EQUILIBRIUM

The Case for Tall Wood Buildings

Baltimore, Washington, Raleigh
March 2013

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

LEARNING OBJECTIVES: AT THE END OF THIS PROGRAM, PARTICIPANTS WILL BE ABLE TO

1. Learn how the use of mass timber in tall buildings offers a new cost-effective options to prospective building owners.
2. Describe why the use of wood products reduces a building's overall environmental impact.
3. Evaluate the results of peer review that confirmed the feasibility, fire safety and other life safety aspects of tall wood buildings..
4. The code consultant has confirmed that a high building of residential occupancy can be designed and constructed to meet the functional statement and fundamental safety objectives of the building codes on a performance basis..

TALL WOOD

Why build timber towers?

Tangible advantages

- Economically compares well to concrete and steel construction
- Great appearance
- Lighter than concrete
- Energy efficient envelope
- Fast installation
- Appropriate for remote sites
- Reduces M & E and finishes installation time (by ½?)
- Clean, dust free and quite site
- Accurate

The world will be 70% urban by 2050

3 billion new residential units

Most in the developing world

Where concrete is the material of choice

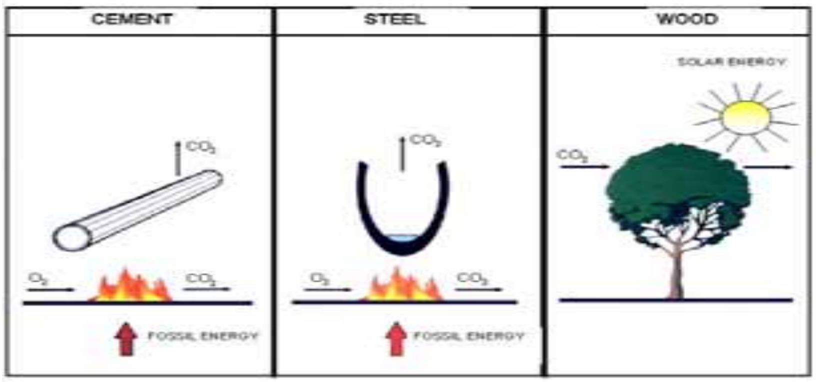
Building industry is resource intensive

Worldwide, the building industry is responsible for:

- 40% consumption of resources [1)]
- 25% - 40% consumption of energy [1)]
- 30% - 40% emission of greenhouse gas [1)]
- 30% - 40% of solid waste generation [1)]
- 60% of the transports [2)]

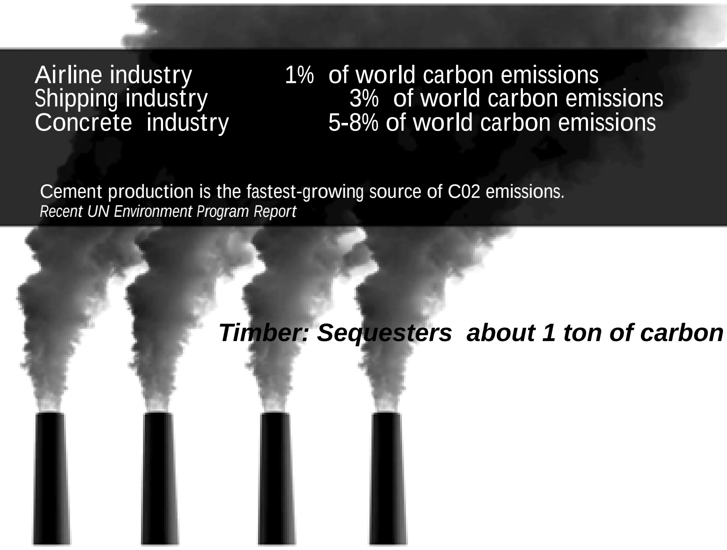
- 1) Source: UNEP SBCI – United Nations Environment Program
- 2) ton kilometres

Energy use of major construction materials



5.000 kWh/m3 | 8.800 kWh/m3 | 175 kWh/m3

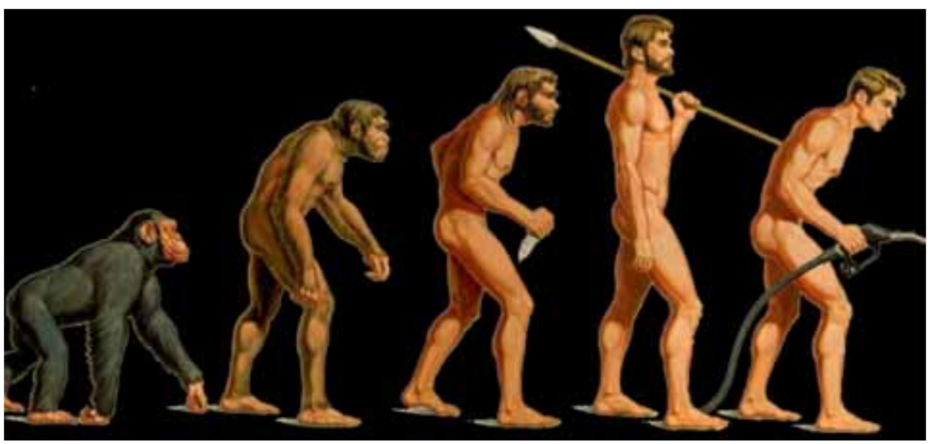
CARBON EMISSIONS



Airline industry 1% of world carbon emissions
Shipping industry 3% of world carbon emissions
Concrete industry 5-8% of world carbon emissions

Cement production is the fastest-growing source of C02 emissions.
Recent UN Environment Program Report

Timber: Sequesters about 1 ton of carbon per m^3



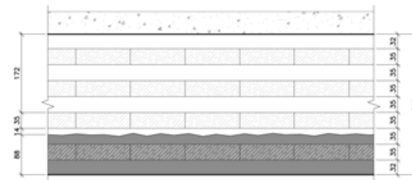
The Fears

WOOD BURNS

Wood does burn …

- But we know how
- And large timber burns slowly
- And retain structural integrity

Combustibility and fire resistance are not the same thing …



DESIGN CHARRING - CLT FLOOR SLAB

The Fears

WOOD BURNS

WOOD ROTS

Wood does rot …

Keep it dry

- Build a good envelope and maintain it
- Protect from the sun and direct rain exposure

If you have to expose it:

- Extensive ongoing research on treatments (nanotechnology)
- Good detailing (sealed or free draining connections)

The Fears

WOOD BURNS

WOOD ROTS

WOOD IS UNPREDICTABLE AND WEAK

Wood is unpredictable and weak

- Engineered wood products are predictable and compare to reinforced concrete in strength
- Ongoing research – new products developed every year

The Fears

WOOD BURNS

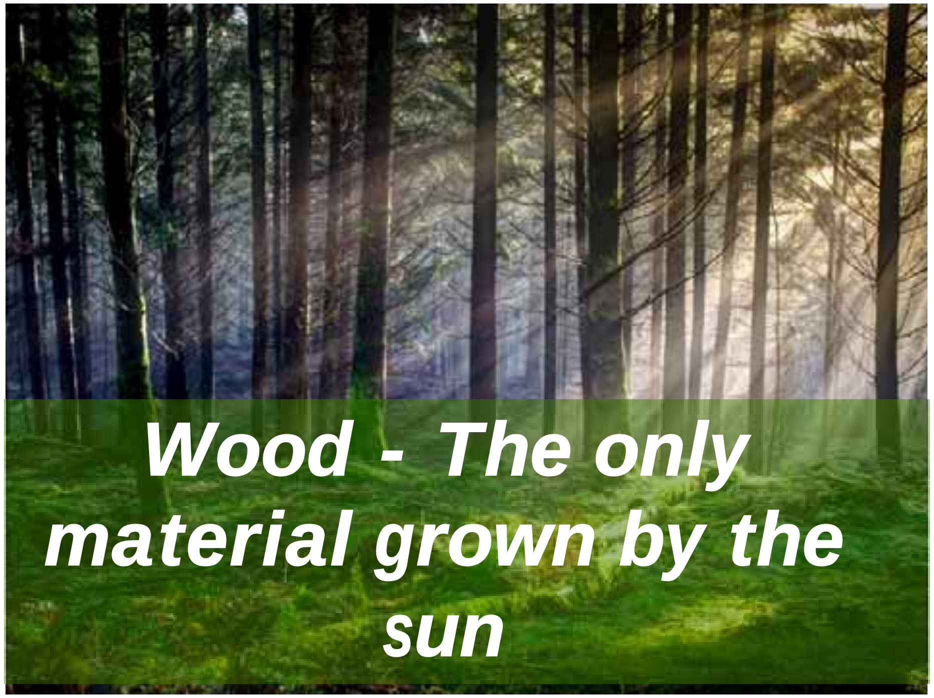
WOOD ROTS

WOOD IS UNPREDICTABLE AND WEAK

WE WILL SHAVE THE PLANET CLEAN

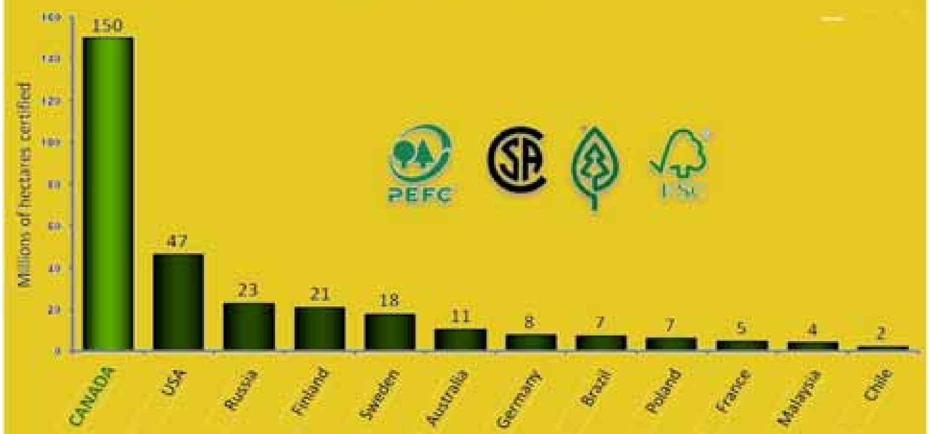
We will shave the planet clean

- Of course, we can. But we aren’t.



Wood - The only material grown by the sun

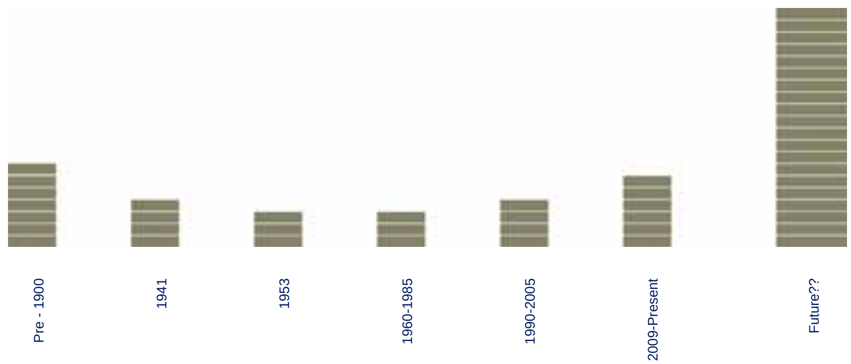
An established track record

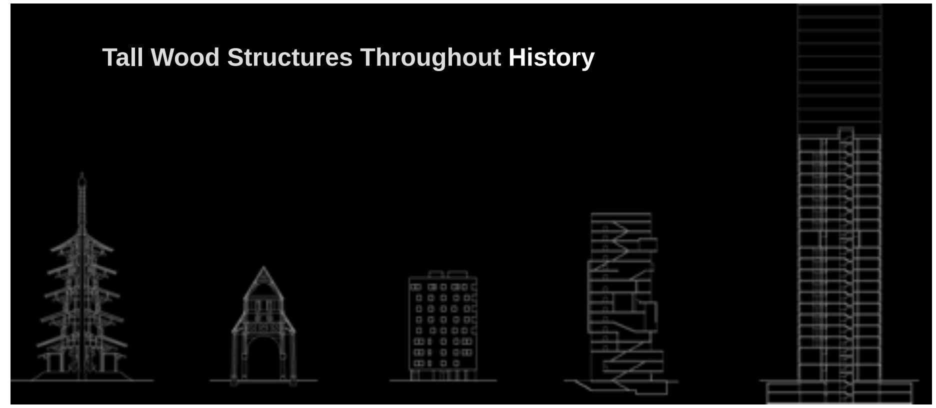


Leckie Building

1913

Building Height and the BC Building Code





Horyu-ji Temple
Date: 603-1603
Nara, Japan
32.5 Meters
Heavy Timber

Stave Church
Date: 1130
Norway
Post + Beam

Murray Grove
Waugh Thistleton Architects
Date: 2008
London, England
KHL CLT

Barenthouse Kirkenes
Reiulf Ramstad Architects
Date: Unrealized
Norway

Lifecycle Tower
CREE
Date: Unrealized
Austria
Glulam beams
Wood-concrete composite floors

MURRAY GROVES
London, England

By Andrew Waugh of Waugh Tinselton Architects







TALL WOOD

Horyu-ji Temple
Nara, Japan

Date: 603 to 1603
32.5m tall

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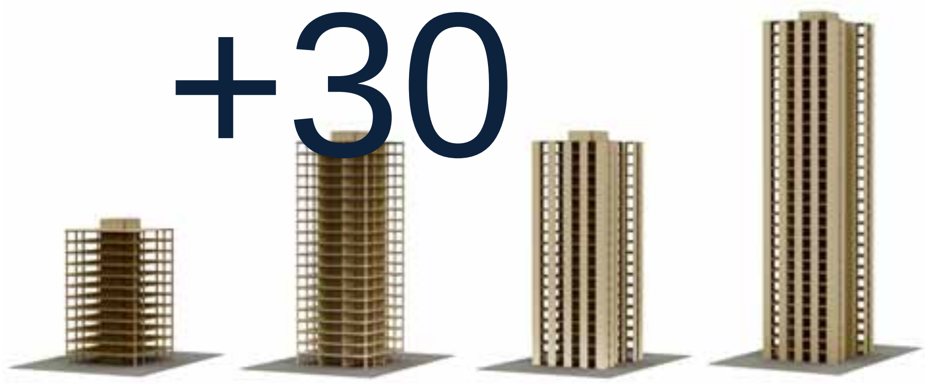
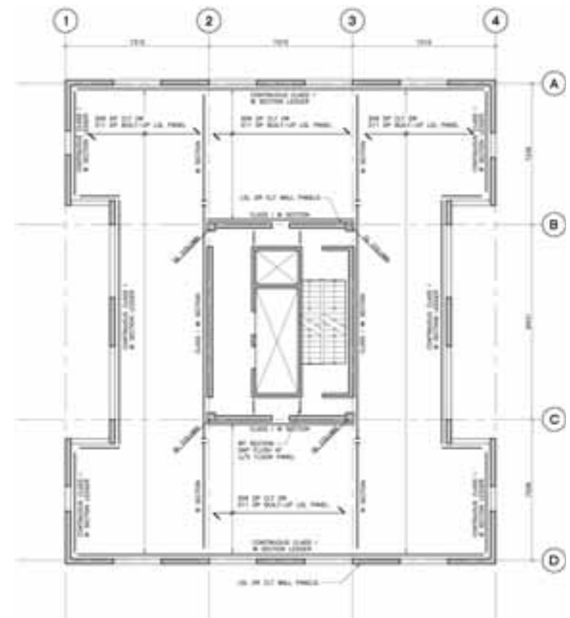
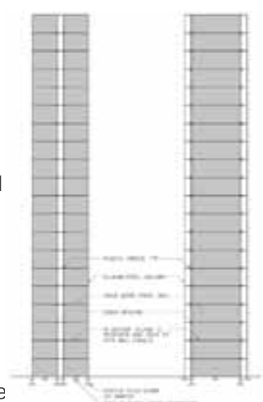
+30



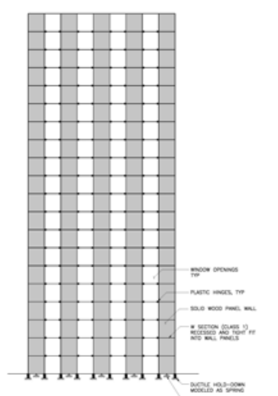


STRUCTURAL CONCEPT

- Lateral system based on universally recognized “strong column – weak beam” concept
- Vertical elements: “Strong” laminated solid wood panel walls and glulam columns
- Horizontal elements: “Weak” and ductile steel beams designed to hinge (using RBS)
- Ductile connections at base and between panels



Typical Core Wall Model



Typical Perimeter Frame Model

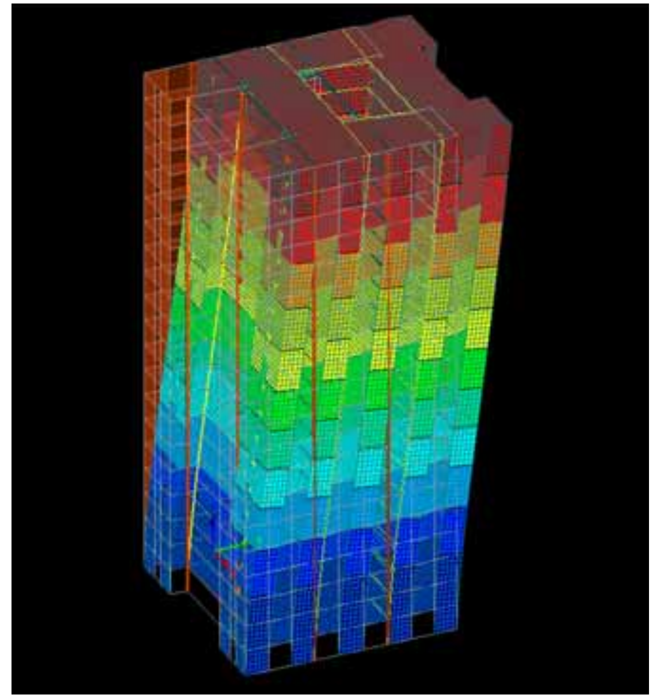
3D VIEWS

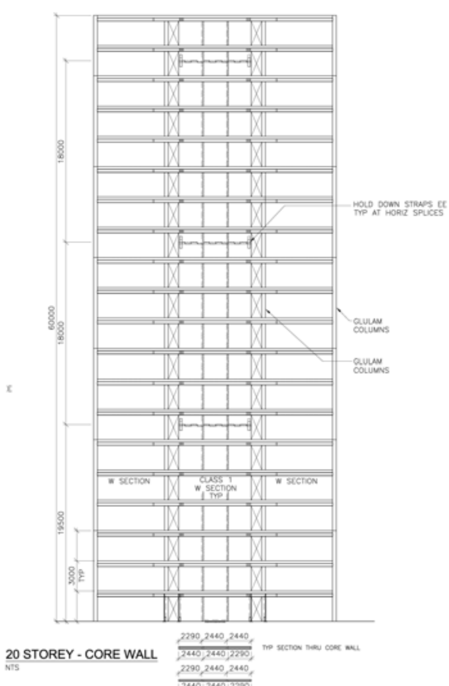
- Steel beams tight-fit into the wall panels to develop bearing and simplify connections
- They act as ledgers as well as ductile links

DUCTILITY RATIO

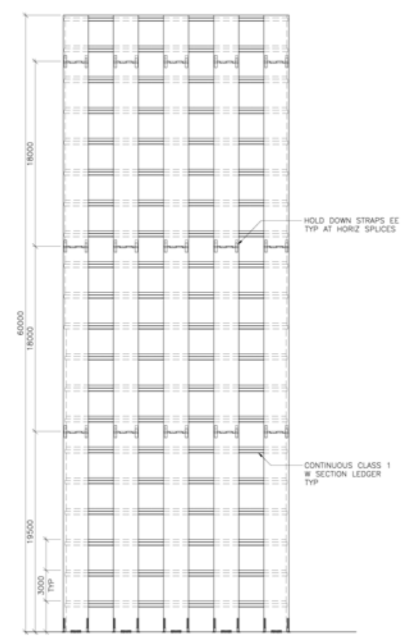
- Based on FP Innovation recommendations:
  Rd = 2.0 Ro = 1.5
- This is conservative as the steel ledger act more like ductile link beams or moment frames
- Equivalent to R = 3.75 and Ω = 2.0
- But the US CLT handbook specifies R = 2.0 and Ω = ???, which is even more conservative.

CLT Shear wall Test - FP Innovations

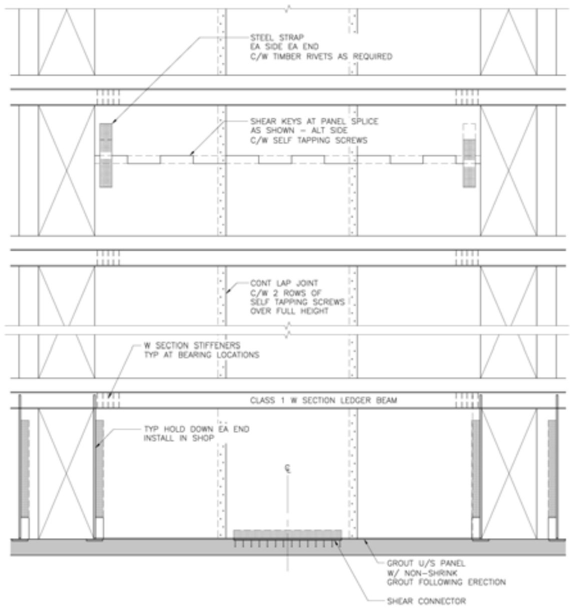




20 STOREY - CORE WALL
NTS

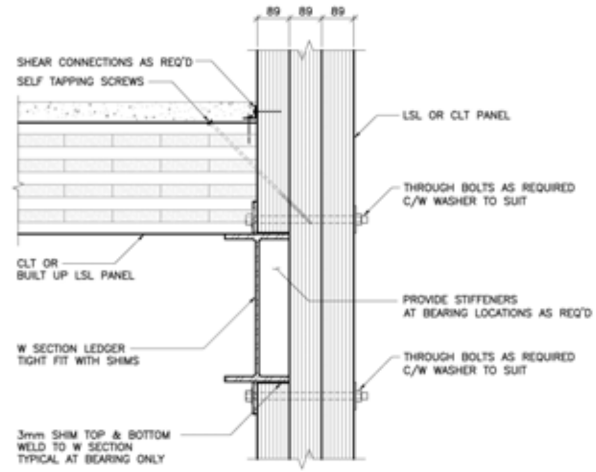


TYPICAL PERIMETER MOMENT FRAME (20 STOREY)
NTS



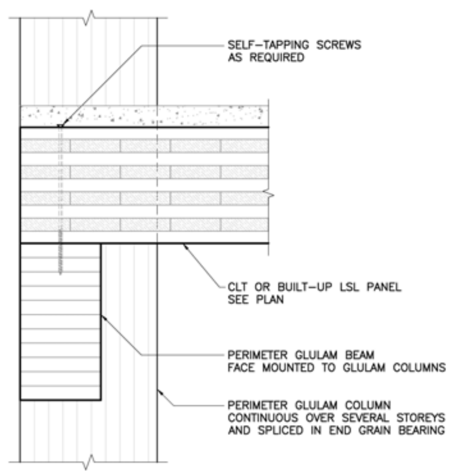
CONCEPTUAL PANEL CONNECTION DETAILS

NTS



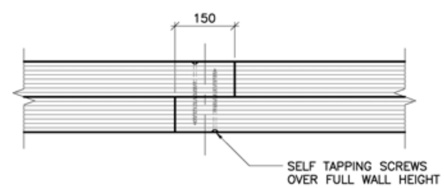
SECTION DETAIL - LEDGER CONNECTION TO TRIPLE LSL (267) PANEL OR 274 CLT

NTS TYPICAL AT CORE OR AT MOMENT FRAMES



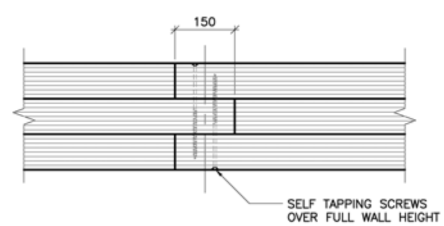
SECTION DETAIL - TYPICAL PERIMETER AT POST AND BEAM

NTS (OPTIONS A & B)



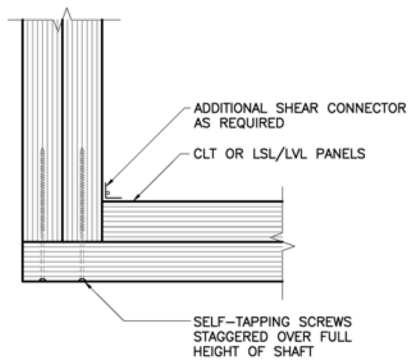
PLAN DETAIL - TYPICAL VERTICAL JOINT DOUBLE PANEL (178 mm)

NTS



PLAN DETAIL - TYPICAL VERTICAL JOINT TRIPLE PANEL (267 mm)

NTS



PLAN DETAIL - TYPICAL WALL INTERSECTION
NTS

FULL-SCALE SHAKING TABLE TESTS ON 7-STOREY CLT BUILDING
E-DEFENSE, MIKI, JAPAN

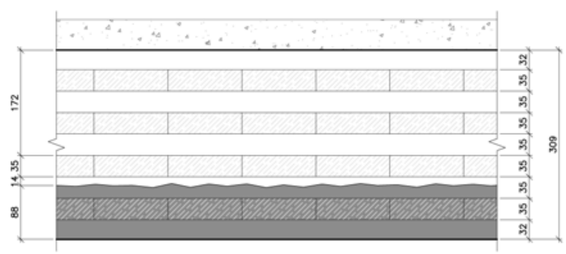
Char depth + heat zone

	d_{heat}	t	β	d_{char}	total
	mm	min	mm/min	mm	mm
CLT Floor Panel [1]	10	120	0.65	78	88
CLT Wall Panel [1]	16	120	0.65	78	94

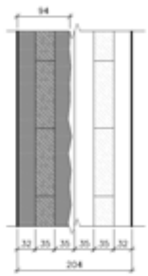
	k_0	d_0	t	β_n	$d_{char,n}$	d_{ef}
		mm	min	mm/min	mm	mm
Glulam Element [2]	1.0	7	120	0.635	76	83

[1] Based on FPInnovations CLT Handbook 2011, Chapter 8 – Fire

[2] Based on Eurocode 5 - EN1995-2-1, Design of Timber Structures, General Rules - Structural Fire Design

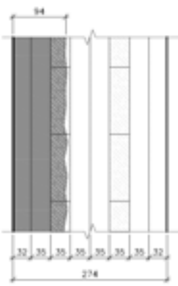


DESIGN CHARRING - CLT FLOOR SLAB
1:5



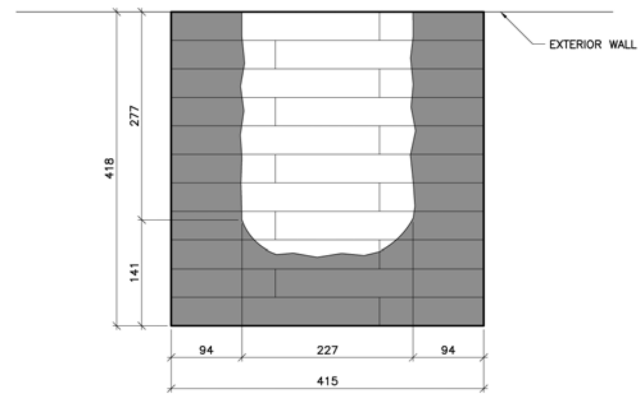
DESIGN CHARRING - 204mm SHEAR WALL

1:5



DESIGN CHARRING - 274mm SHEAR WALL

1:5



DESIGN CHARRING - GLULAM COLUMN EXPOSED ON 3 SIDES

1:5

Region		12 Storey Concrete Frame	12 Storey FFTT Charring Method	12 Storey FFTT Encapsulation Method	20 Storey Concrete Frame	20 Storey FFTT Charring Method	20 Storey FFTT Encapsulation Method
Vancouver		$ 17,550,800	$ 17,518,000	$ 17,856,200	$ 30,097,900	$ 30,297,100	$ 30,989,900
	$ / sf	$283	$283	$288	$292	$294	$300
Northern BC		$ 19,832,404	$ 19,269,800	$ 19,641,820	$ 34,010,627	$ 33,326,810	$ 34,088,890
	$ / sf	$320	$311	$317	$330	$323	$330
Interior BC		$ 18,779,356	$ 18,393,900	$ 18,749,010	$ 32,204,753	$ 31,811,955	$ 32,539,395
	$ / sf	$303	$297	$303	$312	$308	$315
Fraser		$ 17,550,800	$ 17,518,000	$ 17,856,200	$ 30,097,900	$ 30,297,100	$ 30,989,900
	$ / sf	$283	$283	$288	$292	$294	$300
Vancouver Island		$ 18,691,602	$ 18,393,900	$ 18,749,010	$ 32,054,264	$ 31,811,955	$ 32,539,395
	$ / sf	$302	$297	$303	$311	$308	$315

Note: The 20 storey FFTT option indicated is based on the Option 2 design.
The prices shown increases by $2 /SF for the Option 3 structural approach.

Cost the system
Not the structure

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Compare value
Not just cost

Life Cycle Tower One
Bregenz, Austria

By CREE

Forte Tower
Melbourne, Australia

By Inhabitat

Next Steps

- Static non-linear and dynamic non-linear time history analysis
- Finite element analysis of critical connections
- Wind vibration analysis
- Testing
- Look at damper, base isolation and self-centering systems
- Liaison with code authorities

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

J Eric Karsh, M.Eng., P.Eng., Struct.Eng., MIStructE, Ing
ekarsh@eqcanada.com
604 730 1422

Equilibrium Consulting Inc.
202-388 West 8th Avenue, Vancouver BC, Canada
eqcanada.com