake</td>
<td>No damage</td>
</tr>
<tr>
<td>Moderate earthquake</td>
<td>Repairable damage</td>
</tr>
<tr>
<td>Big earthquake</td>
<td>No deaths.</td>
</tr>
<tr>
<td></td>
<td>Damage is ok</td>
</tr>
</tbody>
</table>
Christchurch after the quake
What did we learn?

- Good design can save lives
- Life safety is not enough
- We need “Low Damage Design” to reduce economic losses.
  - Base isolation
  - Controlled repairable damage
  - Rocking systems
Re-building Christchurch

What kind of city do we want?

Warren and Mahoney
Re-building Christchurch

Wood is part of the solution

Old Government Buildings, Wellington, 1876

Wood is green
Design objectives

- Resilient low damage buildings
- Economical repair after an earthquake
- Post-tensioning with replaceable dissipaters may be the best solution

Not only earthquakes

- Acoustics, vibration
- Durability, sustainability
- Cost and time of construction
New technology

- New materials
  - LVL, LSL
  - CLT
- Hi-Tech manufacturing
- New fasteners
  - Screws, rivets
- New structural concepts
  - Post-tensioning
New materials

- Glulam

- LVL
  Laminated Veneer Lumber

- CLT
  Cross Laminated Timber
New materials

- **Glulam**: Straight or curved: Beams, panels

- **LVL**: Long straight and strong
  - Laminated Beams
  - Veneer Columns
  - Lumber Trusses

- **CLT**: Big flat panels
  - Cross Solid timber floors
  - Laminated Solid timber walls
  - Timber

There is a place for all of these, with other materials
New fasteners

Rivets

Screws
Post-tensioned timber

Rocking Concrete Systems: University of California, San Diego
Post-tensioned timber frames

Post-tensioning provides moment connections
Post-tensioned timber walls

Taller buildings will have tubular structure
STIC Research Consortium

Structural Timber Innovation Company

**Partners**
- Timber industry (NZ and Australia)
- NZ Government
- University of Canterbury
- University of Auckland
- UTS Sydney

$10 million (2008-2013)
Hybrid specimen

Testing at Canterbury University

Hybrid specimen 3 – HY3

Top-lateral Force [kN]

\( f_{p0} = 0.6f_{py} \)

Drift

-0.05 -0.04 -0.03 -0.02 -0.01 0 0.01 0.02 0.03 0.04 0.05

PRES-LAM
Flag-shaped hysteresis loops

Self-centering  
Energy dissipation  
Hybrid system

Unbonded Post-Tensioned (PT) tendons  
Mild Steel or Energy Dissipation Devices  
PT tendons and Energy Dissipation Devices

Energy absorption, but no residual deformations
Flag-shaped hysteresis loops

Effect of Dissipation on Seismic Performance

A trade-off between energy dissipation and re-centering

Dissipation also adds moment resistance
UC Test Building

Post-tensioning tendons

Frames

Walls
Expan Head Office

No damage in earthquakes
NMIT Building, Nelson

ISJ Architects, Aurecon
NMIT Building, Nelson

ISJ Architects, Aurecon
Massey University, Wellington
Massey University, Wellington.

Athfield Architects, Dunning Thornton
Precast TCC floors
Massey University, Wellington

Massey University, Wellington.
Athfield Architects, Dunning Thornton
Massey University, Wellington

Massey University, Wellington.
Athfield Architects, Dunning Thornton
Big box construction
Big box construction

Epoxied rod connections
Big box construction

Steel plates with nailed connections
Big box construction

Screwed wood and steel connections
Big box construction

Post-tensioned timber walls, LVL roof trusses with rivets
Post-tensioned beams

Long spans (draped tendons)
Fewer columns
Post-tensioned beams

Hollow beams. LVL chords, plywood webs, draped tendons
Kaikoura Museum, library, council offices, Kaikoura DC

All timber. No concrete. Post-tensioned CLT walls.
Kaikoura

Post-tensioned CLT walls for all lateral loads
Re-building Christchurch

Sheppard and Rout Architects, Kirk Roberts Engineers
Re-building Christchurch

University of Canterbury laboratory testing
Re-building Christchurch

Sheppard and Rout Architects, Kirk Roberts Engineers
Re-building Christchurch

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Opus Architects and Engineers
Re-building Christchurch

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Opus Architects and Engineers
Post-tensioned timber frames

Opus Architects and Engineers
Re-building Christchurch

Opus Architects and Engineers
Re-building Christchurch

Opus Architects and Engineers
Re-building Christchurch

- Exterior view

Opus Architects and Engineers
Re-building Christchurch

Rick Proko Architects, Ruamoko Engineers
Re-building Christchurch

Base-isolated building. Frames both directions with concrete columns and post-tensioned LVL beams.

Rick Proko Architects, Ruamoko Engineers
Re-building Christchurch

Rick Proko Architects, Ruamoko Engineers
NZ -> Other countries

- The Pres-Lam structural concept is patented in New Zealand
- Free use for registered users in NZ
- Patent applied for in USA, Canada, Europe
- Investment enquiries are welcome
- See me if you are interested
### Why use wood?

- Constructability
- Sustainability
- Renewability
- Availability
- Weight
- Cost

<table>
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<tr>
<th>Cost effective</th>
<th>Sustainable</th>
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<td>High performance</td>
<td>Timber building systems</td>
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**Why is it not happening?**

- Fire safety, durability, acoustics, energy
The Supply Chain

- Forest owner
- Logs
- Processor
- Wood products
- Fabricator
- Structural elements
- Erector
- Structural skeleton
- Contractor
- Whole building
- Building owner

They may have to take some risks
# The Design Team

<table>
<thead>
<tr>
<th>Field</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural, seismic</td>
<td>Structural engineer, architect</td>
</tr>
<tr>
<td>Fire</td>
<td>Fire engineer, architect</td>
</tr>
<tr>
<td>Acoustic</td>
<td>Acoustic engineer</td>
</tr>
<tr>
<td>Thermal</td>
<td>Building services engineer, architect</td>
</tr>
<tr>
<td>Durability</td>
<td>Façade engineer, architect</td>
</tr>
<tr>
<td>Environmental</td>
<td>Architect, environmental consultant</td>
</tr>
<tr>
<td>Cost control</td>
<td>Quantity surveyor</td>
</tr>
<tr>
<td>Construction</td>
<td>Project manager</td>
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1. They must all know something about wood
2. They may have to take some risks
## Who carries the risk?

**Client:** building owner

### Design team:
- Structural engineer
- Architect
- Etc

### Construction team:
- Main contractor
- Sub-contractors
- Project manager

### Material suppliers

### Manufacturers

### Others
- Regulators
- Bankers
- Insurers etc
How to reduce the risk?

PROVIDE CONFIDENCE

– Continue research
– Support design professionals
– Educate new players
– Share the knowledge
– Codes and Design Guides
– Celebrate successful projects
– Workshops like today
Conclusions

- We have the technology, more coming
- We have the materials, hybrids coming
- We have the structural systems
- We have the enthusiasm

The hard part is putting it all together

Reduce the risk for all stakeholders

Work together

For a sustainable resilient future
Thank you