Introduction to Mass Timber and Fire:
Current practice and state-of-the-art research

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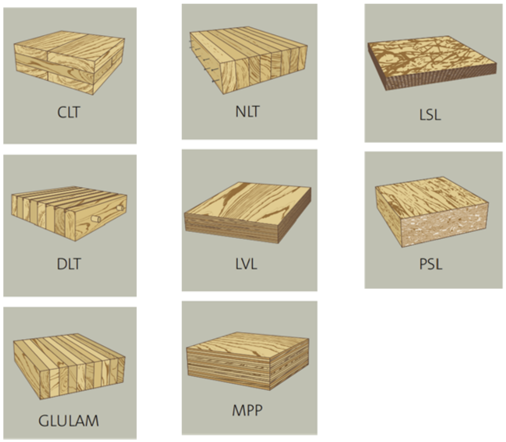
Oregon State University

Part 1:	**Mass timber 101**
Part 2:	**Fire protection design 101**
Part 3:	**Fire behavior of mass timber – ongoing research**
Part 4:	**How to stay informed**

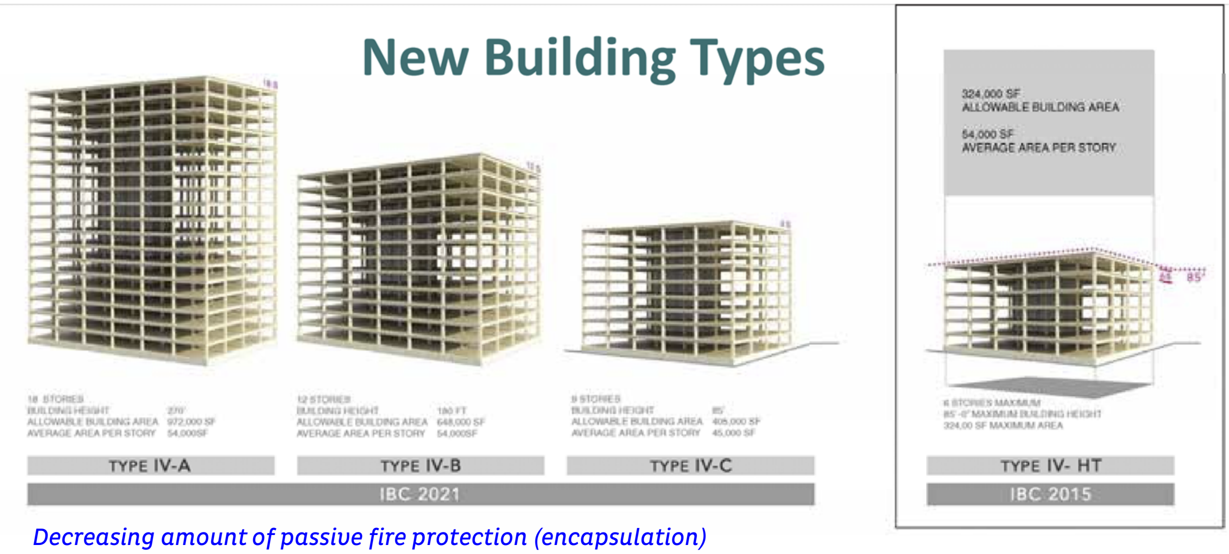
Part 1: Mass timber 101

Thick and compressed layers of wood → Panelized components (mass timber panel, beam, column)

Lamination, fasteners, adhesives



New Building Types



Decreasing amount of passive fire protection (encapsulation) →

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Part 2: Fire protection design 101

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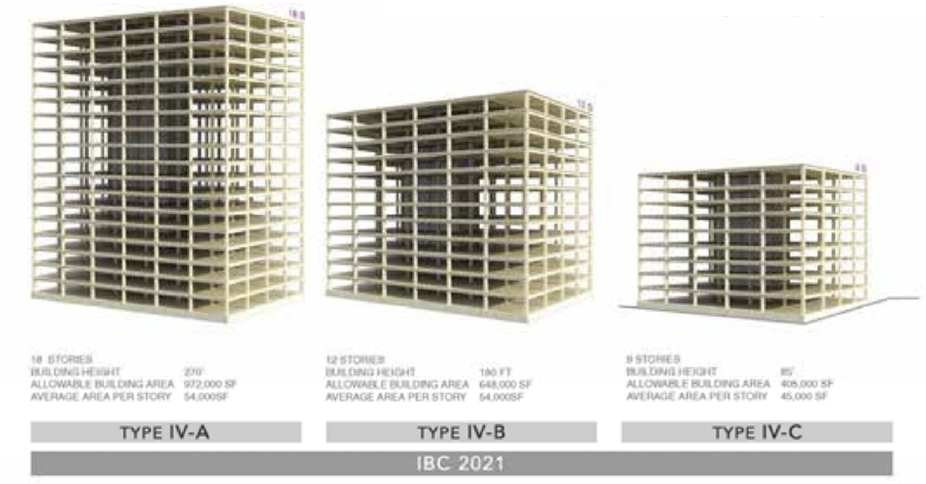
Prescriptive fire protection design



Required hourly rating **3 hour FRR** **2 hour FRR** **2 hour FRR**

FRR: Fire resistance rating

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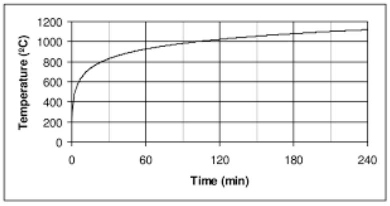
Prescriptive fire protection design

Individual structural component



Subject to ASTM E119 (standard) fire

<u>Fire resistance failure</u>
Average unexposed surface > 250°F above ambient

Any point on unexposed surface > 325°F above ambient

Flaming on unexposed surface

Smoke or gas can ignite cotton waste on unexposed surface

<u>Structural integrity failure</u>
Loss of load carrying capacity

Time to failure criteria per ASTM E119

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Structural fire engineering

Using concepts of structural mechanics, material science, and knowledge of fire dynamics to calculate structural capacities throughout a design-basis fire.

Structural fire engineering

Using concepts of structural mechanics, material science, and knowledge of fire dynamics to calculate structural capacities throughout a design-basis fire.

pyrolysis **charring** **smoldering**

Structural fire engineering

Using concepts of structural mechanics, material science, and knowledge of fire dynamics to calculate structural capacities throughout a design-basis fire.

pyrolysis	charring	smoldering
100 – 250°C *Mass loss of timber in presence of a flame*	300°C	100 – 300°C *Mass loss without a flame at high temperatures*

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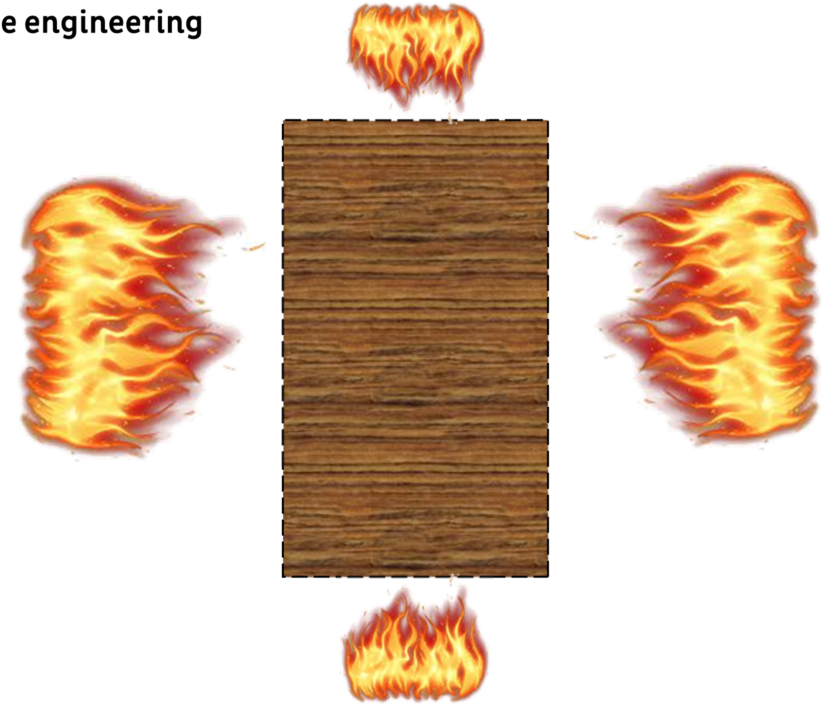
Structural fire engineering



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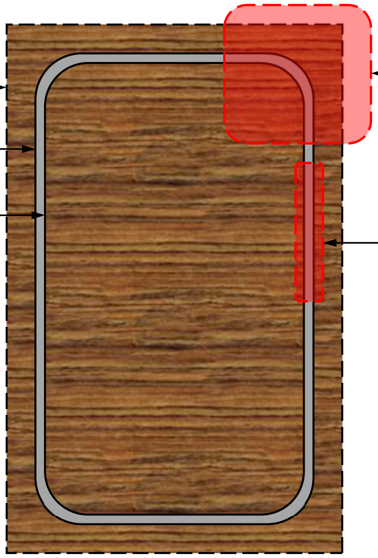
Structural fire engineering

Original timber section

Edge of char

Edge of unheated timber
Timber temperature < 100°C

Structural fire engineering



Original timber section

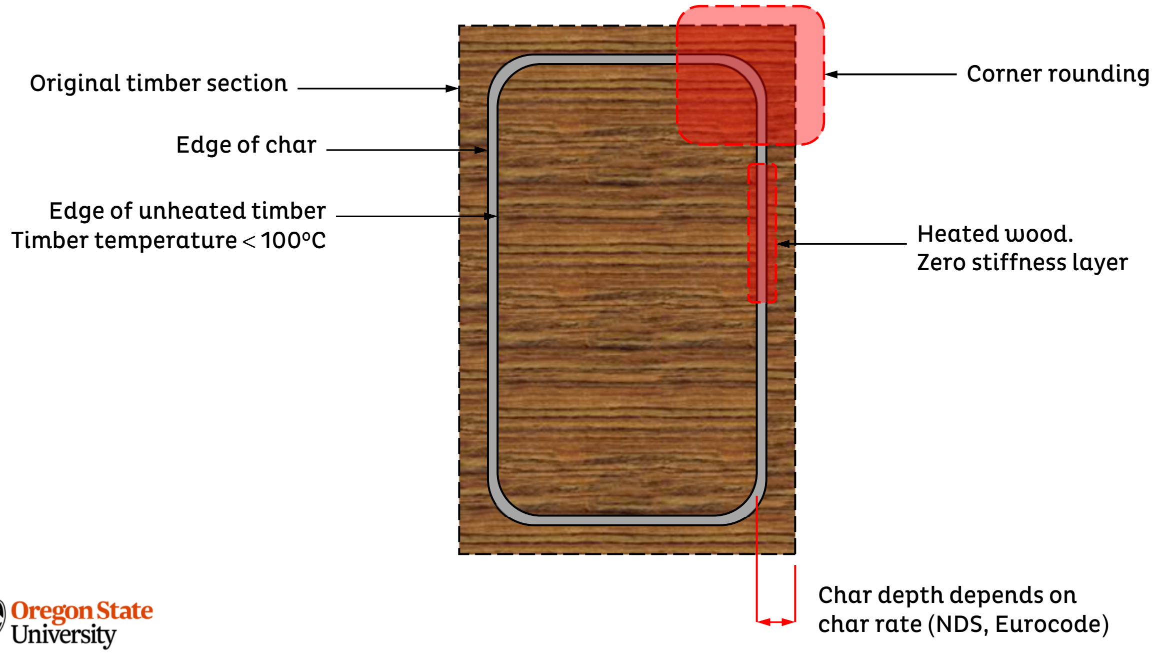
Edge of char

Edge of unheated timber
Timber temperature < 100°C

Corner rounding

Heated wood.
Zero stiffness layer

Structural fire engineering



Original timber section

Edge of char

Edge of unheated timber
Timber temperature < 100°C

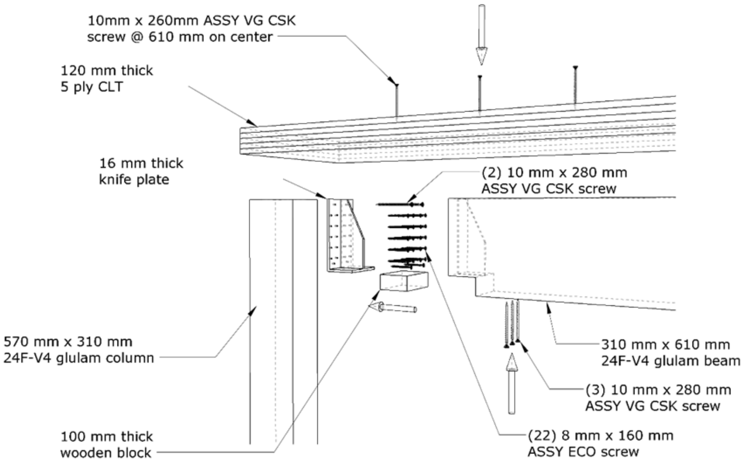
Corner rounding

Heated wood.
Zero stiffness layer

Char depth depends on
char rate (NDS, Eurocode)

Concerns with mass timber and fire

Connections



Smoldering

Part 3: Fire research on mass timber

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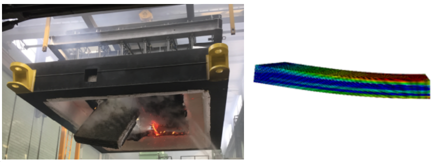
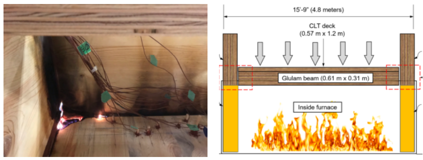
Timber-concrete composite floors



Connections



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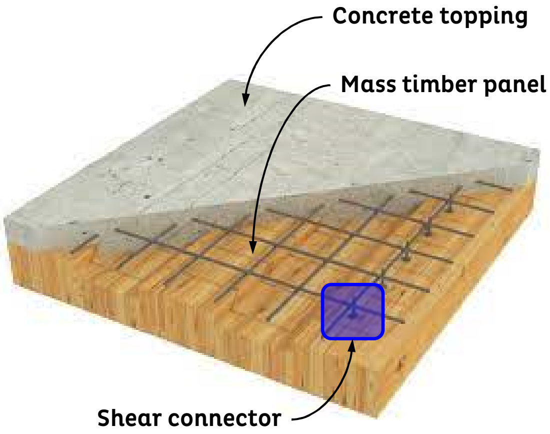
Timber-concrete composite floors



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Timber-concrete composite floors

Testing goals:

1. Examine failure mechanisms within the floor during fire
2. Quantify heat transfer through floor at connectors
3. Compare design methodologies and inherent assumptions

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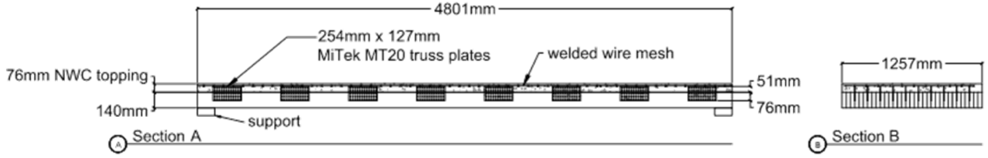
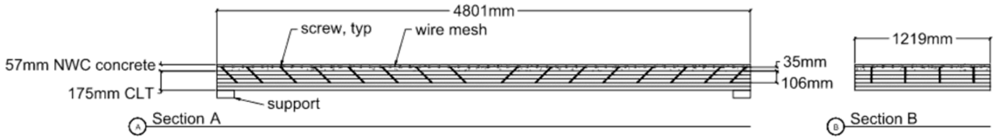
Timber-concrete composite floors

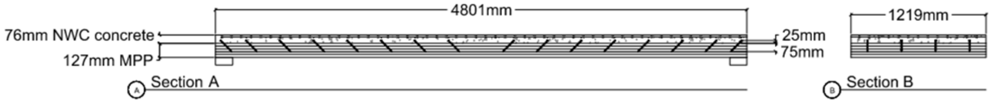
NLT-concrete composite floor



CLT-concrete composite floor



MPP-concrete composite floor



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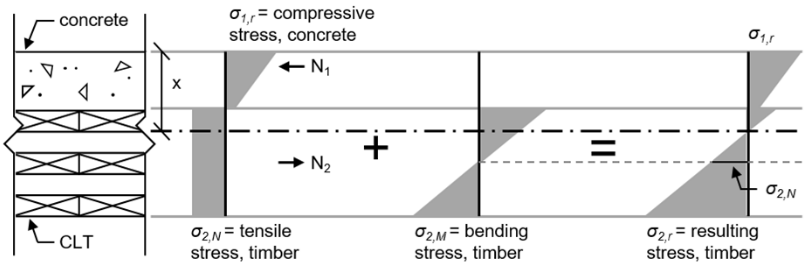
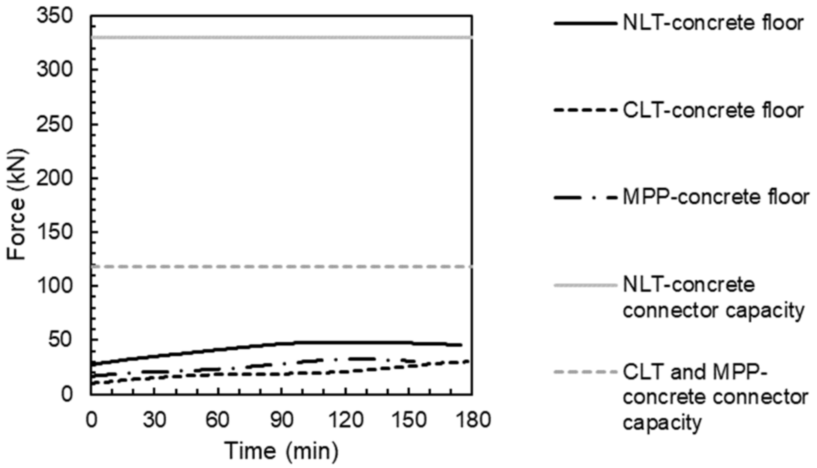
Timber-concrete composite floors
Elasto-plastic method



Assumptions:
- ✓ Plane sections remain plane
- ✓ Full or partial composite action
- ✓ Connectors are rigid and perfectly plastic
- ✓ Linear-elastic behavior of timber and concrete
- ✓ Timber fails before plastic behavior in the concrete
- ✓ Ignore concrete in tension

Frangi, A., Fontana, M. (2003). “Elasto-Plastic Model for Timber-Concrete Composite Beams with Ductile Connection,” *Structural Engineering International.* 13(1), 47-57.

Timber-concrete composite floors
CONCLUSION #1: *Shear connectors do not yield*



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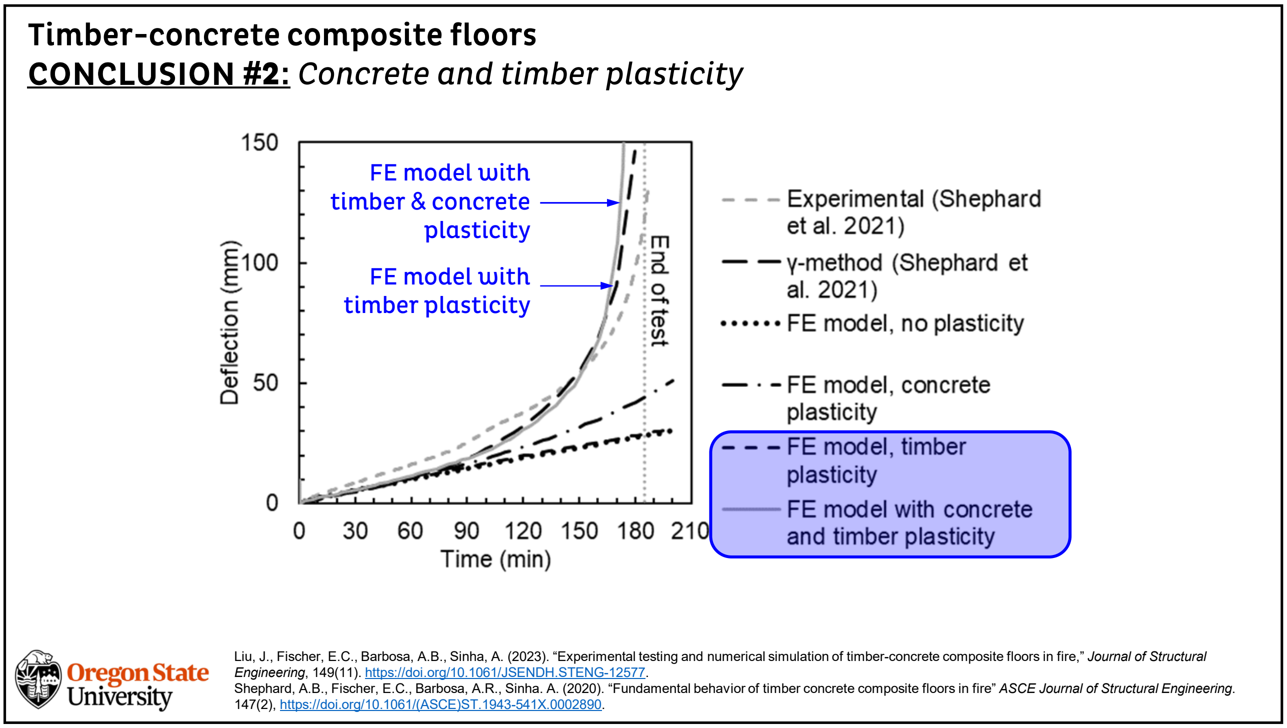

Timber-concrete composite floors

CONCLUSION #2: *Concrete and timber plasticity*

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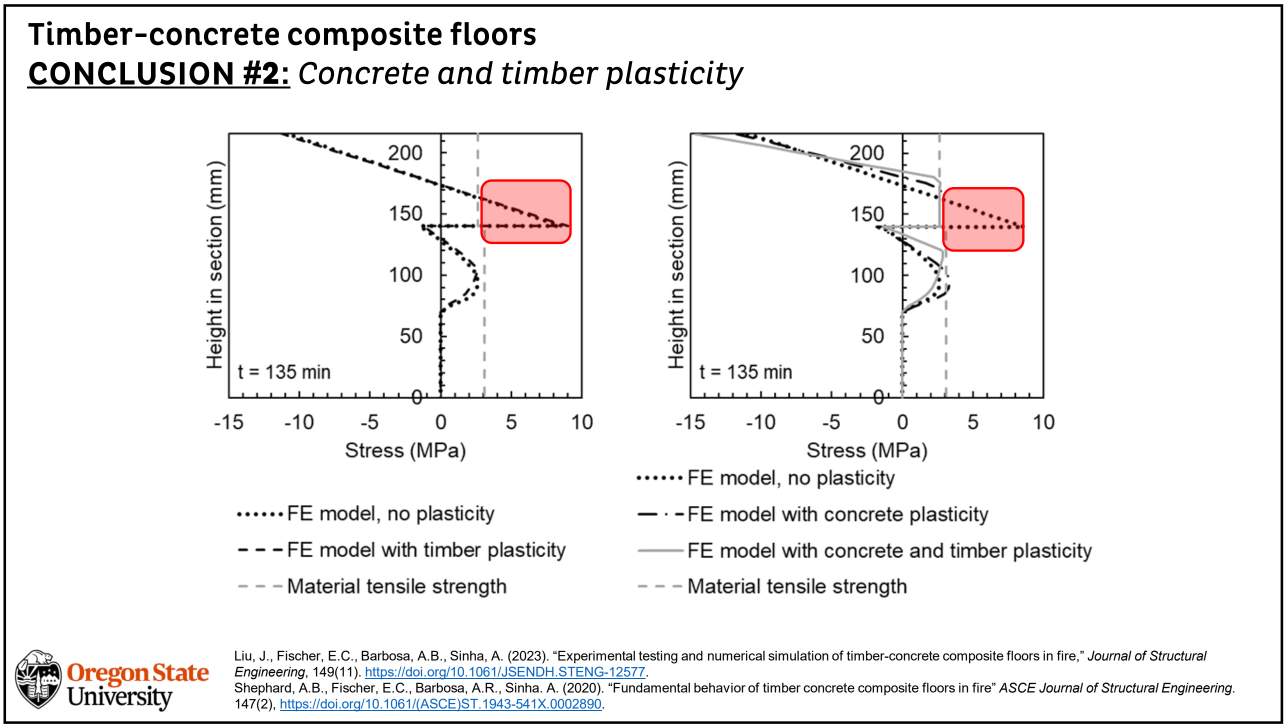

Timber-concrete composite floors

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Timber-concrete composite floors

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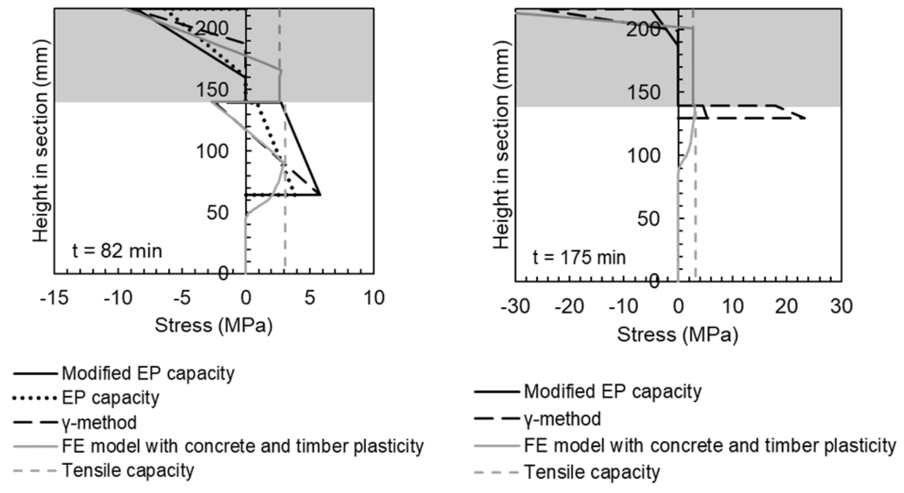

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Timber-concrete composite floors

CONCLUSION #2: *Concrete and timber plasticity*

Failure time in min (% error from experiment)		
	NLT-concrete	CLT-concrete
Experiment	187	165
FE model	175 (-6%)	166 (1%)
γ-method	57 (-70%)	106 (-36%)
Elasto-plastic model	82 (-56%)	129 (-22%)

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Timber-concrete composite floors

CONCLUSION #3: *Presence of shear connectors did not impact char rate*

Source	NLT/timber mm/min (inch/hour)	CLT mm/min (inch/hour)
Experimental (*Average*)	0.56 (1.32)	0.57 (1.35)
NDS	0.76 (1.80)	0.80 (1.90)
Eurocode 5	0.80 (1.90)	NA
CSA 086	0.80 (1.90)	0.80 (1.90)

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Timber-concrete composite floors

Testing goals:

1. Examine failure mechanisms within the floor during fire
2. Quantify heat transfer through floor at connectors
3. Compare design methodologies and inherent assumptions

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Timber connections

Timber connections

Testing goals:

1. Compare charring rates through connection components versus members
2. Measure movement in connections throughout a fire exposure
3. Examine smoldering behavior

Timber connections

Testing goals:

1. Compare charring rates through connection components versus members
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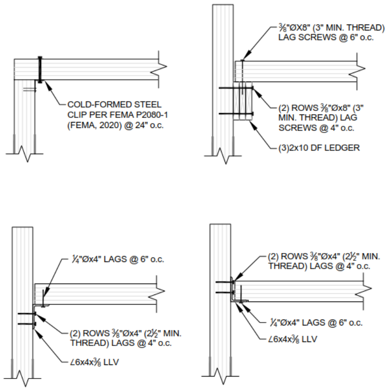
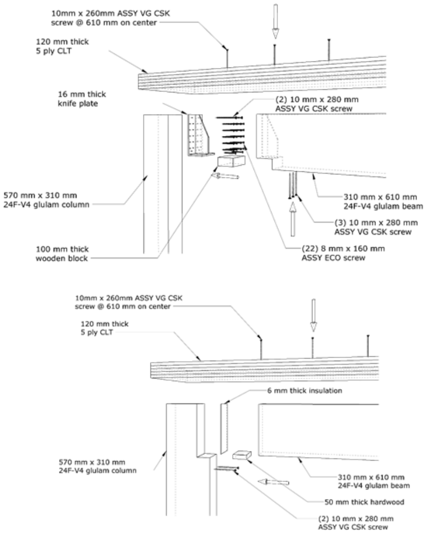
Testing methodology:

1. Expose to ASTM E119 fire (standard fire) for one hour
2. Allow to cool naturally for one hour

Timber connections



Platform frame and balloon frame connections[1]



Glulam beam-to-column connections[2]

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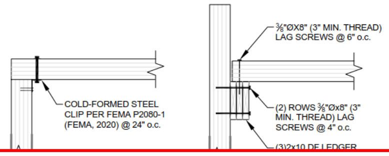
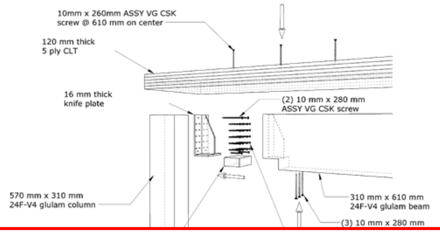
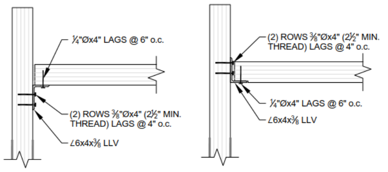
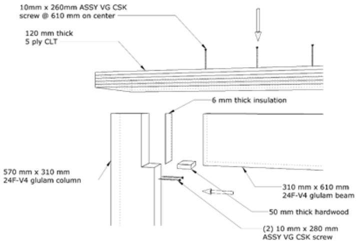
Timber connections





NO STRUCTURAL FAILURE IN ANY TEST





Platform frame and balloon frame connections[1]

Glulam beam-to-column connections[2]

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Timber connections

CONCLUSION #1: *Charring through connections is slower than in member*

Results from platform and balloon framed connections

Connection Type	Location	Average Charring Rate (mm/min.)
--	Middle of Panel	0.75
Platform Framed	Joint	0.46
Wood Ledger	Joint	0.42
Exposed Steel	Floor Bearing	0.50
	Wall Compression	0.50
Concealed Steel	Floor Bearing	0.35

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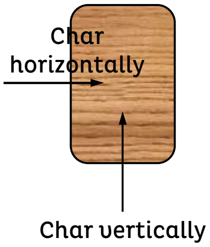

Results from glulam beam-to-column connections

Connection Type	Average Charring Rate (mm/min.) (*with caulking*)		Average Charring Rate (mm/min.) (*(without) caulking*)	
	Horizontal	**Vertical**	**Horizontal**	**Vertical**
Midspan of glulam beam (average)	0.94	0.91	--	--
Knife Plate	0.76	0.33	0.82	0.30
Notched Column	0.90	--	0.97	--
Double Beam	0.95	--	0.84	0.76

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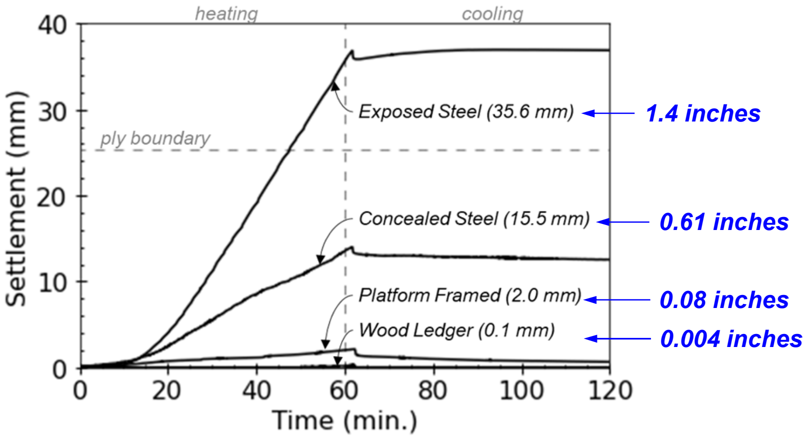
Timber connections

CONCLUSION #2: *Char compression within joints causes movement*



1.4 inches

0.61 inches

0.08 inches

0.004 inches

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Timber connections

CONCLUSION #2: *Char compression within joints causes movement*

Uncaulked connection
Char compression: 0.91 inches

Caulked connection
Char compression: 0.75 inches

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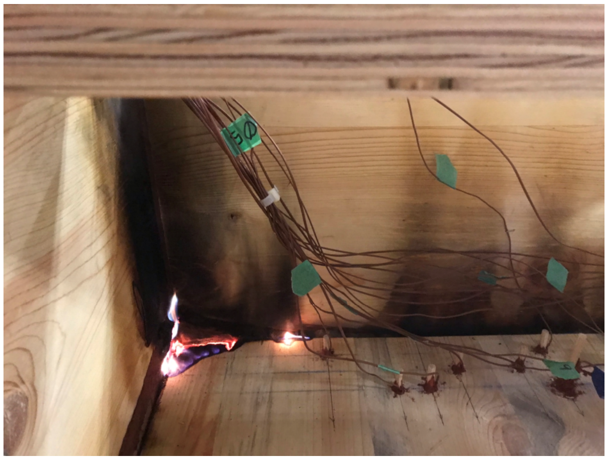
Timber connections

CONCLUSION #3: *Smoldering occurred in every test*



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Timber connections

Testing goals:

1. Compare charring rates through connection components versus members
2. Measure movement in connections throughout a fire exposure
3. Examine smoldering behavior

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Part 4: How to stay informed

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Resources

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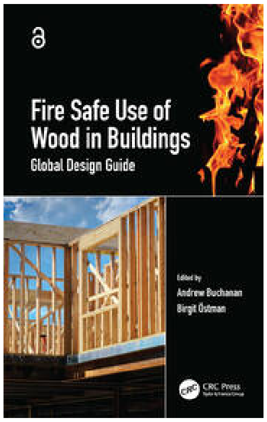
DESIGN INSTITUTE

https://tallwoodinstitute.org/



Fire Safe Use of Wood in Buildings
Global Design Guide

Edited by
Andrew Buchanan
Birgit Östman

CRC Press

(Open Access)

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Questions?

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