Mass Timber Shafts and Shaft-Wall Solutions for Mass Timber Buildings

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Photo: Alex Schreyer
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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.
Course Description

The rapid growth of mass timber construction in the U.S. has led to a variety of solutions for shaft wall framing. Mass timber buildings can have mass timber shaft walls, light-frame wood shaft walls, or shaft walls constructed of a different building material altogether. The prefabricated nature of mass timber shaft walls also makes them a good solution in light-frame projects. This presentation will cover material and detailing options for shaft walls within mass timber buildings as well as mass timber shaft walls in other building types. Specific emphasis will be on meeting structural demands and fire-resistance rating requirements for various construction types and building heights as demonstrated through case studies of real projects.
Learning Objectives

1. Review code provisions that define fire-resistance ratings for Types III, IV, and V construction.

2. Introduce shaft wall material and assembly options.

3. Provide detailing options that establish fire-resistance continuity at framing intersections while meeting structural demands.

4. Discuss the benefits and challenges of mass timber shaft walls and their applicability to different building types.
Shaft Wall Resource

Code provisions, detailing options, project examples and more for light-frame wood and mass timber shaft walls

Free resource at woodworks.org
Common Shaft Walls

Wood Studs

Concrete Walls

Mass Timber

Shaftliner Panels

Or CFS studs

Photo: Quality Contractors

Photo: C.D. Smith Construction

Photo: WoodWorks
Shaft Walls

Shaft Walls Form Shaft Enclosures

“The purpose of shafts is to confine a fire to the floor of origin and to prevent the fire or the products of the fire (smoke, heat and hot gases) from spreading to other levels.”

Source: IBC Commentary to Section 713.1
Types of Shaft Walls

Types of Shafts:
» Elevator
» Stair
» Mechanical

» Code requirements apply to any/all shaft enclosures.
» Some points of shaft wall construction and detailing apply to all types of shafts.
» Some are unique to each type of shaft.
Defining Shaft Wall Requirements

Code requirements for shaft enclosures contained in IBC Section 713:

IBC 713.2: Shaft Walls shall be constructed as Fire Barriers

Many shaft wall provisions contained in IBC Section 707: Fire Barriers
# Interior Fire-Rated Walls: Differences

<table>
<thead>
<tr>
<th>Fire walls</th>
<th>Fire Barrier</th>
<th>Fire Partition</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Building Separation</td>
<td>• Shafts; Occupancy Separation</td>
<td>• Dwelling Unit Separation; Corridors</td>
</tr>
<tr>
<td>• Openings are protected and limited</td>
<td>• Openings are protected and limited</td>
<td>• Openings are protected</td>
</tr>
<tr>
<td>• Continuous from foundation to/through roof and exterior wall</td>
<td>• Continuous from floor to floor through concealed spaces at each level</td>
<td>• May terminate at a fire rated floor/ceiling/roof assembly</td>
</tr>
<tr>
<td>• Structural stability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Shaft Wall Hourly Rating

Section 713: Shaft Enclosures

713.4: Fire-Resistance Rating

» **2 hours** when connecting 4 stories or more

» **1 hour** when connecting less than 4 stories

» Number of connected stories includes basement but not mezzanine

» Fire rating of shaft walls shall not be less than floor assembly penetrated, but need not exceed 2 hours
Shaft Wall Materials

Type III Construction:
» Any material permitted by code for all interior elements
» Fire-retardant treated wood for exterior walls

Type IV-HT Construction:
» Heavy/mass timber members for interior elements
» 1-hr min rating for all interior walls/partitions
» Fire retardant treated wood or CLT for exterior walls

Type V Construction:
» Any material permitted by code for all interior and exterior elements

707.2 Materials.
Fire barriers shall be of materials permitted by the building type of construction.
# Shaft Wall Materials

<table>
<thead>
<tr>
<th></th>
<th>Type III</th>
<th>Type IV-HT</th>
<th>Type V</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interior Shaft Walls</strong></td>
<td>Any code-permitted wood framing</td>
<td>Heavy timber or any code-permitted, 1-hr wood framing</td>
<td>Any code-permitted wood framing</td>
</tr>
<tr>
<td><strong>Exterior Shaft Walls</strong></td>
<td>Fire-retardant treated wood</td>
<td>Fire-retardant treated wood or CLT</td>
<td>Any code-permitted wood framing</td>
</tr>
</tbody>
</table>

There is no restriction on the use of combustible materials (light-frame wood and mass timber) in shaft walls or fire barriers in mass timber buildings of Types III, IV-HT or V construction.
Tall Mass Timber: New Construction Types in 2021 IBC

Type IV-A
- Office Assembly Residential
- Mercantile (12 stories)
- 270 ft. (18 stories)

Type IV-B
- Office Assembly Residential
- Mercantile (8 stories)
- 180 ft. (12 stories)

Type IV-C
- Office (9 stories)
- Residential (8 stories)
- Assembly Mercantile (6 stories)
- 85 ft. (9 stories)
## Shaft Enclosures in Tall Timber

### Shafts material requirements and timber exposure limitations

<table>
<thead>
<tr>
<th>IV-A</th>
<th>IV-B</th>
<th>IV-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 12 Stories or 180 ft: MT protected with 2 layers 5/8” type X gyp (if 2 HR req’d) or 3 layers 5/8” type X gyp (if 3 HR req’d) both sides</td>
<td>NC or MT protected with 2 layers 5/8” type X gyp (IBC 2021 602.4.2.6) both sides</td>
<td>NC or MT protected with 1 layer 5/8” type X gyp (IBC 602.4.3.6) both sides</td>
</tr>
<tr>
<td>Above 12 Stories or 180 ft: Noncombustible shafts (IBC 2021 602.4)</td>
<td>2 HR (not less than FRR of floor assembly penetrated, IBC 713.4)</td>
<td></td>
</tr>
</tbody>
</table>

NC = non-combustible
MT = mass timber
Shaft Enclosure Design in Tall Timber

Shaft Wall Requirements in Tall Mass Timber Buildings

The 2017 International Building Code (IBC) introduced three new construction types—Type II A, II B, and IV C—which allow tall mass timber buildings. For details on the new types and their requirements, see the WoodWorks paper, "Tall Wood Buildings in the 2017 IBC — Up to 15 Stories of Mass Timber." This paper builds on that document with an in-depth look at the requirements for shaft walls, including when and where wood can be used.

Shaft Enclosure Requirements in the 2021 IBC

A shaft is defined in Section 202 of the 2021 IBC as "an enclosed space extending through one or more stories of a building, connecting vertical openings in successive floors, or floors and roof." Therefore, shaft enclosure requirements apply to stairs, elevators, and mechanical electrical (MEP) chases in multi-story buildings. While these applications may be similar in their fire design requirements, they tend to differ in terms of their assemblies, detailing, and construction constraints.

Shaft enclosures are specifically addressed in IBC Section 713. However, because shaft enclosure walls must be constructed as fire barriers per Section 713.2, many shaft wall requirements reference provisions for fire barriers found in Section 707.

Allowable Shaft Wall Materials

Provisions addressing materials permitted in shaft wall construction can be found in both the shaft enclosure sections 713.4 and fire barriers section 707.2 of the code. A relatively new category of wood products, mass timber can encompass well-known and widely used products such as solid laminated timber (SLT) and cross-laminated timber (CLT).
Continuity Provisions

Section 713: Shaft Enclosures

713.5 Continuity.
Shaft enclosures shall have continuity in accordance with 707.5 for fire barriers.

Section 707: Fire Barriers

707.5 Continuity.
Fire barriers shall extend from the top of the foundation or floor/ceiling assembly below to the underside of the floor or roof sheathing, slab or deck above and shall be securely attached thereto. Such fire barriers shall be continuous though concealed space such as the space above a suspended ceiling. Joints and voids at intersections shall comply with Sections 707.8 and 707.9.
Continuity Provisions

FIGURE 1: IBC Commentary Figure 707.5 – Continuity of Fire Barriers

- Fire-resistance-rated floor/ceiling assembly
- Nonfire-resistance-rated floor/ceiling assembly
- Fire-resistance-rated floor/ceiling assembly
- Fire-resistance-rated floor/ceiling assembly or roof/ceiling assembly
- Floor or roof deck
Continuity Provisions

What do these continuity provisions look like?

In mass timber construction, the mass timber floor panel is the “slab”

The mass timber floor panel (slab) does not interrupt the wall’s continuity per the continuity definition of a fire barrier.

Platform mass timber floor to shaft wall permitted by code
Fire barriers, including shaft walls, must extend from top of slab to underside of slab (mass timber panel = slab). Slab does not obstruct continuity.
Supporting Construction Provisions

Section 707: Fire Barriers

707.5.1 Supporting Construction:

The supporting construction for a fire barrier shall be protected to afford the required fire-resistance rating of the fire barrier supported.

Ex., shaft walls that are not continuous to lowest level
Supporting Construction Provisions

Supporting construction differences (any?)

Image: WoodWorks
The intent of a fire barrier is to provide fire confinement. If a fire barrier wall is supported directly by a wall below, the intersecting floor panel should not be considered a supporting element.
Joints in Shaft Walls

Section 202: Definitions

*Joint*. The opening in or between adjacent assemblies that is created due to building tolerances, or is designed to allow independent movement of the building in any plane caused by thermal, seismic, wind or any other loading.
Penetrations in Shaft Walls

Section 713: Shaft Enclosures

713.8 Penetrations.
Penetrations in shaft enclosure shall be protected in accordance with Section 714 as required for fire barriers. Structural elements such as beams or joists, where protected in accordance with Section 714 shall be permitted to penetrate a shaft enclosure.

Section 707: Fire Barriers

707.7 Penetrations.
Penetrations of fire barriers shall comply with Section 714.
Penetrations in Shaft Walls

Where are structural penetrations in shaft walls common?

- Mass Timber Beams to Shaft Wall Connection
- Stair framing to Shaft Wall Connection
Penetrations in Shaft Walls

To some, a new way of thinking:
Many are familiar with firestopping for MEP, but not structure, especially mass timber structure

» Some firestopping systems available as tested configurations for wood conditions
» Most manufacturers can provide engineering judgement details, certification statements for this condition

Images: AWC & FP Innovations
Shaft Wall Assemblies

Assembly selection considerations:

» Fire resistance rating requirement (1-hr or 2-hr)
» Size and height of shaft
» Structural needs (gravity & lateral loads)
» Acoustics
» Space available for wall (allowed thickness)
Shaft Wall Assemblies

Options for Mass Timber Shaft Walls in Mass Timber Buildings

Exposed Mass Timber Shaft Walls

Mass Timber Shaft Walls w GWB
How do you determine fire-resistance rating of exposed mass timber shaft walls?

1. Calculations in Accordance with IBC 722 \(\rightarrow\) NDS Chapter 16
2. Tests in Accordance with ASTM E119

\[ a_{eff} = 1.2a_{char} \]
Design Example: 2-hr CLT Wall

Example 6: Exposed CLT Wall - Allowable Stress Design

Cross-laminated timber (CLT) wall with an unbraced height of L=120 inches and loaded in compression in the strong-axis direction. The design loads are \( w_{ud}=14,000 \text{ psf} \) and \( w_{du}=6,150 \text{ psf} \) including estimated self-weight of the CLT panel. Walls above are supported on a CLT floor slab and aligned with a CLT wall below. Sealing of wall joints with fire-rated caulk restricts hot gases from venting through half-lap joints at edges of CLT panel sections. Calculate the required section dimensions for a 2-hr structural fire resistance time when subjected to an ASTM E119 fire exposure.

Calculate column load:
\[
P_{col} = P_{load} + P_{snow} = 6,150 \text{ psi} + 14,000 \text{ psi} = 20,150 \text{ lb/foot of width.}
\]

From PRG 320, select a 7-ply CLT panel made from 1-3/8 in x 3-1/2 in. lumber boards (CLT thickness of 9-5/8 inches). For CLT grade E1, tabulated properties are:

- Reference compression stress, \( f_{c0} = 1800 \text{ psi} \) (PRG 320 Annex A, Table A1)
- Reference bending moment, \( P_{3.0} = 41,370 \text{ ft-lb/ft of width} \) (PRG 320 Annex A, Table A2)
- Reference bending stiffness, \( E_{3.0} = 1.089 \times 10^6 \text{ lb-in}^2/\text{ft of width} \) (PRG 320 Annex A, Table A2)
- Reference shear stiffness, \( G_{3.0} = 1.4 \times 10^5 \text{ lb-ft/ft of width} \) (PRG 320 Annex A, Table A2)

Calculate the effective wall compression capacity:
\[
A_{wall} = \frac{b_d \cdot h_{wall}}{4.12(1.375)} = 66 \text{ in}^2/\text{ft of width}
\]
\[
P_r = f_{c0} \left( \frac{b_d \cdot h_{wall}}{4.12(1.375)} \right) = 118,800 \text{ lb/ft of width} \] (NDS 10.3.1)

Calculate the apparent wall buckling capacity:

Using NDS Equation 10.4-1, the value for \( (E/l)_{app} \) can be calculated. Since PRG-320 assumes that \( E/G = 16 \) for CLT, NDS Equation 10.4-1 can be rewritten as:
\[
(E/l)_{app} = \frac{E/l_{eff}}{K_i E/l_{eff} A_{eff}^2}
\]

For pinned-pinned column buckling, \( K_i = 11.8 \); therefore:
\[
(E/l)_{app} = \frac{1.089 \times 10^6}{1 + \left( \frac{1.11 \times (1.089 \times 10^6)}{1.4 \times 10^5} \right)^2} = 665 \times 10^4 \text{ lb-in}^2/\text{ft of width}
\]

Credit: AWC TR10
Table 2: North American Fire Resistance Tests of Mass Timber Wall Assemblies

<table>
<thead>
<tr>
<th>Mass Timber Panel</th>
<th>Manufacturer</th>
<th>CLT Grade or Timber Grade</th>
<th>Exposed Side Protection</th>
<th>Panel Connection</th>
<th>Unexposed Side Protection</th>
<th>Load Rating</th>
<th>Fire Resistance Achieved (Hours)</th>
<th>Actual Fire Endurance</th>
<th>Source</th>
<th>Testing Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-ply (114mm 4.488 in)</td>
<td>Nordic</td>
<td>SPF 1650 Fb 1.5EMSR x SPF #3</td>
<td>2 layers 1/2&quot; Type X gypsum</td>
<td>Half Lap</td>
<td>None</td>
<td>Reduced 76% Axial Capacity</td>
<td>1.5</td>
<td>106 min</td>
<td>1 (Test 2)</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>3-ply (1.78 69mm)</td>
<td>Structurlam</td>
<td>V2</td>
<td>1 layer 5/8&quot; Type X gypsum</td>
<td>Half Lap</td>
<td>None</td>
<td>Reduced 60% Max Design Load</td>
<td>1</td>
<td>76 min</td>
<td>8</td>
<td>Intertek December 2013</td>
</tr>
<tr>
<td>3-ply (1.78 69mm)</td>
<td>Structurlam</td>
<td>V2</td>
<td>1 layer 5/8&quot; Type X gypsum</td>
<td>Half Lap</td>
<td>None</td>
<td>Unreduced 100% Max Design Load</td>
<td>1</td>
<td>66 min</td>
<td>9</td>
<td>Intertek November 2014</td>
</tr>
<tr>
<td>3-ply (105mm)</td>
<td>Nordic</td>
<td>E1</td>
<td>1 layer 5/8&quot; Type C or Type X gypsum</td>
<td>Half Lap</td>
<td>None</td>
<td>Reduced, 50% Allowable Compression Parallel to Grain</td>
<td>1</td>
<td>Not Provided</td>
<td>10</td>
<td>UL (V320)</td>
</tr>
<tr>
<td>3-ply (105mm)</td>
<td>Nordic</td>
<td>E1</td>
<td>None</td>
<td>Half Lap</td>
<td>None</td>
<td>Loaded, See Manufacturer</td>
<td>0.5</td>
<td>32 min</td>
<td>20</td>
<td>Intertek 5/17/2012</td>
</tr>
<tr>
<td>3-ply (78mm)</td>
<td>Nordic</td>
<td>E1</td>
<td>5/8&quot; Type X gypsum over 2x3 SPF Stud @ 24&quot; on w/ 1 1/2&quot; mineral wool between stud</td>
<td>Half Lap</td>
<td>None</td>
<td>Loaded, See Manufacturer</td>
<td>1</td>
<td>83 min</td>
<td>22</td>
<td>Intertek 12/30/2011</td>
</tr>
<tr>
<td>5-ply (31 mm)</td>
<td>Nordic</td>
<td>E1</td>
<td>2 layers 5/8&quot; Type C or Type X gypsum</td>
<td>Half Lap</td>
<td>2 layers 5/8&quot; Type C or Type X gypsum</td>
<td>Reduced, 50% Allowable Compression Parallel to Grain</td>
<td>2</td>
<td>Not Provided</td>
<td>10</td>
<td>UL (V320)</td>
</tr>
<tr>
<td>5-ply (75mm)</td>
<td>Nordic</td>
<td>E1</td>
<td>1 layer 5/8&quot; Type C or Type X gypsum</td>
<td>Half Lap</td>
<td>1 layer 5/8&quot; Type C or Type X gypsum</td>
<td>Reduced, 50% Allowable Compression Parallel to Grain</td>
<td>2</td>
<td>Not Provided</td>
<td>10</td>
<td>UL (V320)</td>
</tr>
<tr>
<td>5-ply (75mm)</td>
<td>Nordic</td>
<td>E1</td>
<td>None</td>
<td>Half Lap</td>
<td>None</td>
<td>Reduced, 50% Allowable Compression Parallel to Grain</td>
<td>1</td>
<td>Not Provided</td>
<td>10</td>
<td>UL (V320)</td>
</tr>
<tr>
<td>5-ply (175mm)</td>
<td>Smartlam</td>
<td>SL-V4</td>
<td>2 layers 5/8&quot; Type X gypsum</td>
<td>Spline</td>
<td>2 layers 5/8&quot; Type X gypsum</td>
<td>Loaded, See Manufacturer</td>
<td>3.5</td>
<td>219 min</td>
<td>5</td>
<td>NRC Fire Laboratory Nov 2014</td>
</tr>
<tr>
<td>5-ply (6.78&quot;)</td>
<td>Smartlam</td>
<td>V1</td>
<td>None</td>
<td>Half Lap</td>
<td>None</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>120 min</td>
<td>11</td>
<td>Western Fire Center 5/25/2017</td>
</tr>
<tr>
<td>5-ply (175mm 8.873&quot;)</td>
<td>Nordic</td>
<td>SPF 1950 Fb MSR x SPF #3</td>
<td>None</td>
<td>Half Lap</td>
<td>None</td>
<td>Reduced 37% Axial Capacity</td>
<td>1.5</td>
<td>113 min</td>
<td>1 (Test 4)</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply (105mm)</td>
<td>Structurlam</td>
<td>SPF #1/#2 x SPF #1/#2</td>
<td>None</td>
<td>Half Lap</td>
<td>None</td>
<td>Reduced 35% Axial Capacity</td>
<td>1</td>
<td>57 min</td>
<td>1 (Test 8)</td>
<td>NRC Fire Laboratory</td>
</tr>
<tr>
<td>5-ply (175mm 6.875&quot;)</td>
<td>DR Johnson</td>
<td>V1</td>
<td>None</td>
<td>Half Lap</td>
<td>None</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>120 min</td>
<td>11 (Test 1)</td>
<td>Western Fire Center 9/28/2016</td>
</tr>
<tr>
<td>5-ply (175mm 6.875&quot;)</td>
<td>Smartlam</td>
<td>SL-V4</td>
<td>None</td>
<td>Half Lap</td>
<td>None</td>
<td>Loaded, See Manufacturer</td>
<td>1.5</td>
<td>101 min</td>
<td>11 (Test 2)</td>
<td>Western Fire Center 9/30/2016</td>
</tr>
<tr>
<td>5-ply (175mm 6.875&quot;)</td>
<td>Smartlam</td>
<td>V1</td>
<td>None</td>
<td>Half Lap</td>
<td>None</td>
<td>Loaded, See Manufacturer</td>
<td>2</td>
<td>120 min</td>
<td>11 (Test 3)</td>
<td>Western Fire Center 1/26/2017</td>
</tr>
</tbody>
</table>
Shaft Wall Assemblies

Options for Light-Frame Shaft Walls in Mass Timber Buildings

**FIGURE 4: UL U305**

1-Hour Single Wall
- UL U305
- GA WP 3510
- UL U311
- IBC 2012 Table 721.1(2), Item 14-1.3
- UL U332

1-Hour Double Wall
- UL U341

1-Hour Wall with Shaftliner
- UL V455
- UL V433
Shaft Wall Assemblies

Options for Light-Frame Shaft Walls in Mass Timber Buildings

2-Hour Single wall
- UL U301
- UL U334
- IBC 2012 Table 721.1(2) Item Number 14-1.5
- IBC 2012 Table 721.1(2) Item Number 15-1.16

2-Hour Double Wall
- UL U342
- UL U370
- GA WP 3820

FIGURE 5: UL U334

2-Hour Wall with Shaftliner
- UL U336
- UL U373
- UL U375
- UL V455
- UL V433
- GA ASW 1000
Shaftliner Systems - Benefits & Limitations

Benefits
» Allows installation from one side only – useful in small MEP shafts where finishing from inside isn’t possible

Limitations
» Some have height limitations, both per story and overall system
» Not structural, requires back-up wood wall
Floor to Shaft Wall Detailing

Construction erection and sequencing will inform efficient floor to wall intersection

[Diagram showing floor to shaft wall detailing with labels: Gypsum wallboard (if required), Mass timber shaft wall, Ledger for floor framing, Floor framing, Wood Ledger]
Floor to Shaft Wall Detailing

Steel Ledger

Shaft wall assembly

Mass timber floor panel

Steel ledger for floor framing support

Photo: WoodWorks
Floor to Shaft Wall Detailing

Recall fire barrier continuity definition:

*shall extend ... to the **underside of the floor or roof sheathing, slab or deck above and shall be securely attached thereto***

CLT is the “slab,” and it is not disrupting the continuity of the shaft wall.
Floor to Shaft Wall Detailing

Additional consideration:
» Adequate CLT bearing area
Shaft wall – Support Details
Shaftliner Systems – Support Details
Shaftliner Systems – Configuration Options

Can also utilize wood framed shaft walls or mass timber shaft walls on 1-3 sides and CH studs with shaftliner on remaining side(s)
Shaftliner Systems – Configuration Options

H-stud shaftliner with wood stud wall backup

3 sides of wood shaft walls installed first. If shaft is small enough, might suggest shaftliner system on more than one side.
Shaftliner Systems – Configuration Options

3 sides of wood shaft walls installed first. If shaft is small enough, might suggest shaftliner system on more than one side.

CH-stud shaftliner
Considerations for Lateral Systems

Prescriptive Code Compliance:
- Concrete Shear Walls
- Steel Braced Frames
- Light Frame Wood Shear Walls (65 ft max)
- CLT Shear Walls (65 ft max)
- CLT Rocking Walls

2021 SDPWS, ASCE 7-22
Currently in testing!
A prescriptive method for CLT rocking walls has been proposed (in case we get questioned on this)
Floor to Shaft Wall Detailing

Consider Differential Material Movements & Tolerances in Detailing
Mass Timber Shaft Wall Acoustics
# Acoustics & Sound Control

## Inventory of Tested Assemblies

### Table 7: Single CLT Wall

<table>
<thead>
<tr>
<th>CLT Wall Panel</th>
<th>Left Side Finish</th>
<th>Right Side Finish</th>
<th>STC</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>None</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 layers ½” type X gypsum</td>
<td>None</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>CLT 3-ply (3.07”)</td>
<td>2 layers ½” type X gypsum + 2x2 studs @ 16” o.c.</td>
<td>2 layers ½” type X gypsum</td>
<td>40^5</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>2 layers ½” type X gypsum + 2x2 studs @ 24” o.c.</td>
<td>None</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>
Mass Timber Shafts and Shaft Wall Solutions for Mass Timber Buildings

Presented by:
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Content also provided by:
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Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.
Project Information

- Confidential Office Project in the Pacific Northwest
- 6 Stories Mass Timber Type III-A over Type I-A basement structure
- Team
  - Architect: LEVER
  - Structural Engineer: Holmes
  - Fire & Life Safety Code Consulting: Holmes
Shaft Code Requirements

- IBC Section 713: Shaft Enclosures

- Shafts are constructed as fire barriers

- Shaft fire resistance rating (independent of construction type)
  - 1 hr: < 4 stories
  - 2 hrs: 4 stories or more

*not less than the floor it is penetrating
Shaft Code Requirements

• **713.5 Shaft continuity requirements per fire barrier requirements**

> 713.5 *Continuity.* Shaft enclosures shall be constructed as *fire barriers* in accordance with Section 707 or *horizontal assemblies* constructed in accordance with Section 711, or both, and shall have continuity in accordance with Section 707.5 for *fire barriers* or Section 711.2.2 for *horizontal assemblies*, as applicable.

• **707.5 Fire barrier continuity requirements**

> 707.5 *Continuity.* *Fire barriers* shall extend from the top of the foundation or floor/ceiling assembly below to the underside of the floor or roof sheathing, slab or deck above and shall be securely attached thereto. Such *fire barriers* shall be continuous through concealed spaces, such as the space above a suspended ceiling. Joints and voids at intersections shall comply with Sections 707.8 and 707.9.
Shaft Code Requirements

- 707.5.1 Supporting Construction: required to be the same fire resistance rating of the fire barrier being supported

From Section 718.2:

707.5.1 Supporting construction. The supporting construction for a fire barrier shall be protected to afford the required fire-resistance rating of the fire barrier supported. Hollow vertical spaces within a fire barrier shall be fireblocked in accordance with Section 718.2 at every floor level.
# Shaft Code Requirements

## Floor & secondary members FRR requirements per construction type

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<thead>
<tr>
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<th>Type III</th>
<th>Type IV</th>
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“Why have a shaft supported by a floor with a fire rating higher than the remainder of the building? Won’t you just end up with your shaft still standing while the building collapses around it?”
Shaft Code Requirements

“Why have a shaft supported by a floor with a fire rating higher than the remainder of the building? Won’t you just end up with your shaft still standing while the building collapses around it?”

Answer:
• Required by IBC!
• Without this, potential for fire spread through 2hr shaft to occur at 1hr fire exposure
Building Overview

270’x140’ 6 storey all mass timber superstructure

Structural System:

- Number of innovative structural solutions outside of design codes
- Long-span composite (CLT/GLT) floor cassettes (requires testing)
- Perimeter lateral & gravity structure (requires testing)
- Internal CLT shear walls with BRB hold-downs (relies on previous testing)
Shaft Schematic Approaches

III A Building
1 hr Structural Frame
Shaft Schematic Approaches

IIIA Building
1hr Structural Frame
2hr Shaft
Shaft Schematic Approaches

General Structural Gravity System:

- Columns
- Girders spanning east-west
- Mass Timber Double T Cassettes spanning north-south
Shaft Schematic Approaches

Particular shaft difficulties

- This project uses an exterior distributed lateral system, therefore no internal shear cores to frame out shaft openings
- All shaft openings must accommodate lateral movement without attracting lateral load
- Intent is to avoid cracking of brittle materials during a serviceability level event
- Exposed cassette soffit makes framing out openings difficult
# Shaft Schematic Approaches

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<td>Tied into shaft</td>
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<td>Typical construction, simple detailing, Load failure may occur</td>
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1: Floor Framed Around Shaft Opening

- 2hr shaft
- 2hr partition bypasses slab, runs continuously to base
- 1hr floor
- Girder collects beams, creates clear opening in slab
1: Floor Framed Around Shaft Opening

- 2hr partition bypasses slab, runs continuously to base
- 2hr rated, self-supporting shaft wall (shaftwall or gypsum within steel frame)
- Slotted holes to allow for differential vertical movement
- Lateral support to shaft from slab
1: Floor Framed Around Shaft Opening

2hr partition bypasses slab, runs continuously to base

This detail difficult to achieve architecturally
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Option 1 - Initial Design

Option 2 - Second Design

Option 3 - Final Design
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2: Floor Supported by Shaft

2hr shaft

2hr partition bypasses slab, rests on steel frame

1hr floor

Steel frame fills opening, supports 2hr partition infill
2: Floor Supported by Shaft

2hr partition bypasses slab, rests on steel frame

2hr rated, self-supporting shaft wall (shaftwall or gypsum within steel frame)

Steel hanger from shaft frame to support floor
2: Floor Supported by Shaft

- 2hr partition bypasses slab, rests on steel frame

- Difficulty for detailing fire barrier continuity

- This detail difficult to achieve architecturally
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<td>Shaftlined core w/ steel frame</td>
<td>Simpler detailing than 1b</td>
<td>Still requires seismic gap, shaft likely not strong enough</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1d</td>
<td>Tied-in Shaft</td>
<td>2Hr</td>
<td>2Hr</td>
<td>2Hr</td>
<td>Shaft</td>
<td>Shaftlined core w/ steel frame</td>
<td>Doesn't require seismic gap, shaft strength not required</td>
<td>Detailing would be difficult. Shaft needs to be slipped into shaft assembly with 2Hr and core shaft would likely not be strong enough.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1e</td>
<td>Tied-in Grav Core</td>
<td>2Hr</td>
<td>2Hr</td>
<td>2Hr</td>
<td>Shaft</td>
<td>Sim to platform framing but with 'flexible' walls</td>
<td>Typical construction, simple detailing</td>
<td>Vertical load down shaft needs to be resisted at transfer slab level. Also shaft can't sit on floor which is preferred detail.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2a</td>
<td>Typ Partition Framing</td>
<td>2Hr</td>
<td>2Hr</td>
<td>2Hr</td>
<td>Shaft</td>
<td>Typ light framed partition on 1hr floor</td>
<td>Often used on projects similar toTyp Partition Framing</td>
<td>1Hr structure supporting 2Hr floor must comply with IBC requirements. 1Hr structure supporting 2Hr floor must comply with IBC requirements.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2b</td>
<td>2hr Partition Framing</td>
<td>2Hr</td>
<td>2Hr</td>
<td>2Hr</td>
<td>Shaft</td>
<td>Typ light framed partition on 2hr floor</td>
<td>Satisfies all requirements, requires add'l bays of 2hr structure in project</td>
<td>Option 3 - Final Design</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Shaft Schematic Approaches

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Shaft</th>
<th>Floor</th>
<th>Example</th>
<th>Reason to use</th>
<th>Reason to not use</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Typ Shear /Grav Core</td>
<td>Self</td>
<td>Self</td>
<td>Tied into shaft</td>
<td>CMU core, platform-framed wood construction</td>
<td>Typical construction, simple detailing</td>
<td>Core not strong enough to resist loads attracted. Could detail to yield but may crack at SLE. Poor seismic performance.</td>
</tr>
<tr>
<td>1b</td>
<td>Isolated Shear /Grav Core</td>
<td>Self</td>
<td></td>
<td>Isolated from shaft</td>
<td>CMU core</td>
<td>Stops core attracting seismic load</td>
<td>Tricky detailing to slip floor relative to shaft, negates benefit of CMU core, seismic gap may be large</td>
</tr>
<tr>
<td>1c</td>
<td>Isolated Shear Core</td>
<td></td>
<td>Framed around shaft</td>
<td>Shaft</td>
<td>Shaftlined core w/ steel frame</td>
<td>Simpler detailing than 1b</td>
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<td></td>
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<td>Shaft</td>
<td>Shaftlined core w/ steel frame</td>
<td>Doesn’t require seismic gap, shaft strength not required</td>
<td>Detailing would be difficult. Shaft needs to be slipped in-plane to not attract load &amp; crack</td>
</tr>
<tr>
<td>1e</td>
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<td></td>
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<tr>
<td>2a</td>
<td>Typ Partition Framing</td>
<td></td>
<td>Framed around</td>
<td>Typical light-framed partition on 1hr floor</td>
<td>Often used on projects, similar to typ partition framing</td>
<td>Satisfies all requirements, however requires add'l bays of 2hr structure in project</td>
<td>1hr structure supporting 2hr shaft doesn’t comply with IBC</td>
</tr>
<tr>
<td>2b</td>
<td>2hr Partition Framing</td>
<td>Floor</td>
<td></td>
<td>shaft</td>
<td>Typ light-framed partition on 2hr floor</td>
<td>Per above but complies with IBC</td>
<td>Option 3 - Final Design</td>
</tr>
</tbody>
</table>

- **Shaft** (Self): Shaft rating (Self), 2HR (Self) for firewall. **Floor** (Self): Floor rating (Self). **Example**: Shaft is tied into the floor. **Reason to use**: CMU core, platform-framed wood construction. **Reason to not use**: Core not strong enough to resist loads attracted. Could detail to yield but may crack at SLE. Poor seismic performance.
3: Shaft Supported by Floor

- **2hr shaft**
- **Simple, in sequence partition framing bears on slab, moves with drift + deflection like typical partitions**
- **Glulam beams + CLT floor of cassette system wrapped with gypsum to add one hour of protection**
- **2hr floor**
- **Columns up-sized for char**
- **Girders not governed by fire loading scenario, but steel connection adapted to 2hr requirement**
- **Protected steel posts pick up glulam beams**

2hr shaft

2hr floor
3: Shaft Supported by Floor

Simple, in sequence partition framing bears on slab, moves with drift + deflection like typical partitions.

Glulam beams + CLT floor of cassette system wrapped with gypsum to add one hour of protection.

2hr protection afforded to floor structure (1hr char, 1hr from gyp lining).
3: Shaft Supported by Floor

<table>
<thead>
<tr>
<th>Element</th>
<th>1hr</th>
<th>2hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT Deck &amp; GLT Ribs</td>
<td>Unwrapped</td>
<td>(2) layers ⅝” gyp added</td>
</tr>
<tr>
<td>GLT Girders</td>
<td>Unwrapped</td>
<td>Unwrapped</td>
</tr>
<tr>
<td>GLT Girder - Column Connection</td>
<td>Embedded bearing pl w/ 1.8” blocking for char protection</td>
<td>Embedded bearing pl w/ 1.8” gyp for insulation protection</td>
</tr>
<tr>
<td>GLT Column Size (at base)</td>
<td>14.25x18”</td>
<td>14.25x25.5”</td>
</tr>
</tbody>
</table>
Detailing

Simple, in sequence partition framing bears on slab, moves with drift + deflection like typical partitions

Glulam beams + CLT floor of cassette system wrapped with gypsum to add one hour of protection
Framing Variations
Framing Variations

- 2hr Girders - 2-hr end connection 1.8"thk (GL blocking over (2) 5/8" Gyp)
- Upsized 2hr columns
- 1hr gyp lining added to deck structure
Framing Variations

Floor supported on steel posts, posts track down to ground floor concrete transfer slab

Floor supported on steel beams which frame out opening. Transfer slab inefficient due to openings

Elevator shaft walls supported by 2hr rated floor
Questions?

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