AMERICAN WOOD COUNCIL

Cross Laminated Timber (CLT)

Fire Testing Overview

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Disclaimer

Required by our lawyers

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Learning Objectives

- Discuss the History of CLT
- Learn about the Tall Wood Building Ad Hoc Committee
- Review the ATF Fire Tests
- Outline the Recent CLT Fire Testing at RISE

Cross- Laminated Timber

Recently-Developed Forms of Mass Timber:

Cross-Laminated Timber (CLT)

- 1985 1st CLT patent - France
- 1993 1st CLT projects - Switzerland and Germany
- 1995-1996 Improved press technology
- 1998 1st multi-story res building - Austria
- Early 2000's
- CLT use (Europe) increased significantly
  - Green building movement driven
  - Better efficiencies, product approvals, improved marketing and distribution channels
  - Over 500 CLT buildings in England
- Recent - US and Canadian use of CLT

ICC Tall Wood Building Ad Hoc Committee

Project Scope

In December 2015, the ICC Board established the ICC Ad Hoc Committee on Tall Wood Buildings noting the purpose of the ad hoc committee was to

1. Explore the science of tall wood buildings
2. Investigate the feasibility, and
3. Take action on developing code changes for tall wood buildings.

This scope required further refinement by the committee.

ICC Tall Wood Building Ad Hoc Committee

TWB AD HOC OBJECTIVES

- TWB identified performance objectives to be met:
- No collapse under reasonable scenarios of complete burn-out of fuel without automatic sprinkler protection being considered
- No unusually high radiation exposure from the subject building to adjoining properties to present a risk of ignition under reasonably severe fire scenarios
- No unusual response from typical radiation exposure from adjacent properties to present a risk of ignition of the subject building under reasonably severe fire scenarios

ICC Tall Wood Building Ad Hoc Committee

TWB AD HOC OBJECTIVES (Con't)

- No unusual fire department access issues
- Egress systems designed to protect building occupants during design escape time, plus a factor of safety
- Highly reliable fire suppression systems to reduce risk of failure during reasonably expected fire scenarios. Degree of reliability proportional to evacuation time (height) and risk of collapse.

ATF Compartment Fire Test

ICC Tall Wood Building Ad Hoc Committee

Fire Work Group created fire test scenarios to study and validate the TWB code change proposals

- **Test structure represented multi-story condo**
- **30 ft x 30 ft interior dimensions**
- **Corridor and stair included in the structure**
- **UL "modern furnishings" fuel load imposed → 570 MJ/m2**
  - **Fuel load was approximately 85th percentile of Group R fuel loads from survey of Group R's**

Two-Story Fire Test

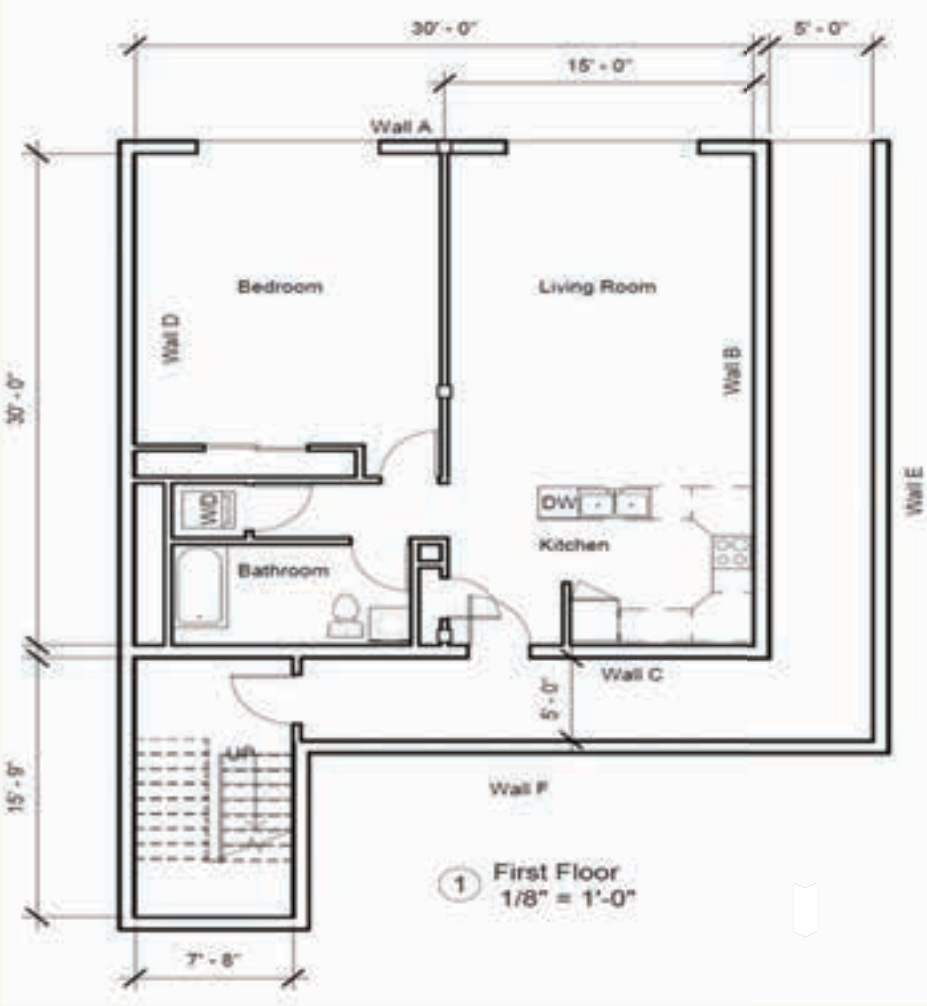
Purpose: Perform tests of realistic fire scenarios applicable to tall wood construction in order to evaluate occupant and firefighter tenability for egress and suppression efforts, and to provide data necessary to guide further development of relevant code and standard provisions

- Conducted at U.S. government facilities (ATF)
- Supervised by U.S. Forest Product Laboratory staff

Test Structure Floor Plan

Fire Work Group Plan

- One bedroom apartment
- 30 feet X 30 feet interior dimensions.
- UL “modern furnishings” fuel load imposed 570 mj/m2
- Fuel load was approximately 95 percentile of Group R
- 20-minute rated door between compartment and corridor
- 90-minute rated door between corridor and stairwell



Two-Story Structure

- Ceiling height: 9 ft (2.7 m)
- 5-ply CLT

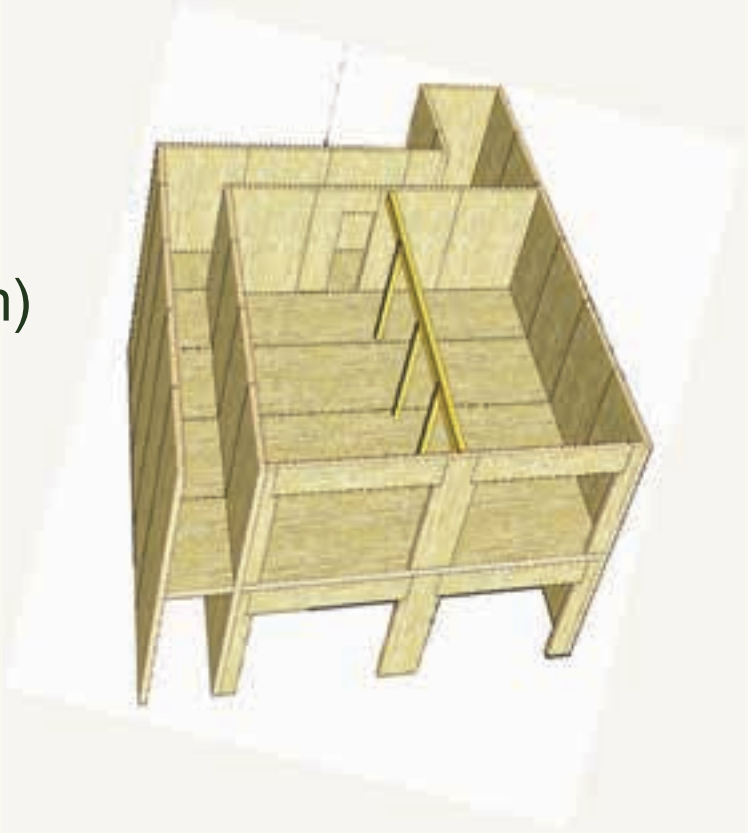
-Douglas-Fir – Larch species group

-Lamination Thickness: 1.375 inches(35 mm)

-CLT Thickness: 6.875 inches (175 mm)

-Polyurethane Adhesive

- Corridor around each apartment and a stairwell
- Ceiling loaded to 20 PSF



Fire Test Scenarios

Test	Description	Date
Test 1	All mass timber surfaces protected with 2 layers of 5/8” Type X GWB	5/23/17
Test 2	30% of CLT ceiling area in living room and bedroom exposed	5/31/17
Test 3	Two opposing CLT walls exposed – one in bedroom and one in living room (there is a partition wall)	6/20/17
Test 4	All mass timber surfaces fully exposed in bedroom and living room. Sprinklered – normal activation	6/27/17
Test 5	All mass timber surfaces fully exposed in bedroom and living room (except bathroom). Sprinklered – 20 min delayed activation	6/29/17

Apartment Furnishings – Kitchen & Living Room

Photos provided by
U.S. Forest Products
Laboratory, USDA

Apartment furnishings – Bedroom & Bath

Photos provided by U.S. Forest Products Laboratory, USDA

Test #1 – All Mass Timber Protected

All mass timber surfaces protected with 2 layers of 5/8” Type X GWB

TEST #1- 2 LAYERS GWB

Test #1 – All Mass Timber Protected

Photos provided by U.S. Forest Products Laboratory, USDA

Test #2 – 30% CLT Ceilings Exposed

30% of CLT ceiling area in living room and bedroom exposed

Live load applied using water barrels

ATF Fire Test #2 – 30% Exposed

Test #2 – 30% CLT Ceilings Exposed

Photos provided by U.S. Forest Products Laboratory, USDA

ATF Fire Test #2 – 30% CLT Ceilings Exposed

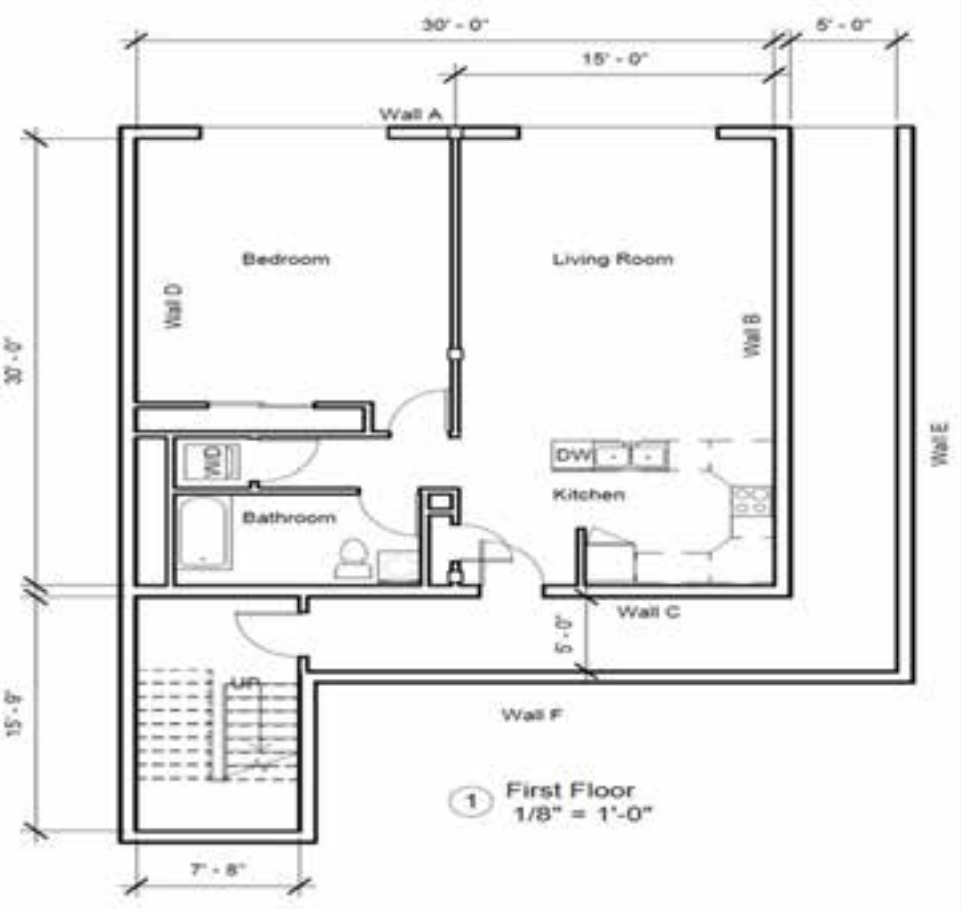
Post-Fire Condition of Glulam After Gypsum Removal

- Fire intensity decreased subsequent to consumption of furnishings and contents (known as decay phase)
- Exposed mass timber surfaces self-extinguished in the decay phase
- Mass timber surfaces protected with 2 layers of 5/8” Type X GWB remained mostly uncharred

Section of Exposed Ceiling (90º Angle)

Test #3 – Exposed Walls

Two opposing CLT walls exposed one in bedroom and one in living room



Test #3 – Exposed Walls


Ignition


Living Room/
Kitchen Flashover


Bedroom Flashover


Ignition


Ignition


Ignition

Photos provided by U.S. Forest Products Laboratory, USDA

Test #4 – Sprinkler Protected, Exposed

Test #4 – Sprinklers Protected, Exposed

All mass timber surfaces fully exposed in bedroom and living room.

Sprinkler – normal activation

Photos provided by U.S. Forest Products Laboratory, USDA

Test #5- Delayed Sprinkler

Test #5 – Delayed Sprinklers

All mass timber surfaces fully exposed in bedroom and living room.

Sprinkler – water delayed for 20 minutes after sprinkler activation within the test compartment…approximately 23 minutes from ignition

Flashover conditions were reached in the kitchen, and the bedroom was very near reaching flashover

The sprinkler system effectively suppressed the fire

Photos provided by U.S. Forest Products Laboratory, USDA

Results – Event Log

Test No.	Time After Ignition (mm:ss)				
	Flashover (600°C) Living Room	Flashover (600°C) Bedroom	Flames in Hallway	Compartment door Fails	Sprinkler Activation
1 1st floor	13:27	17:20	26:51	57:46	N/A
2 2nd floor	11:42	17:20	30:38	63:59	N/A
3 2nd floor	12:37	17:00	13:06 (door frame installation error)	29:42 (door frame installation error)	N/A
4 1st floor	-	-	-	-	2:37
5 1st floor	-	-	-	-	23:00

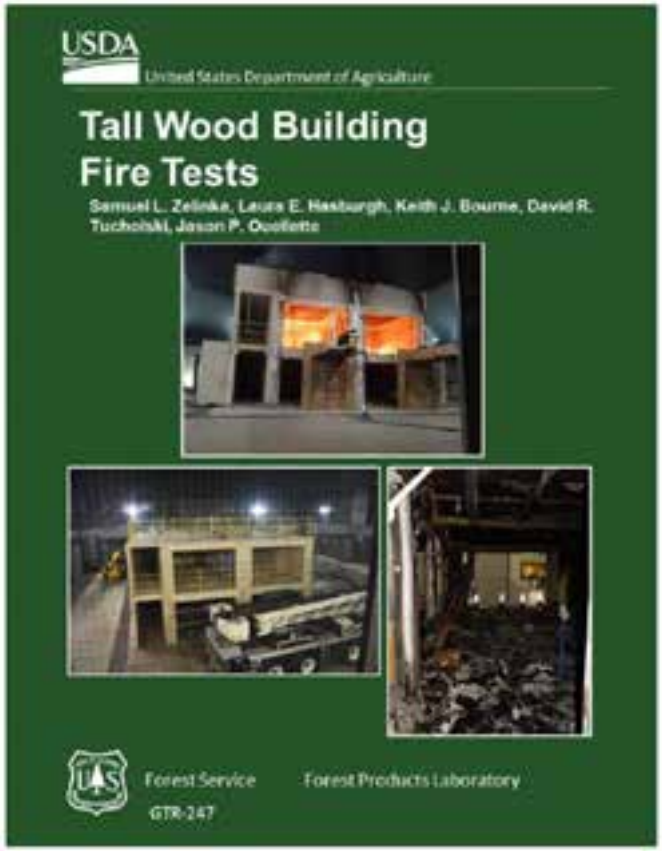
ATF Fire Tests

Full Report on FPL Website:

https://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr247.pdf

Fire Test Videos on AWC Website:

www.awc.org/tallmasstimber
Link to you tube videos available on this page



Research at RISE

Similar to ATF compartment tests in 2018, *EXCEPT:*

- PRG 320-18 compliant CLT
- Increased areas of exposed mass timber

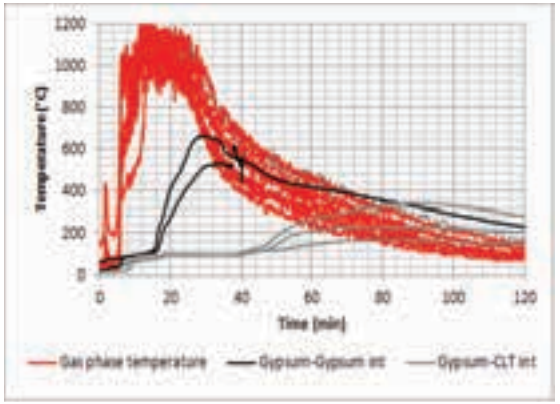
Reason for Additional Testing

- **Tests performed at ATF used previous generation of CLT**
  - PRG 320-18 – compliant CLT not available at the time
  - Type IV-B exposed mass timber limits based on these tests
- **2021 IBC requires compliance with PRG 320-18**
  - Mismatch between the material requirements for CLT vs. the exposed mass timber area limits in 2021 IBC
  - Additional testing on PRG 320-18-compliant CLT needed to determine appropriate area limits

Research at RISE

Objective:

- Determine whether increased areas of exposed mass timber are justifiable using CLT compliant with PRG 320-18



Objectives

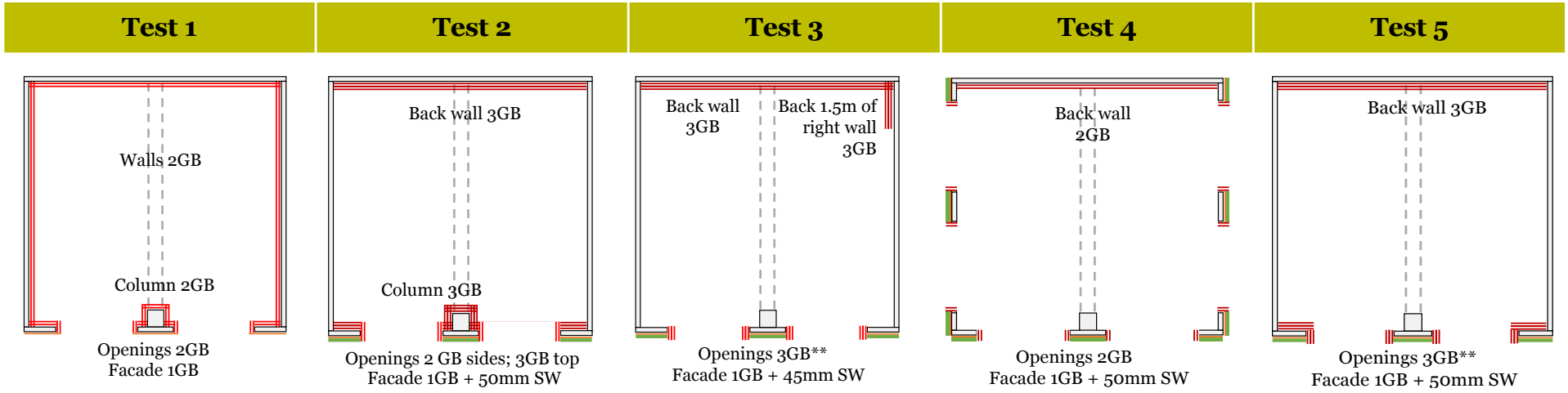
Primary

- Design and perform 5 compartment fire tests with **PRG 320-2018 compliant CLT** & varying amounts of exposed mass timber areas.
- Assess against performance criterion: decay of the fire is required to be continuous until 4 hours after ignition.

Secondary

- Design and test **intersections between exposed mass timber members**
- **Record façade exposure** allowing for comparisons with standard façade testing methods.
- **Predictive modeling**
- Case study for **restoring exposed CLT** members after a fire.

Test Configurations



Configurations based on a combination of:

- Performance of the previous test
- Modeling predictions
- Opinion of the steering group

Test videos

Test 1 - Exposed timber: 53.8 m^2

Test 2 - Exposed timber: 91.2 m2

Test 3 - Exposed timber: 96.2 m2

Test 4 - Exposed timber: 77.9 m2

Test 5 - Exposed timber: 97.2 m2

Reference without PRG320(2018) compliance - Exposed: 67 m2

Test Videos

Test 1 - Exposed timber: 53.8 m^2

Test 2 - Exposed timber: 91.2 m^2

Test 3 - Exposed timber: 96.2 m^2

Test 4 - Exposed timber: 77.9 m^2

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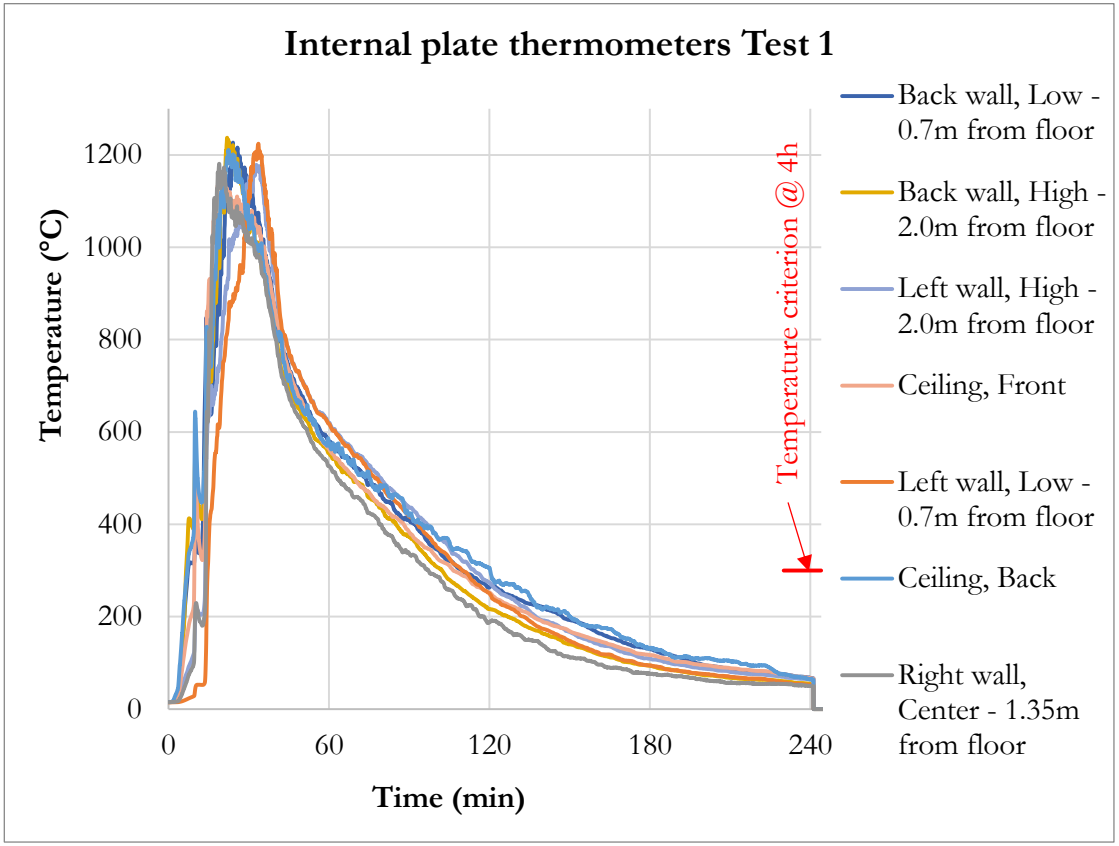
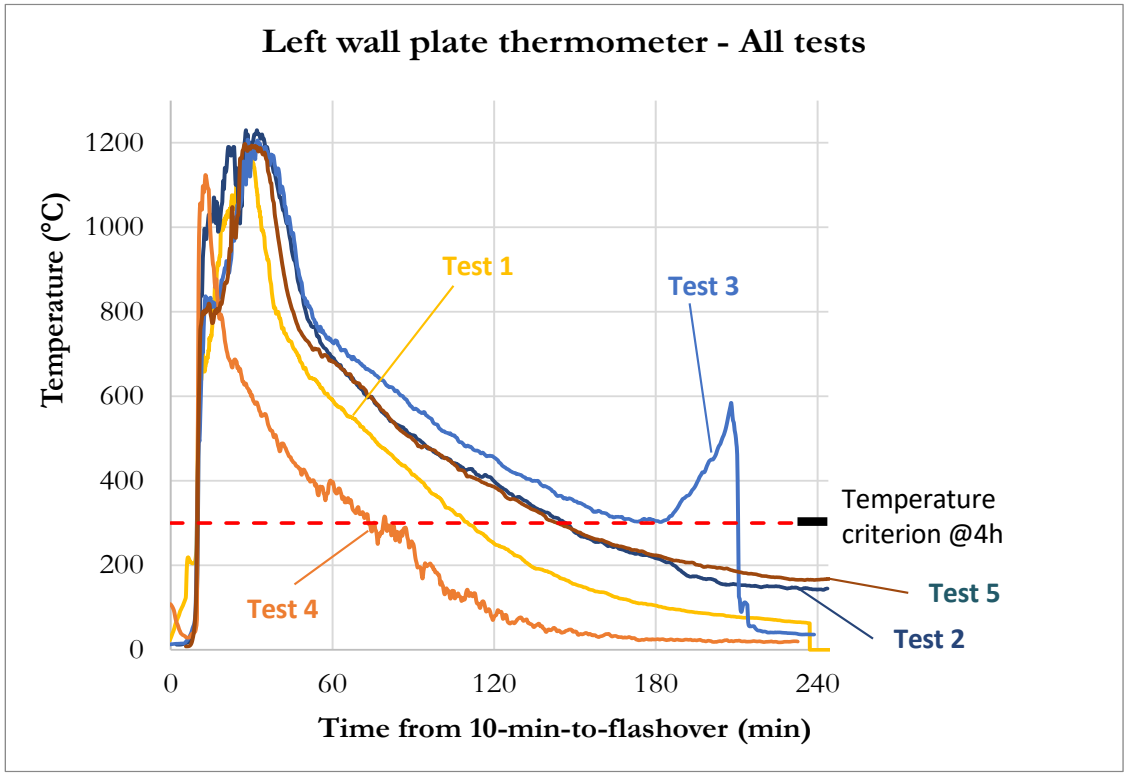
Reference <u>without</u> PRG320(2018) compliance - Exposed: 67 m^2

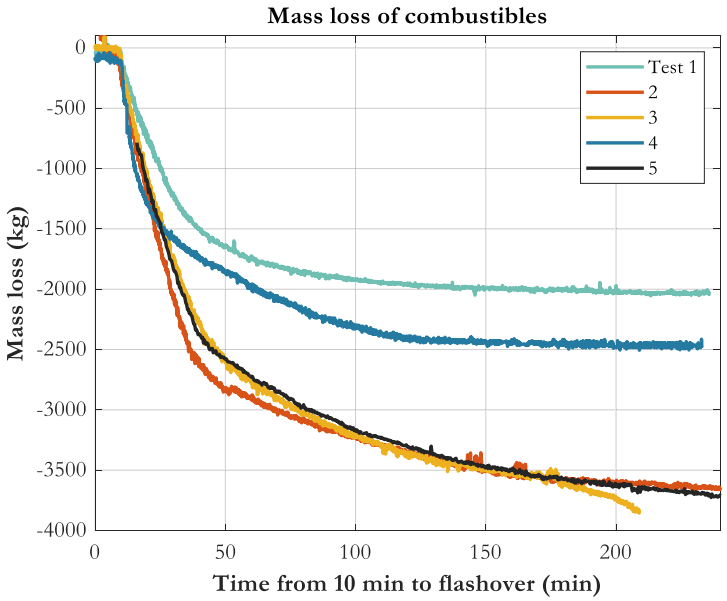
Fire Test Results

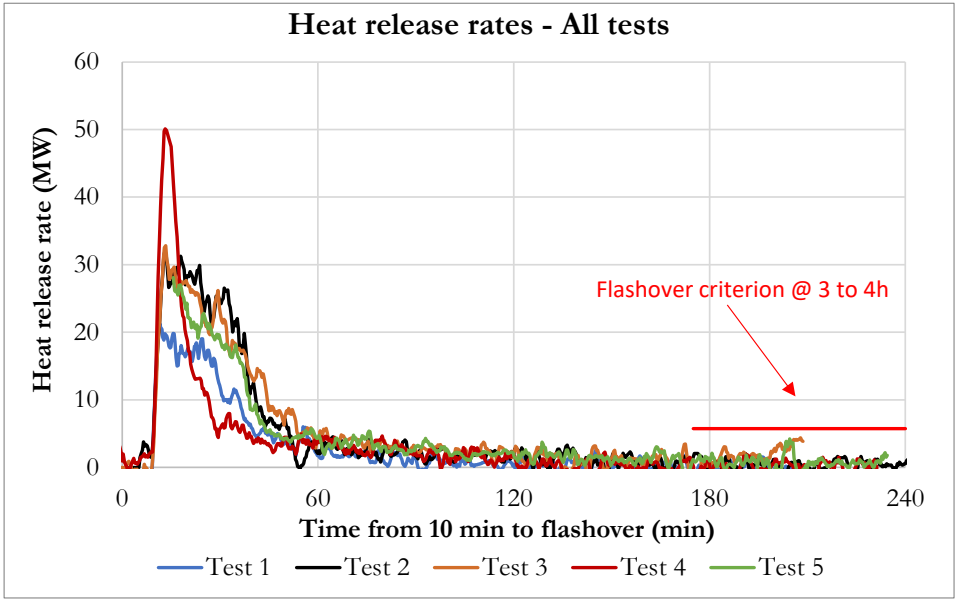


Fire Test Results

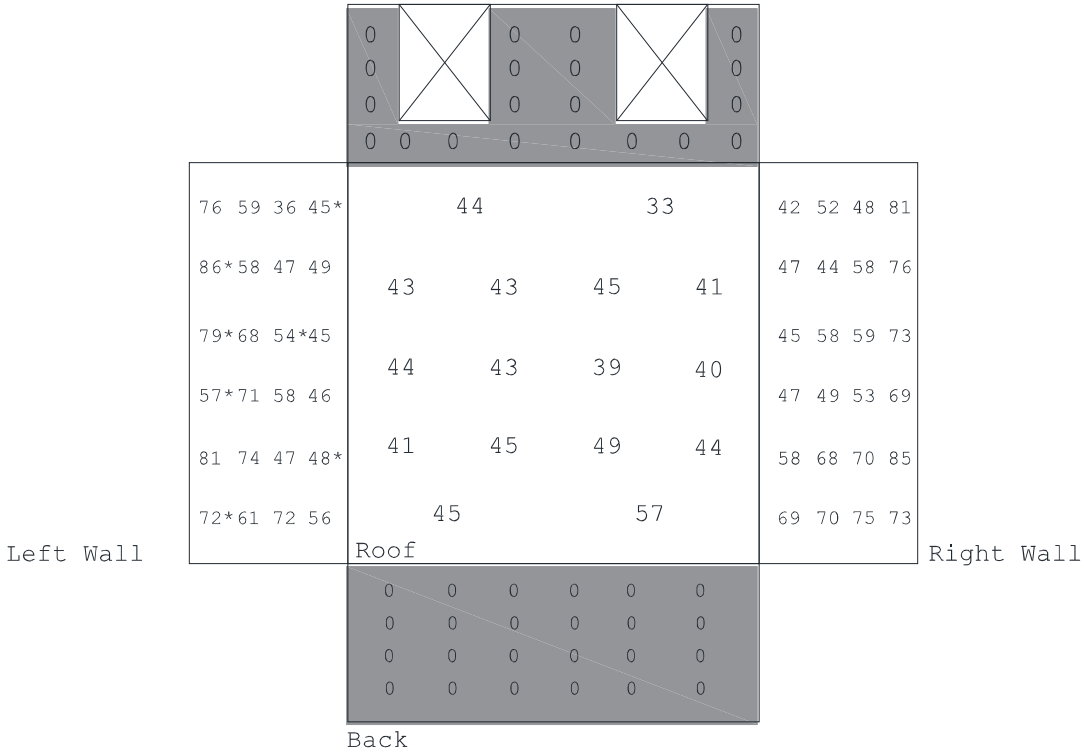


Test Results



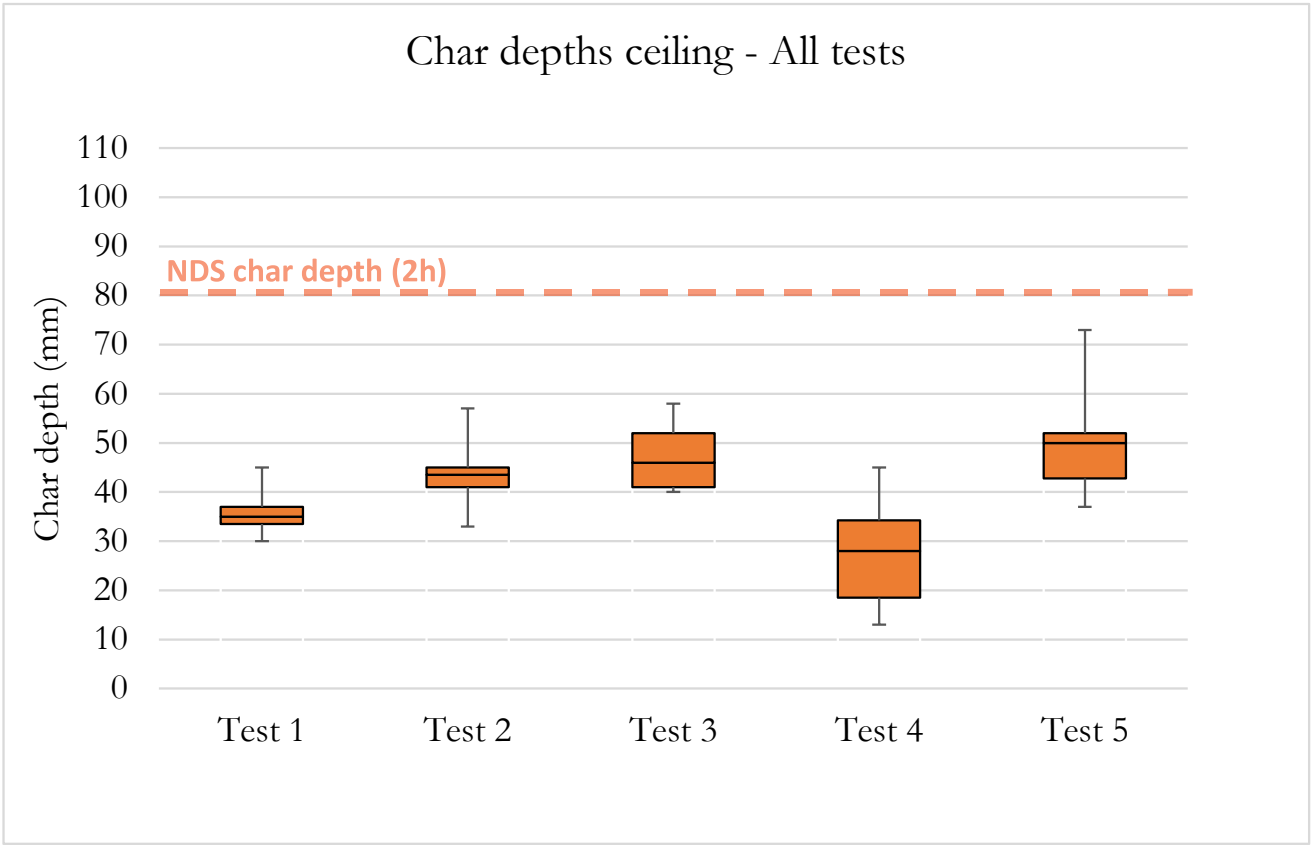


Fire Test Results – Char Depths



* Highlights increased uncertainty in char estimation due to unclear Resistograph curve.

Fire Test Results – Char Depths



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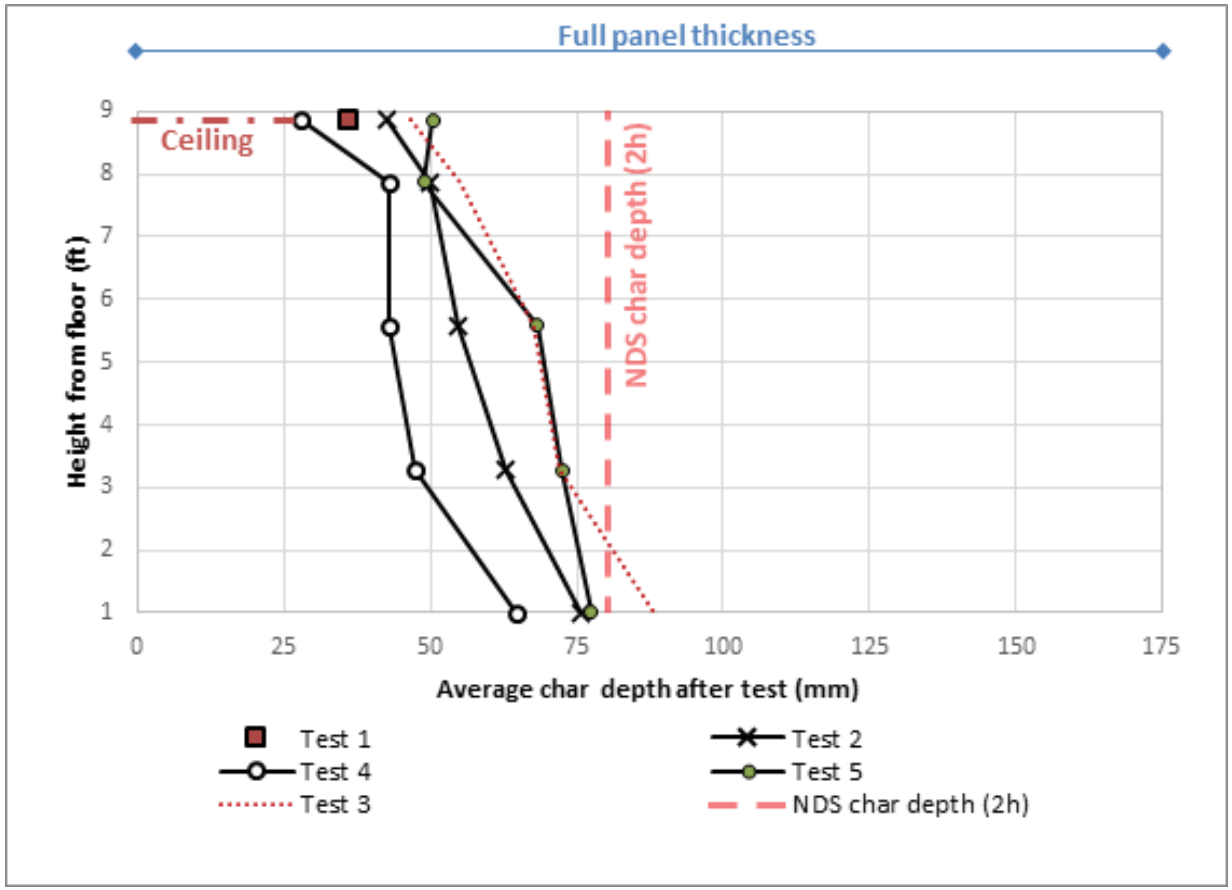


Intersections

- All airtight sealed mass timber intersections were effective to prevent fire spread.
- One of the designed intersections had locally no airtight seal and led to smoke and some flaming through the intersection
- Geometrical tolerances need to be accounted for.
- The sealing material does not have to be resistant against elevated temperatures if positioned in a well insulated location.

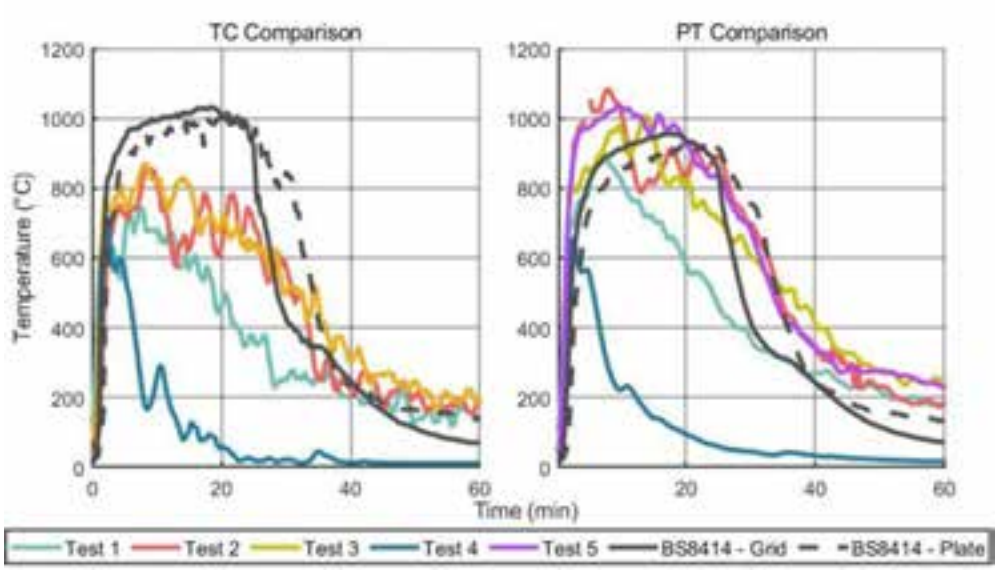
Secondary Objective

Record façade exposure allowing

for comparisons with standard

façade testing methods.

Facade Exposure



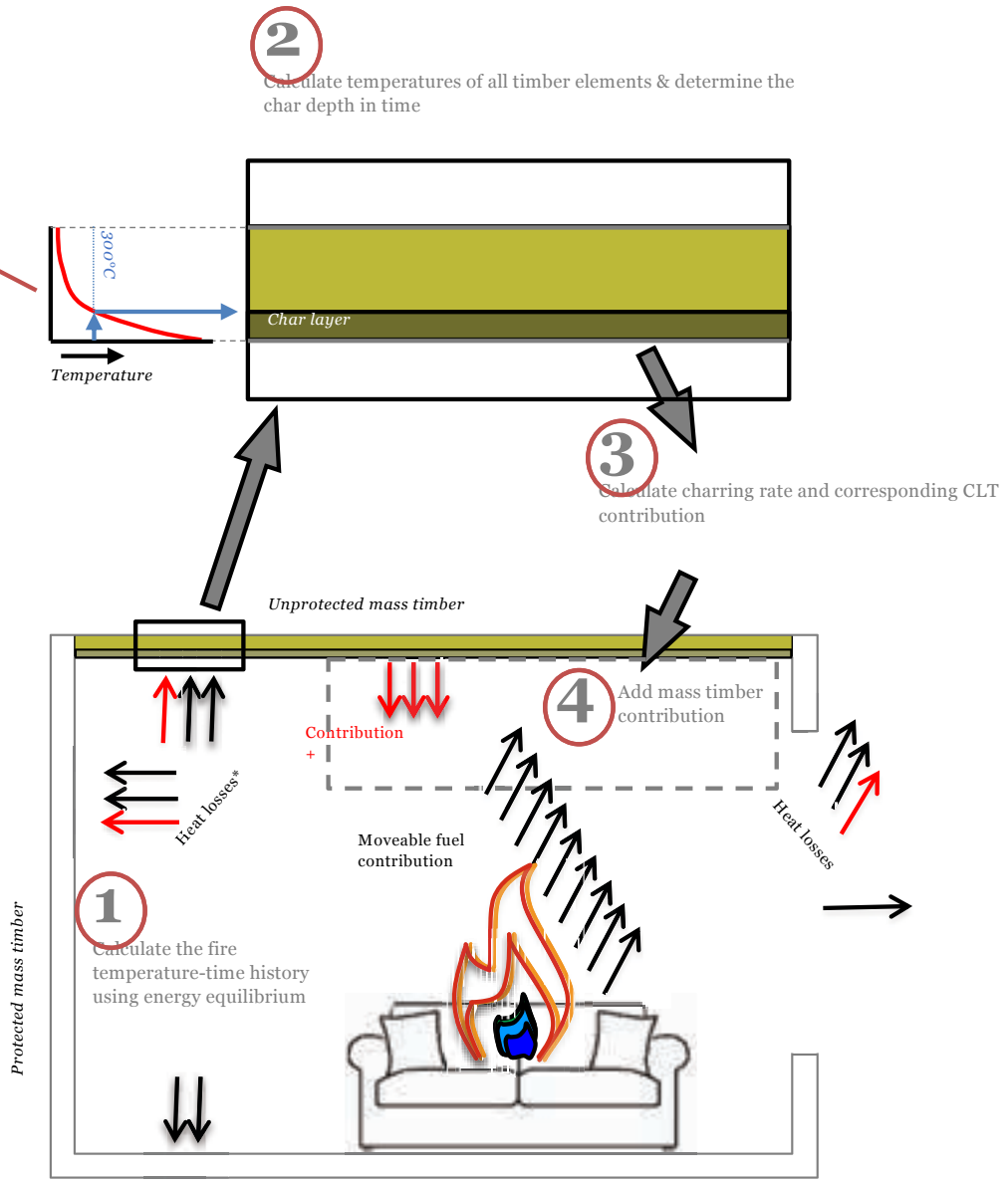
British BS 8414 test

Secondary objective

Predictive modeling

Predictive Modeling

This can be used for structural calculations



Secondary Objective

Case study for **restoring**

exposed CLT members after a

fire.

Rehabilitation of Charred CLT Video

Characteristics

- Flexural stiffness and bending capacity maintained
- Shear capacity reduced, but sufficient for most applications

Conclusions

- CLT is what makes Tall Mass Timber Buildings possible.
- CLT has been extensively fire tested.
- CLT performs very differently in fire conditions than lightweight wood construction.

Questions?

Thank you!

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