Multi-storey timber buildings and carbon footprinting.

Forest Owners and Wood Processors Joint Conference

Appleby, Nelson
October 2009

Stephen John

Timber Engineering Group

University of Canterbury

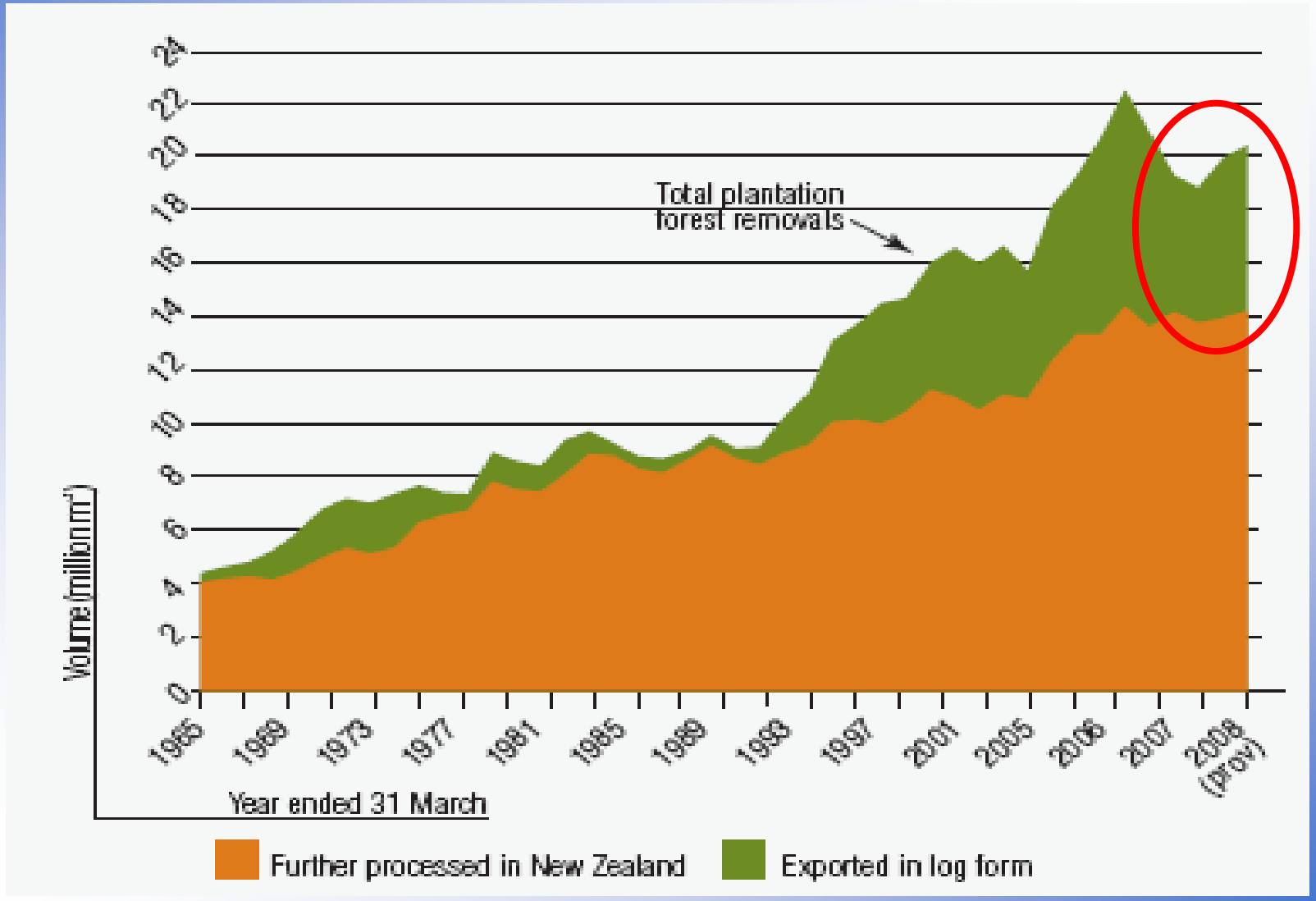
Overview

- Multi-storey timber buildings
- *Pre-lam* technology
- Carbon footprinting (of buildings).

One problem……?

Over 30% of harvest leaves NZ as logs!

One problem……?


Total plantation
forest removals
Volume (million m³)
0
2
4
6
8
10
12
14
16
18
20
22
24
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
2006
2007
2008
(Proy)
Year ended 31 March
Further processed in New Zealand
Exported in log form

The other problem……

- Kyoto Protocol……and beyond…..
- NZ's commitment to the International community - to return GHG emissions to 1990 levels
- NZ 2007 ….22% higher than 1990

Can we kill two birds with one stone?

Light timber frame

Light timber frame - USA

Why not do this in timber?

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Conventional reinforced concrete for commercial multi-storey buildings

The U.S. PRESSS Five-Storey Test Building (Pre-cast Seismic Structural Systems)

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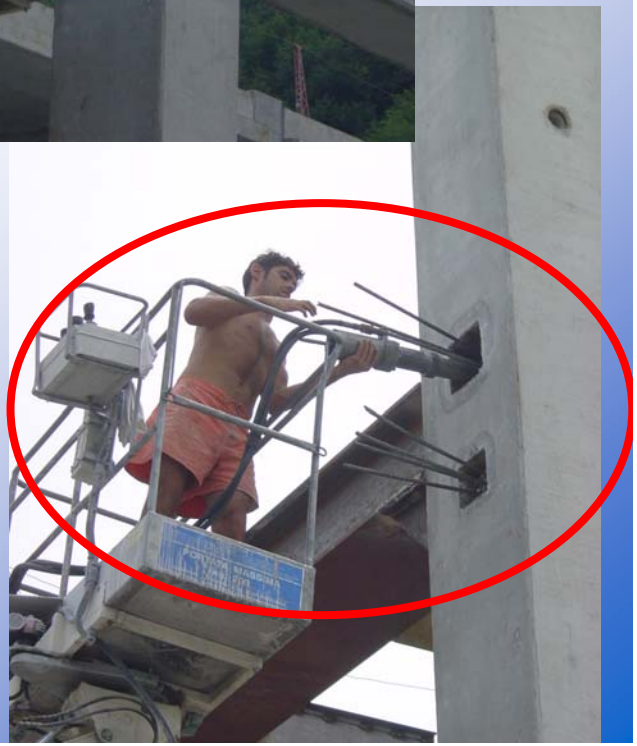
Pre-cast concrete components with steel cables for pre-stressing and post-tensioning

Post-tensioning

Big lego! – with elastic bands



Why not do this in timber?

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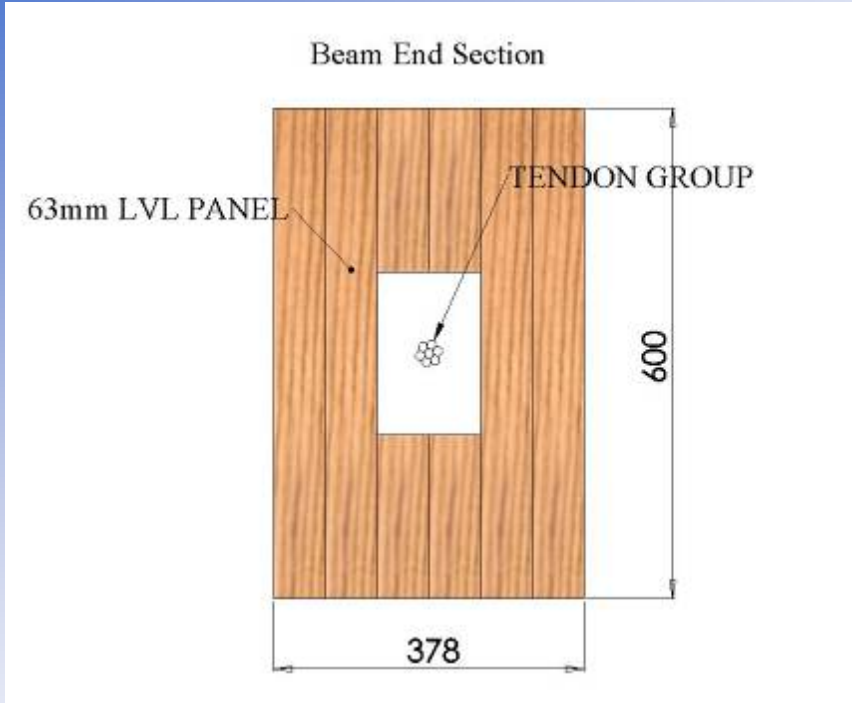
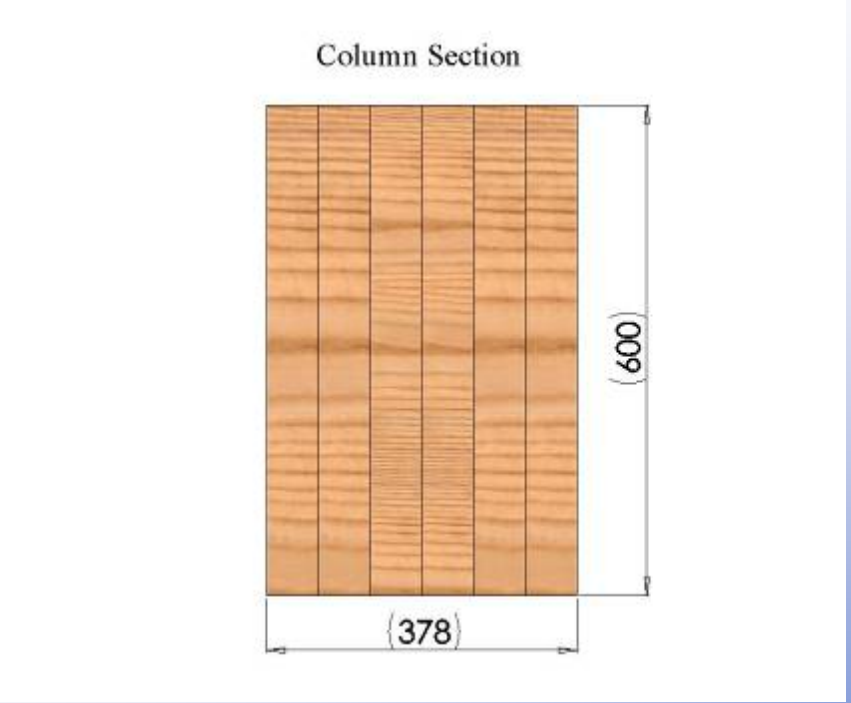
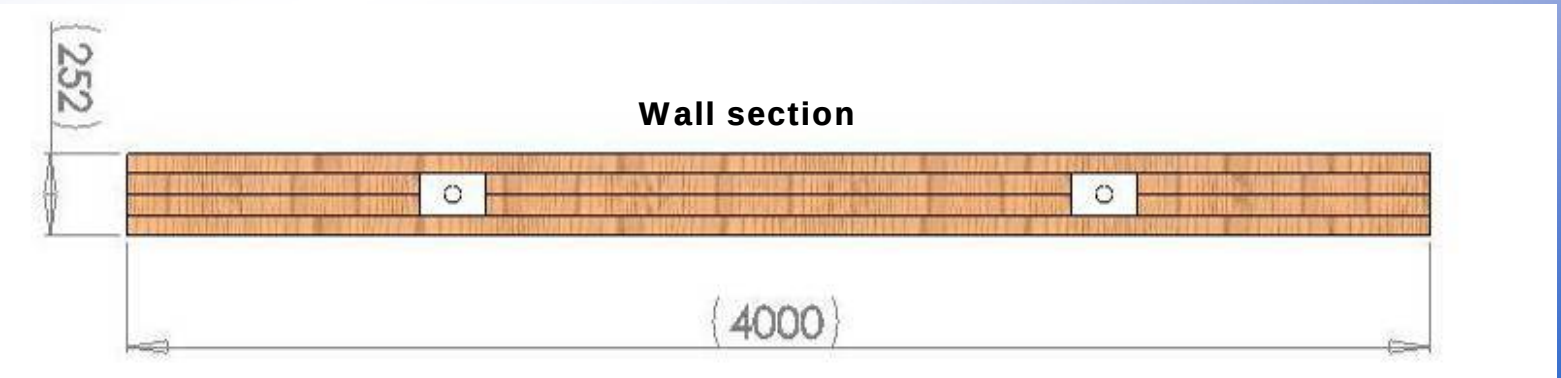
Pre-cast (PRESSS) concrete for commercial multi-storey buildings

Structural Members







Post-tensioned beams and columns

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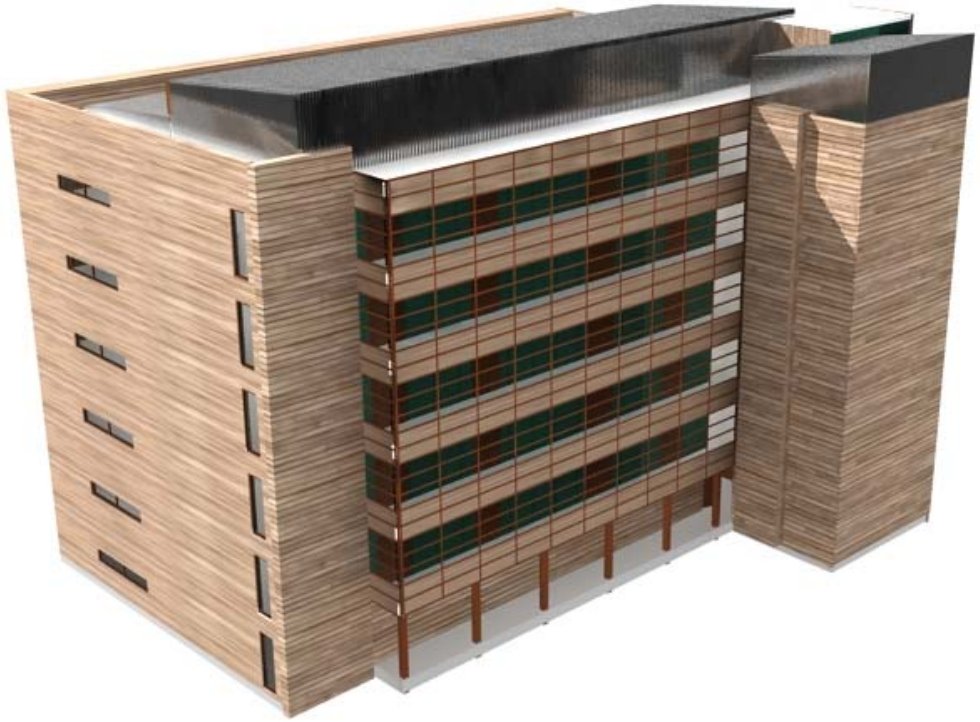
Beams and columns, prefabricated from LVL

Steel tendons inserted through internal cavities

Long spans

Fewer columns

Multi-storey timber building



- World-leading, innovative research at University of Canterbury

STIC Research Consortium

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Structural Timber Innovation Company Ltd

- Funding from Industry
  - CHH, NPI, PMA, BRANZ
  - Wesbeam Pty, Forest and Wood Products (Aust.)
- Matched by NZ government
  - $2m /year for 5 years
- R&D on timber buildings
  - Canterbury - frames and walls, seismic, fire safety, sustainability
  - Auckland – long span roofs, fasteners
  - UTS Sydney – floors, acoustics

Research began over 4 years ago

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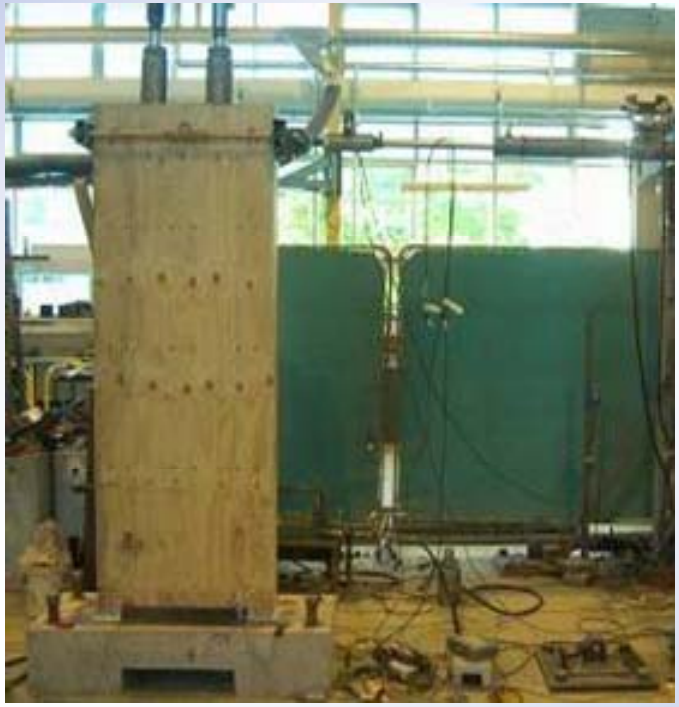
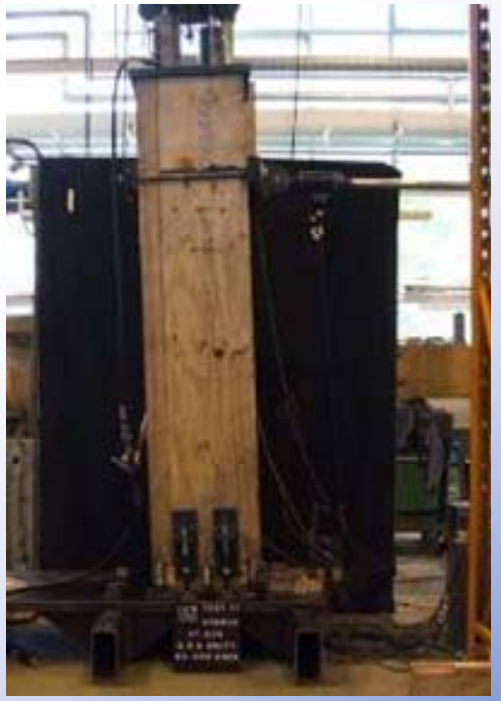
Seismic testing

Frame



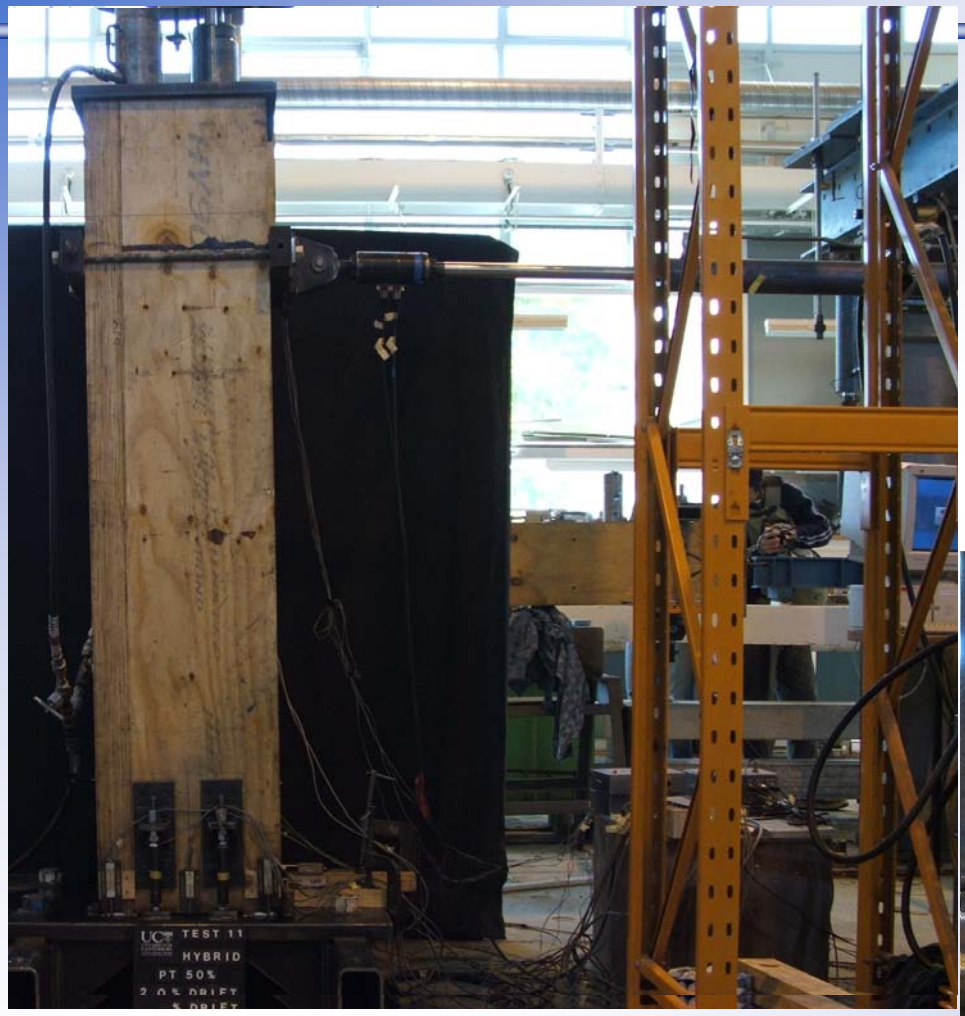
Wall

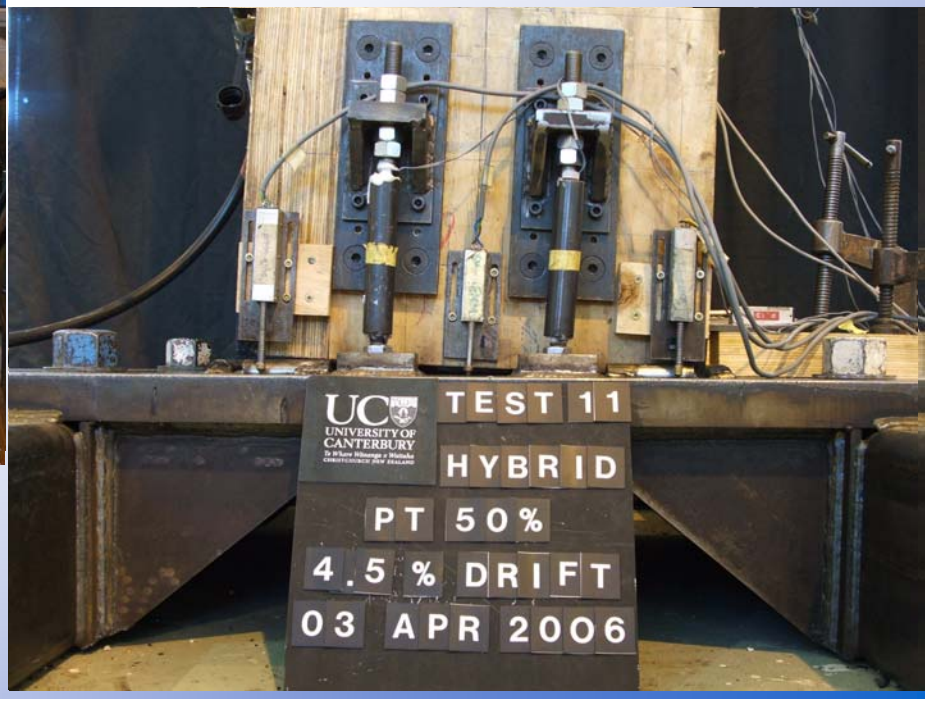


Column

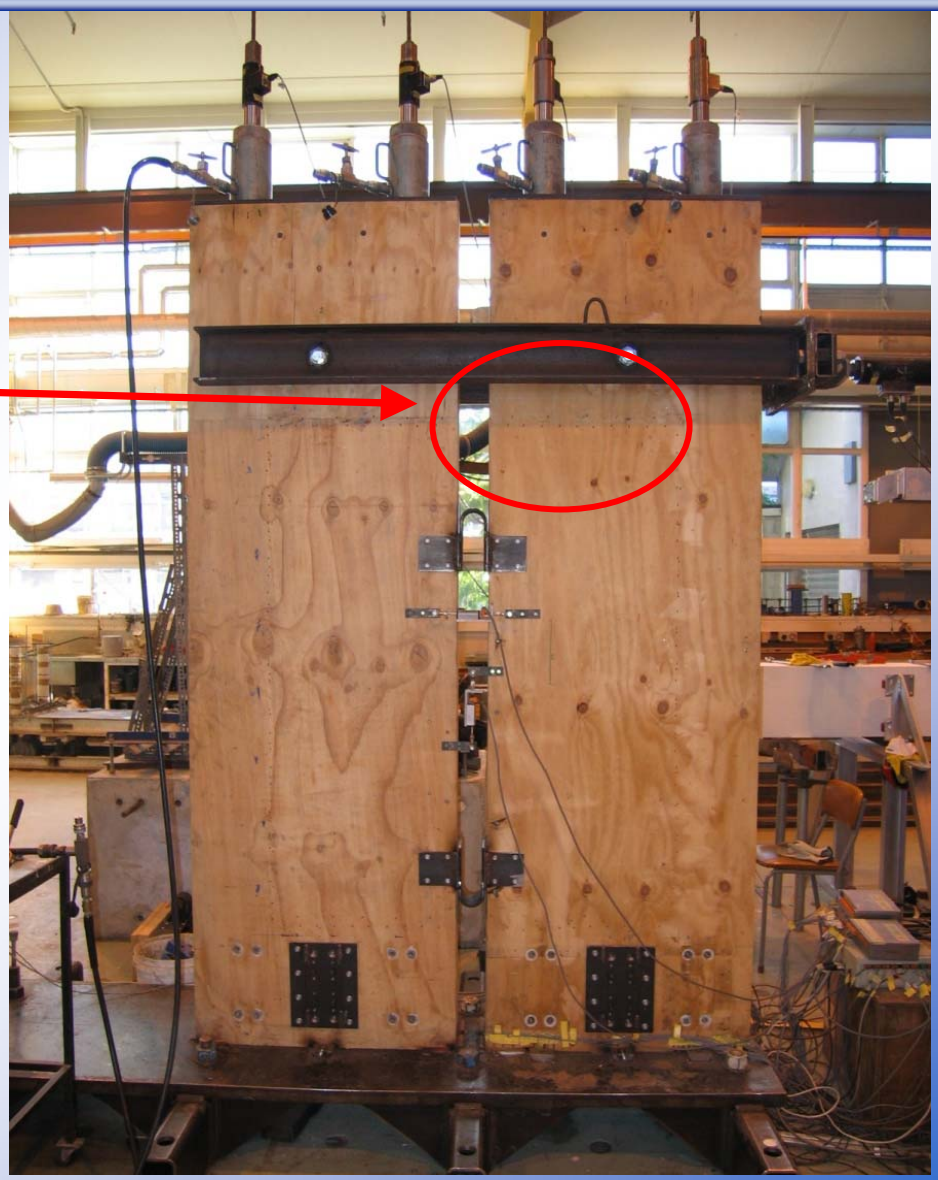
Seismic testing at University of Canterbury

Controlled rocking mechanism





Coupled Rocking walls using UFP



Fire testing

Noise transmission

Sustainability

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BREATHE IN...

Too much carbon dioxide in the atmosphere is one of the biggest factors in global warming. So the big question is; how do we get those harmful levels of CO_2 out of the atmosphere and safely locked up?

Actually, the answer's very simple. Use more wood.

Once a tree has breathed in CO_2 from the atmosphere it will hold it, locked in its cells, unable to escape, until such time as burning or natural disintegration releases it. And that could take years. Decades. Centuries even.

Nana's antique chest of drawers, for example, still holds all the CO_2 that its parent tree absorbed over 400 years ago.

AND HOLD...

Your wooden house, or wooden deck, are doing exactly the same thing right now. Storing CO_2 and looking good while they do it.

Help fight climate change. Use more wood so we can plant more trees, and start an ever-increasing cycle which can only do good – for our society, our economy and our planet.

It's a simple exercise really. As simple as breathe in.. and hold.

For more information on this amazing and infinitely versatile material visit:

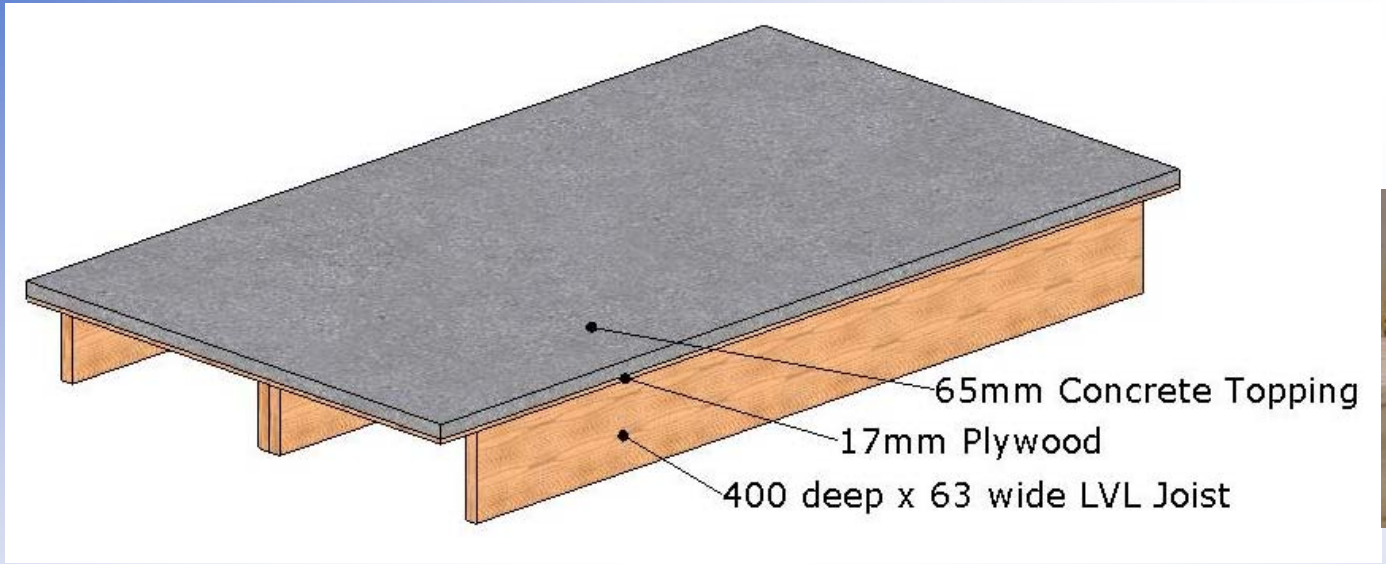
www.nzwood.co.nz

NZ WOOD
For a better world

Long-term behaviour

Creep, relaxation, durability

Composite Floor Systems



- Semi-Prefabricated timber concrete flooring unit
- 2.4 m wide and 9m long
- Use embedded coach screw for composite action

Today……first 2/3rds scale two-storey building using *Pres-Lam*

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PRES-LAM


PRES-LAM

Two-storey building

Earthquake Testing:

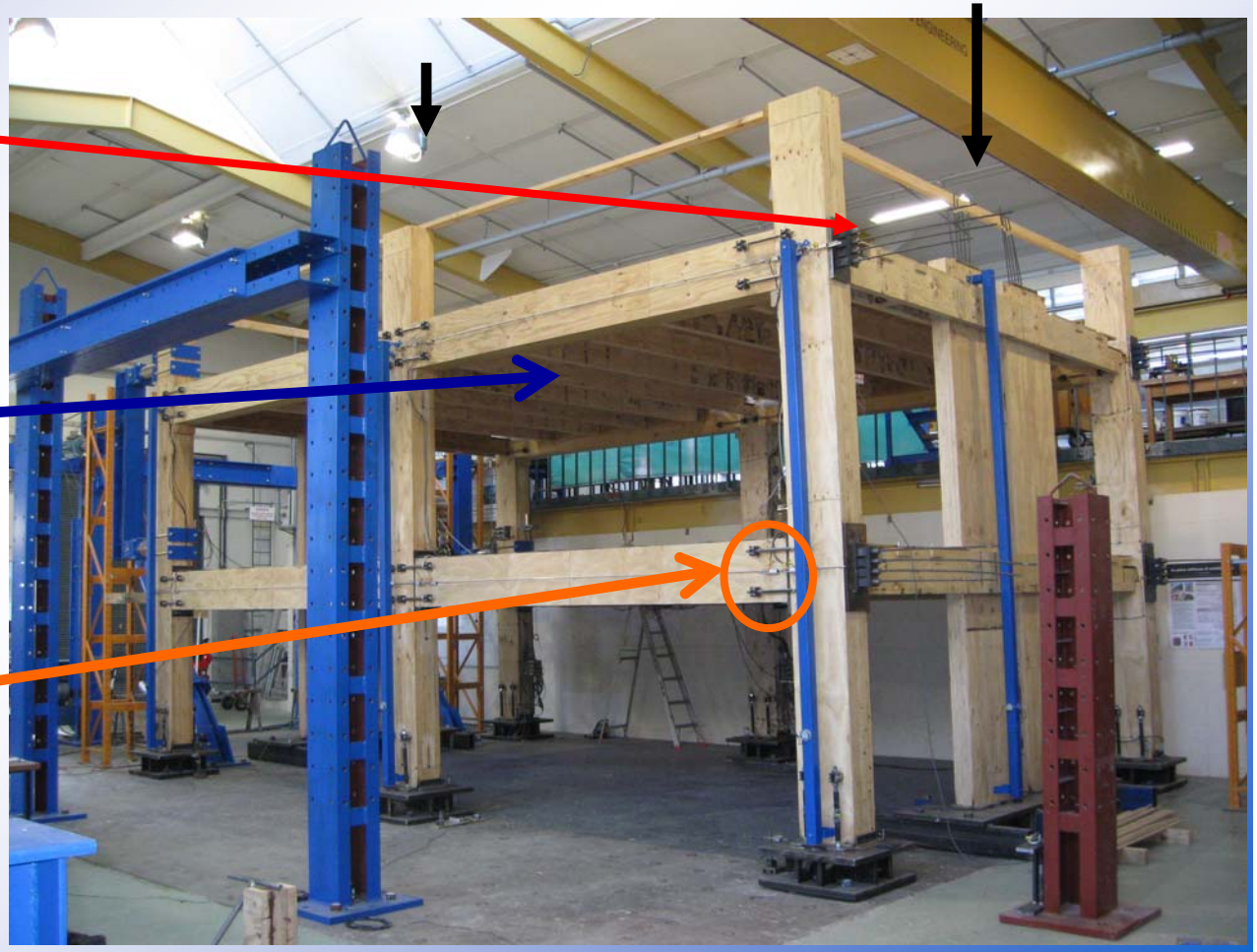
Seismic Frames

Shear Walls

Post-tensioning tendons

Floors

Energy dissipation



Pres-Lam

Pres-Lam is a

- Prestressed
- Pre-fabricated
- Laminated timber building system.
- A sustainable alternative to heavier, non-renewable, concrete and steel framing.

Pres-Lam

- Long lengths of pre-fabricated, laminated timber
- Bound together with prestressing steel tendons

Previously problems of joining large pieces of wood

Pre-stressing cables

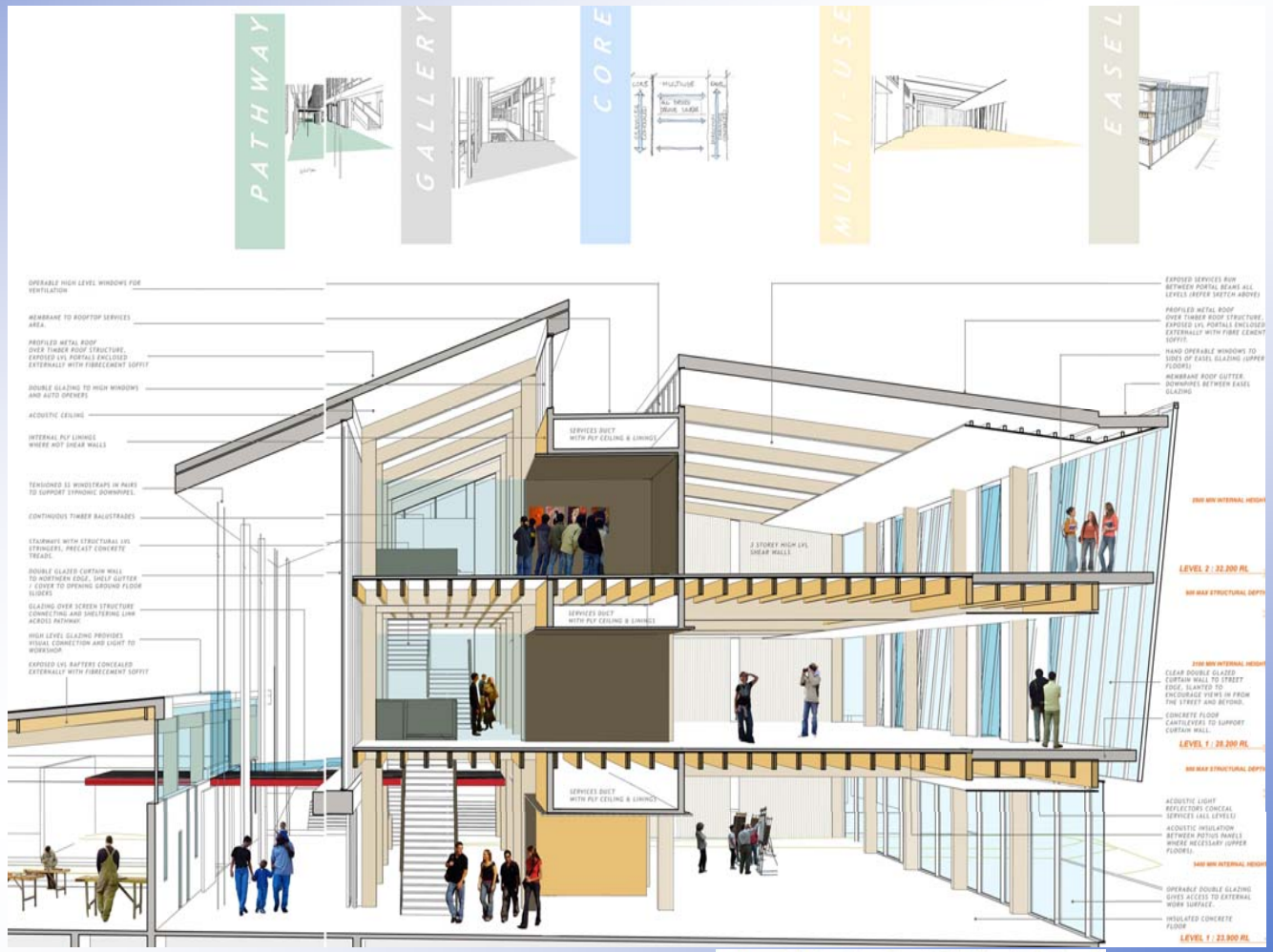
Pres-Lam

Key points:

- Utilising large members leads to fewer internal columns and walls – open plan
- Timber is lighter in weight – less foundations
- Very high resistance to seismic and wind
- Safe in fire – performance exceeds building code
- Durability – last for many hundreds of years
- Performance – easy to heat and cool
- Reduced environmental impact – more later.
- Cost – potentially faster and less expensive to construct, through good design and pre-fabrication

A World First: NMIT – Arts and Media (Nelson, NZ)

Structural Concept



PRES-LAM

NMIT – Arts and Media

Structural Concept

Nile Street Elevation – South Side

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Buildings……

Carbon footprinting

…….and the benefits of using (more) timber

Building industry – 'Carbon footprint'……..

- **Worldwide……**
- Buildings consume up to 40% of all energy worldwide
- Buildings use up to 40% of raw material resources worldwide
- Buildings release between 20-30% of all global CO_2 emissions
- Contribute up to 50% of all land-fill
- Buildings – a very significant effect on the environment

Energy and CO_2 benefits of more wood in buildings

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1. Reduced operational energy usage and emissions – through reduced fossil fuel for heating and cooling, over life of building
2. Increased pool of carbon in wood and wood products
3. Less fossil fuel for making wood rather than steel, concrete, aluminium (embodied energy and CO_2 emissions)

Timber has low embodied emissions

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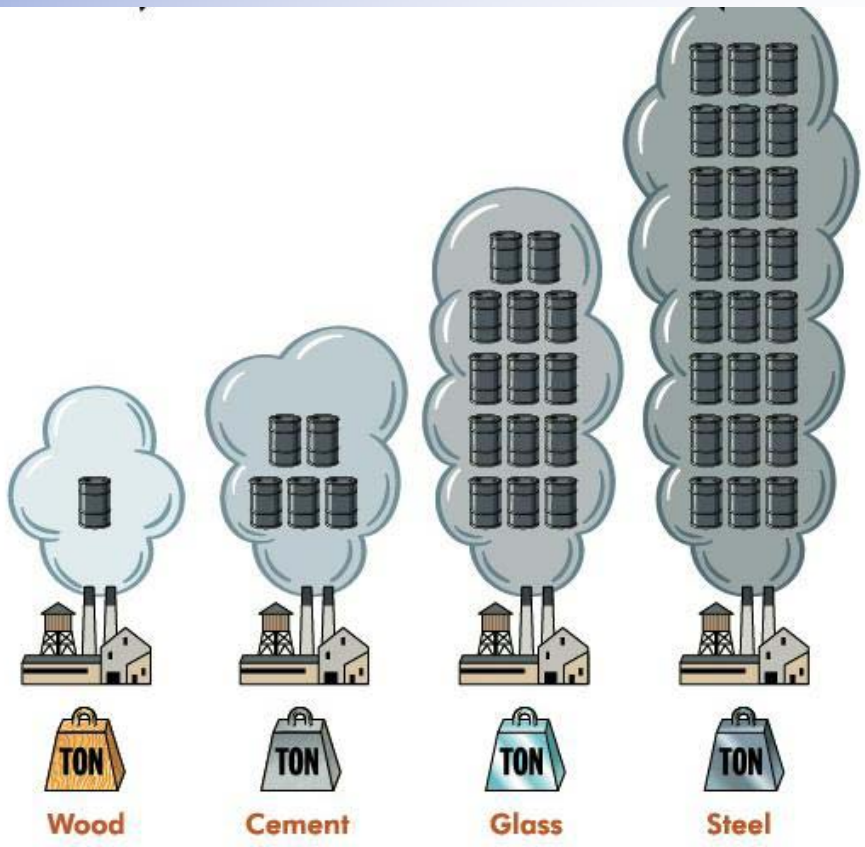
Energy comparison: For every ton of wood produced and used



Manufacturing wood is energy efficient. Consider the amount of energy it takes to produce one ton of cement, glass, or steel, compared to one ton of wood. It takes 5 times more energy for cement, 14 times more for glass, and 24 times more for steel.

It requires 24 times more energy for one ton of steel to be produced and used

Energy and CO_2 benefits of more wood in buildings

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1. Reduced fossil fuel for heating and cooling, over life of building (operational phase)
2. Increased pool of carbon in wood and wood products
3. Less fossil fuel for making wood rather than steel, concrete, aluminium
4. Displacement of fossil fuel by burning wood waste materials

"Wood is good"

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- ***Intuitively "Wood is good"***
- ***Wood = Green?? How green?***
- ***How do we measure 'goodness' for buildings?***
- ***Rating tools – Green Building Council, NZGBC, LEED, etc.***
- ***Future rating systems……?***
- ***Environmental impacts – LCA***
- ***Carbon footprinting of buildings – focus on CO_2 emissions (GWP)***

Life Cycle Assessment (LCA)

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- A rigorous process ----Lifetime environmental merits of products or processes – environmental impacts…
  - Extracting & processing raw materials
  - Manufacturing

  ----------cradle-to-gate----------
  - Transportation, distribution & construction
  - Operational usage & maintenance
  - Recycling or final disposal

  ----------cradle-to-grave----------

- ISO 14000

Carbon stored in timber buildings

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- Roughly around 50% by weight of (dry) wood products is carbon.
- A typical NZ house uses 21 m^3 of framing timber
  - Equates to 4.2 tonnes of carbon
  - Or 15.4 tonnes of CO_2 equivalents
- This carbon / CO_2 has been removed from the atmosphere by the growing trees.
- How much is stored and does using more timber store more carbon?

End-of-life very important

- End-of-life scenarios.....
- Currently nearly all materials to landfill
  - Problems of partial decomposition and release of CO2 /methane back in to atmosphere
- But 60 years out.....
- Permanent storage.....

Carbon stored in timber buildings

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- Permanent storage…..is this realistic?
- Secure landfill – no release of gases
- Collection of methane for energy production

  (CH4 from Burwood used to heat QEII pool)
- Efficient burning of waste and demolition timber
- Re-use of products in other wood buildings
- Replacement of any deconstructed building with a new building containing at least the same amount of timber (but only counted once)

Carbon footprinting

- Does it include just the emissions…….a *gross* footprint…….?
- Most manufacturing processes release CO_2 to the atmosphere – mostly via fossil fuel usage
- Or does it consider carbon ‘stored’ within those materials ……..a *net* footprint?
- Wood materials can provide a net removal of CO_2 from the atmosphere
- ……. storage of CO_2 for as long as the timber material “exists”
- Assumption/s about end of life – permanent storage
- Important to have a clear understanding of what is being counted.

Carbon footprinting

- A simple carbon footprint for a building…..
- <u>Materials only</u>

1. Collect accurate data on quantities of materials
2. Use an appropriate, accurate dataset of GWP coefficients (Kg CO_2 eq. / Kg material)
3. Simple spreadsheet calculation

Quantity x GWP = CO_2 tonnes

= Total tonnes CO_2

Carbon footprinting

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- Full lifecycle

4. Use LCA to include
   - transport
   - operational usage
   - maintenance
   - end-of-life
5. Area of building.....how many m^2 ?

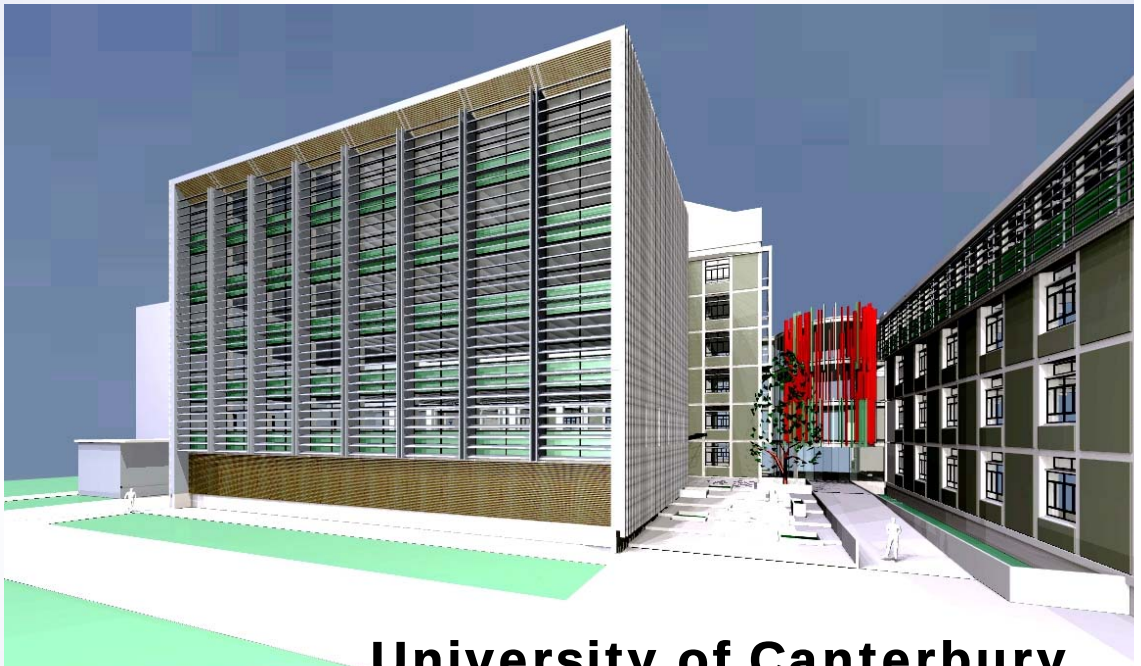
6. Carbon footprint = CO_2 emissions in tonnes/ m^2

Six storey timber design project

- How does using <u>more</u> wood affect the carbon footprint?

  - Materials;
    - Timber
    - Steel
    - Concrete
    - Timberplus

  Employing LCA Sustainability;
    - Operating energy
    - Embodied energy
    - CO_2 footprint



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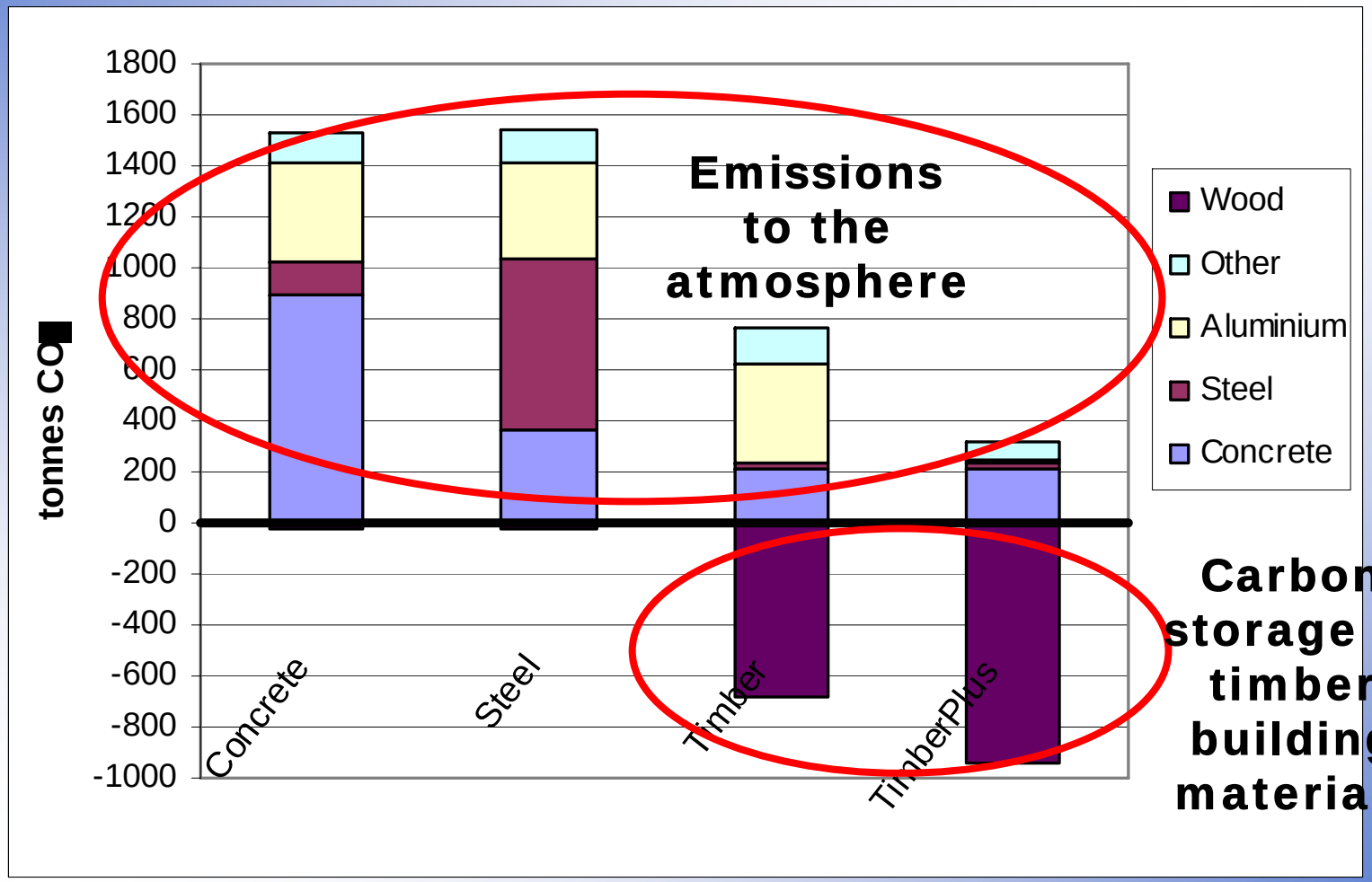
Biological Sciences

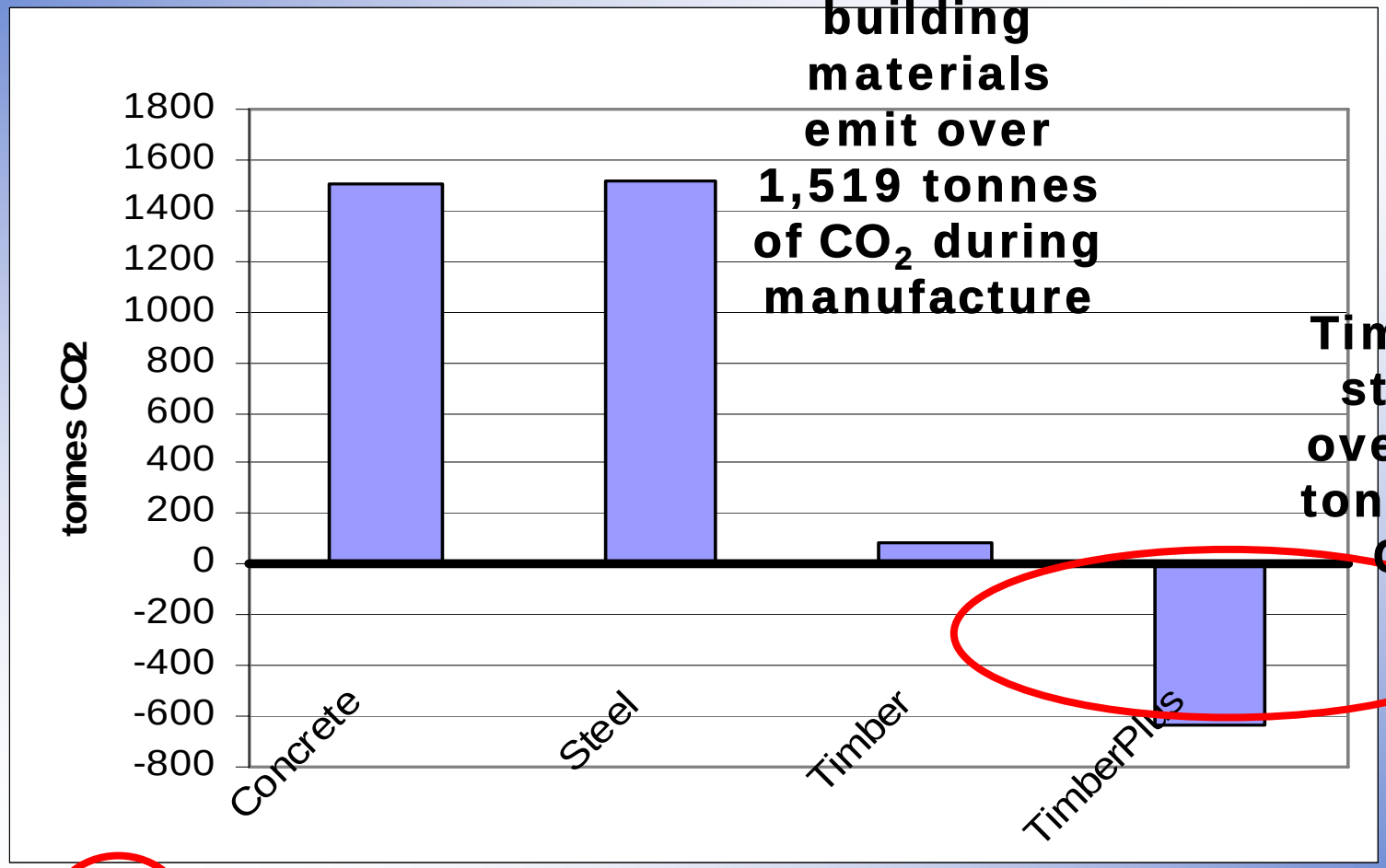
(being built in concrete)

Multi-storey buildings – materials only



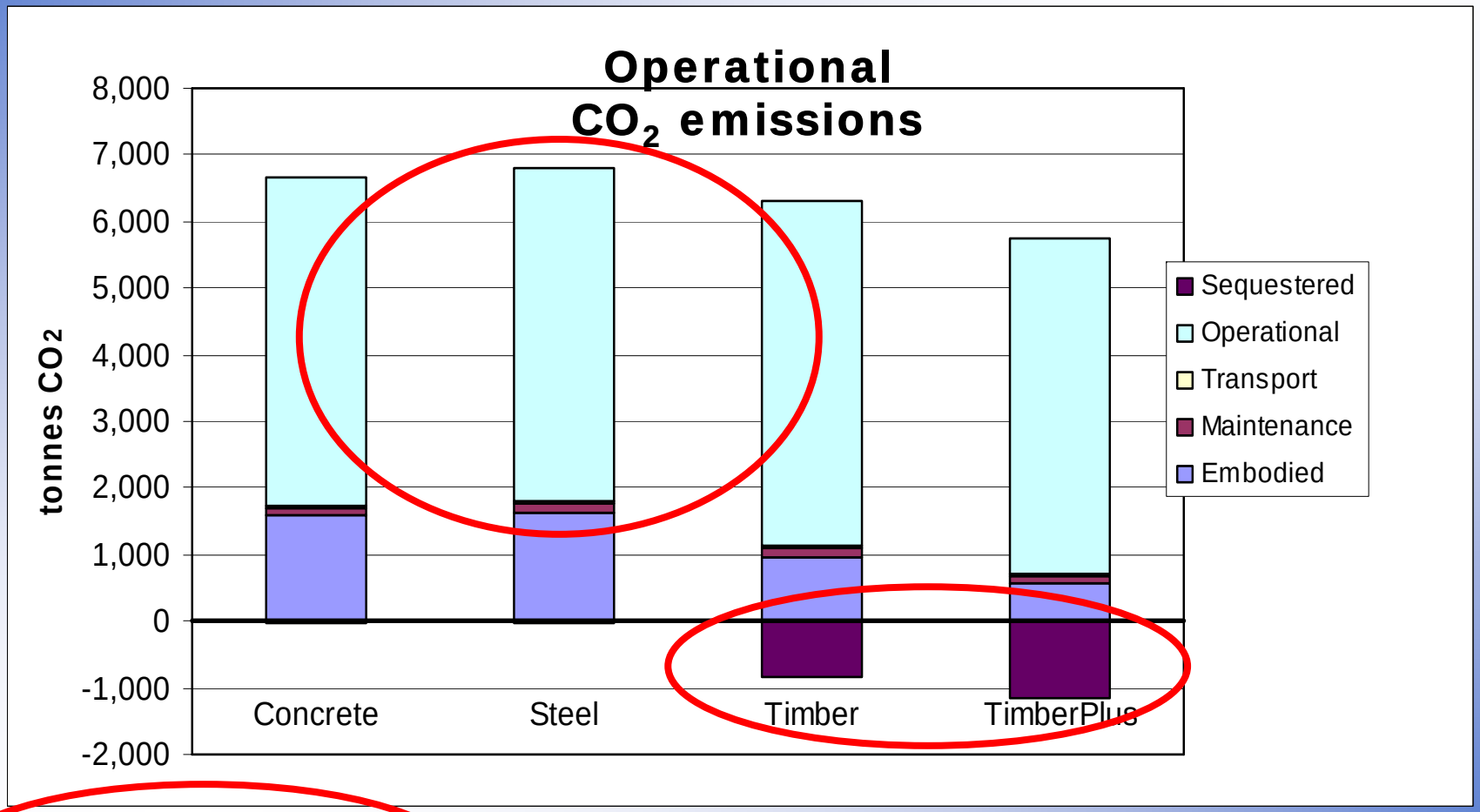
GWP emissions for the materials in the four buildings, assuming permanent storage of carbon in wood products.

Multi-storey buildings – materials only



Net GWP emissions for the materials in the four buildings, assuming permanent storage of carbon in wood products.

Multi-storey buildings – over full lifecycle



Total lifecycle GWP emissions for the four buildings, assuming permanent storage of carbon in wood products

Multi-storey buildings – over full lifecycle

Net lifecycle GWP emissions for the four buildings, assuming permanent storage of carbon in wood products.

Carbon footprint

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		Concrete	Steel	Timber	TimberPlus
Concrete	tonnes CO_2	895	366	213	213
Steel	tonnes CO_2	132	665	26	26
Aluminium	tonnes CO_2	383	383	383	12
Other	tonnes CO_2	117	132	148	61
Wood	tonnes CO_2	-28	-27	-688	-945
Total	tonnes CO_2	**1499**	**1519**	**82**	**-633**
Total / m^2	kg CO_2 / m^2	420	430	20	-180

Carbon footprint

Negative

Multi-storey buildings

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	Cradle to gate - Materials		Cradle to grave – full life cycle	
Building Design	**Gross CO_2eq.** Emissions tonnes	Carbon footprint tonnes/m^2	**Net CO_2eq.** Emissions tonnes	Carbon footprint tonnes/m^2
Concrete	1,499	0.42	6580	1.86
Steel	1,519	0.43	6723	1.90
Timber	82	0.02	5414	1.53
TimberPlus	-633	-0.18	4558	1.29

Cradle to gate emissions compared to cradle to grave emissions (tonnes CO_2eq.) in the four building designs with the associated carbon footprint (tonnes/m^2), assuming permanent storage of carbon in wood products.

NZWood carbon calculator

- www.NZWoodco.nz

Carbon Calculator

Athena Carbon calculator

Building Components

- **Columns and beams**
- **Roofs**
- **Exterior walls**
- **Interior walls**
- **Intermediate floors**
- **Windows**

Conclusions

- Investment in forestry, hand-in-hand with innovation in timber buildings (eg. Pre-lam) can together help New Zealand
- meet it's CO_2 reduction targets
- and improve real returns to the NZ forest industry through significant value added manufacturing
- Future rating systems will incorporate LCA and a carbon calcuator for buildings

Conclusions

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More trees,

more forests,

Innovation driven by research

Using more timber,

in more timber buildings.

The end……

But…….Pres-lam buildings eat carbon by the mega-tonne…….!!