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Shaft Wall Solutions for Light-Frame and Mass Timber Buildings

An overview of design considerations, detailing options and code requirements

It is fairly common for mid-rise wood buildings to include shaft walls made from other materials. However, wood shaft walls are a code-compliant option for both light-frame and mass timber projects—and they typically have the added benefits of lower cost and faster installation.

A shaft is defined in Section 202 of the 2018 International Building Code[1] (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-engineering-plumbing (MEP) chases in multi-story buildings. While these applications might be similar in their fire design requirements, they often have different construction constraints and scenarios where assemblies and detailing may also differ.

This paper provides an overview of design considerations, requirements, and options for light wood-frame and mass timber shaft walls under the 2018 and 2021 IBC, and considerations related to non-wood shaft walls in wood buildings.

CONTENTS

Fire Resistance

Fire Barrier Construction

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

Provisions addressing materials permitted in shaft wall construction are given in both the shaft enclosures section (713.3) and fire barriers section (707.2). These


Credit: StructureCraft

Hotel Magdelena in Austin, TX

sections state that fire barriers can be constructed of any material permitted by the building's type of construction. This means dimension lumber (light-frame wood construction) or mass timber may be used for shaft walls in Type III, IV, and V bulidings per the construction type definitions in IBC Section 602. The one exception is when shaft walls in Type III or IV construction are also exterior walls. This requires that the exterior/shaft walls be fire retardant-treated wood framing. Under the 2018 IBC, exterior walls in Type IV construction are also permitted to be cross-laminated timber (CLT) when certain coverings are provided. For more on this, see *Shaft Walls That Are Also Exterior Walls.*

Fire-resistance ratings (FRRs) are defined in IBC Section 202 as *"The period of time a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function or both, as determined by the tests, or the methods based on tests, prescribed in Section 703."* Per IBC Section 713.4, shaft enclosures are required to have an FRR of not less than 2 hours when connecting four or more stories. An FRR of not less than 1 hour is required for shaft enclosures connecting less than four stories. Often misunderstood by designers is the difference between confinement of fire and the ability to continue to provide structural support. Fire resistance-rated walls may be required to do one or the other or both depending on the wall assembly and application. Shaft enclosures are only one type of fire barrier application and fire barriers are only one type of fire resistance-rated wall assembly. Requirements for these assemblies often differ from those for exterior walls, fire walls, and fire partitions—specifically requirements relating to continuity, structural support/stability, and penetrations.

Continuity

As defined in IBC Section 202, fire barriers are *"a fire resistance-rated wall assembly of materials designed to restrict the spread of fire in which continuity is maintained."* This clearly describes the intended function of this element as providing fire confinement.

IBC Section 707.5 states the requirements for fire protection continuity of fire barriers. It requires that fire barriers *"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 space, such as the space above a suspended ceiling."* This is one of the main distinctions between a fire barrier and fire partition. A fire partition (for example a corridor wall) is permitted to terminate at the underside of a fire resistance-rated floor/ceiling or roof/ceiling assembly while, under certain conditions, a fire barrier is required to extend up to the underside of the floor/roof sheathing.

This continuity condition is depicted in the code commentary in simplistic form where the shaft wall runs parallel to the floor framing (Figure 1). However, in platform-frame buildings there will usually be shaft walls that directly support perpendicular framing elements. It is important to understand that continuity of the assembly can be maintained, even in these scenarios.

Having a single fire resistance-rated assembly running from the bottom to the top of a shaft enclosure with no interruptions, such as a masonry wall, is considered by some to be the clearest path to meeting this requirement. However, given the potential costs and structural challenges associated with integrating masonry shaft walls in wood-frame buildings, wood-frame shaft walls are becoming increasingly popular. The requirement of IBC Section 707.5 is for continuity, but this doesn't dictate the use of only one assembly or material. Since *fire protection continuity* doesn't equate to *wall framing* or *membrane protection continuity,* using means of fire protection other than the tested wall assembly in the depth of the framed floor can be an effective way to provide the required continuity.

Ultimately, the detail used will reflect what the building official accepts in terms of fire protection continuity of the shaft wall's required FRR. In varying degrees (depending on the detail) the shaft wall will need to be interrupted to attach the adjacent floor framing and floor sheathing. The methods used at this floor-to-wall intersection will also depend somewhat on the floor framing configuration. See *Detailing Floor-to-Wall Intersections* for examples of how this condition has been detailed by different designers.

Example of fire barrier wall continuity, extending to underside of floor/roof sheathing above

Example of a fire partition wall

Supporting Construction

Going back to the definition of a fire barrier, there is no described intent for the fire barrier to provide structural support to the building during a fire event; it is merely intended to confine the fire for the duration of the required fire rating. Unlike fire wall assemblies, fire barriers and shaft enclosures do not specifically require structural stability unless they are also an exterior wall per IBC 707.4. However, it is important that the building elements supporting the fire barrier also remain in place for the same duration.

IBC Section 707.5.1 requires that *"The supporting construction for a fire barrier shall be protected to afford the required fire-resistance rating of the fire barrier supported."* In the scenario where a fire barrier wall line is vertically discontinuous (e.g., fully stopped at a floor), it is clear that the floor is indeed a direct support. For example, if the floor were to fail at 1 hour, the wall above could not continue to contain the fire for 2 hours. However, in the condition where the fire barrier wall is supported by another fire barrier wall below and the floor is merely a framing element in between, the fire endurance of the floor assembly that lies between the two fire barrier assemblies would not affect the ability of the fire barriers above and below to perform for the full duration of their intended fire resistance. In this scenario, maintaining the code's continuity requirements for the wall through the floor depth should also satisfy the supporting construction requirements.

Before discussing methods used to establish continuity of the shaft wall at floor and roof intersections, the relevance of provisions related to joints and penetrations should be addressed.

Joint vs. Intersecting Assemblies

In some instances, confusion comes from looking at IBC Section 707.8, which states:

"Joints made in or between fire barriers, and joints made at the intersection of fire barriers with underside of a fire resistance-rated floor or roof sheathing, slab or deck above, and the exterior vertical wall intersection shall comply with Section 715."

Compliance with Section 715 requires that the "joint" be protected with a material that meets ASTM E1966 or Underwriters Laboratory (UL) 2079. (See IBC Section 715.3.) However, the "joints" referenced in Sections 707.8 and 715 are those where a linear gap exists between the top of the fire barrier and underside of the floor sheathing that would allow free passage of fire. Examples include a seismic isolation joint or an expansion joint. The code commentary to IBC Sections 707.8 and 715.1 further clarifies this.

A joint is defined in IBC Section 202 as: *"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."*

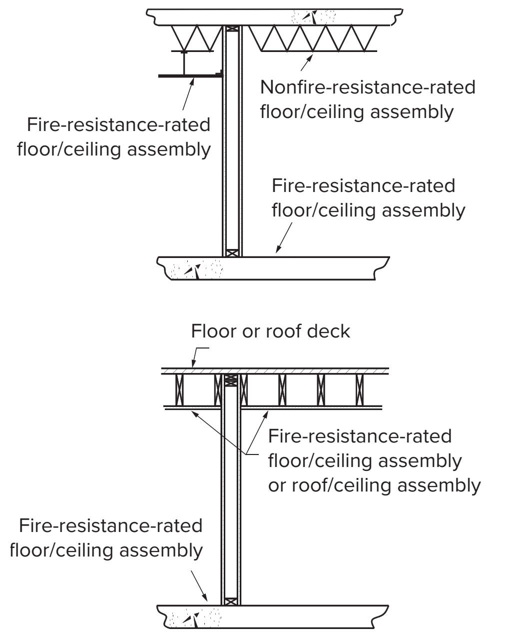


FIGURE 1: IBC Commentary Figure 707.5 – Continuity of fire barriers

In Figure 1, which depicts a typical fire barrier condition, note that the wall and its membrane (gypsum wallboard) continue to the underside of the floor sheathing with no reference to the need for a fire-rated "joint."

Figure 715.1 from the IBC Commentary (Figure 2) uses shading to illustrate the "joint" at the head of the wall where the actual fire barrier stops short of the floor sheathing, such as would be the case for a seismic joint or isolation/expansion joint.

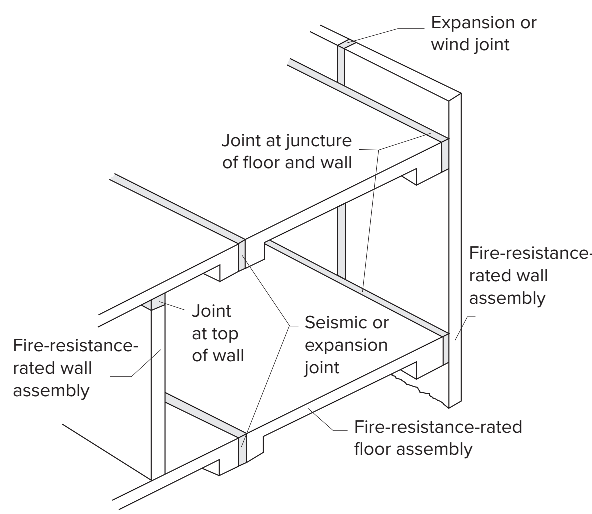


FIGURE 2: IBC Commentary Figure 715.1 – Examples of joint locations

A joint occurs at the top of a wall when the fire-resistance rating of the wall assembly stops short of the floor or roof deck above. Providing joint protection in compliance with Section 715.3 is not necessary when the fire-resistance rating of the fire barrier is maintained to the bottom of the deck (as is common in light-frame shaft wall construction). This can be achieved in several ways, including:

- Extending shaft wall *framing* to underside of sheathing: In this scenario, the top plate of the fire resistance-rated wall assembly continues to the underside of the floor/roof sheathing with gypsum attached per the approved assembly. This is the condition shown in the code commentary Figure 707.5 (Figure 1). This is commonly done either where the joists span parallel to the shaft wall or where they span perpendicular to and are hung from the shaft wall using top flange hangers.
- Extending shaft wall *rating* to underside of sheathing: When supporting floor framing in a platform-frame condition, the top plate of the lower wall occurs at the underside of the floor joist. The fire rating can still continue to the underside of the floor/roof sheathing by either continuing the wall membrane (gypsum) up and around the joist (creating a membrane penetration) or by using exposed wood blocking in the depth of the floor framing and providing an FRR matching that of the wall above and below through calculated fire resistance (described in *Detailing Floor-To-Wall Intersections*).

Structural Shaft Wall Penetrations

It is often necessary to penetrate a shaft wall with a structural member such as floor sheathing, a landing beam, or floor joists. The allowance for these penetrations comes from IBC Section 713.8, which states that *"Penetrations in a 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."*

The common objection to shaft wall structural penetrations comes from Section 707.7.1, which includes language regarding prohibited penetrations in fire barriers. The penetrations for exit access are restricted as described in Sections 1023.5 and 1024.6 for interior exit stairways and exit passageways. However, these sections only directly address penetrations to accommodate MEPF and therefore do not contradict Section 713.8.

Stair landing beam shaft wall structural penetration prior to firestop system installation

IBC Section 714.4 requires that penetrations into or through shaft walls (fire barriers) comply with Sections 714.4.1 through 714.4.3. There are two kinds of shaft wall penetrations to consider: "through penetrations" and "membrane penetrations." These terms are defined in IBC Section 202. By definition, a membrane penetration is *"a breach in one side of a floor-ceiling, roof-ceiling or wall assembly to accommodate an item installed into or passing through the breach."* The penetrant does not need to be a cable, cable tray, conduit, tubing, or pipe in order to be a "penetrant." Structural elements penetrating one side of a wall, celling or floor assembly are considered membrane penetrations, as described in Section 713.8.

As such, Section 714.4.2 requires membrane penetrations to comply with Section 714.4.1 (unless noted exceptions are met). This section requires that either:

1. Penetrations shall be installed as tested in an approved fire resistance-rated assembly (i.e., incorporated during the conduct of an ASTM E119 test of the wall or floor assembly, per Section 714.3.1.1) or, *more commonly*
2. Protected by an approved penetration firestop system installed as tested in accordance with ASTM E 814 or UL 1479, with an F (flame) rating of not less than the required FRR of the wall penetrated (per Section 714.4.1.2).

The provisions for membrane penetrations (i.e., a landing beam penetrating one side of a shaft wall, etc.) are circular referencing these same options available for through penetrations. As noted above, the option given in IBC Section 714.4.1.2 is the most common approach and typically involves the use of a tested, approved firestop system (fire caulk is commonly a component of this system) to seal around structural penetrations in shaft walls. The firestop manufacturer's tested system report should be referenced for appropriate installation details and product applications.

Stair shaft at exterior wall

Shaft Walls That Are Also Exterior Walls

In building types such as multi-family, it is common to have stair and elevator shafts located at the ends and corners of the building. When a shaft wall also forms a portion of the perimeter of the building, the following code provisions apply.

Section 713.6 Exterior walls. *Where exterior walls serve as a part of a required shaft enclosure, such walls shall comply with the requirements of Section 705 for exterior walls and the fire resistance-rated enclosure requirements shall not apply.*

Exception: Exterior walls required to be fire resistance-rated in accordance with Section 1021.2 for exterior egress balconies, Section 1023.7 for interior exit stairways and ramps and Section 1027.6 for exterior exit stairways and ramps.

Section 1023.7 Interior exit stairway and ramp exterior walls. *Exterior walls of the interior exit stairway and ramp shall comply with the requirements of Section 705 for exterior walls. Where nonrated walls or unprotected openings enclose the exterior of the stairway or ramps and the walls or openings are exposed by other parts of the building at an angle of less than 180 degrees (3.14 rad), the building exterior walls within 10 feet (3048 mm) horizontally of a nonrated wall or unprotected opening shall have a fire-resistance rating of not less than 1 hour. Openings within such exterior walls shall be protected by opening protectives having a fire protection rating of not less than 3/4 hour. This construction shall extend vertically from the ground to a point 10 feet (3048 mm) above the topmost landing of the stairway or ramp, or to the roof line, whichever is lower.*

As noted in the above code sections, shaft walls that are also exterior walls can be rated per the exterior wall requirements. IBC Tables 601 and 602 provide the FRR requirements for exterior walls. It is important to note that exterior walls with a fire separation distance greater than 10 ft are only required to be rated for exposure to fire from the inside face of the exterior walls per IBC Section 705.5. IBC Section 202 provides a definition of fire separation distance. Following the provisions of the code sections cited above, it is not uncommon to have a nonrated shaft wall along the perimeter of the building. Under this circumstance, the sections of exterior wall adjacent to the shaft must be rated for a minimum of 1 hour for a minimum of 10 ft away from the shaft. The intent of the code here is to prevent a fire in the main area of the building from running through the unrated exterior wall and then over and into the shaft.

Shaft Enclosure Tops

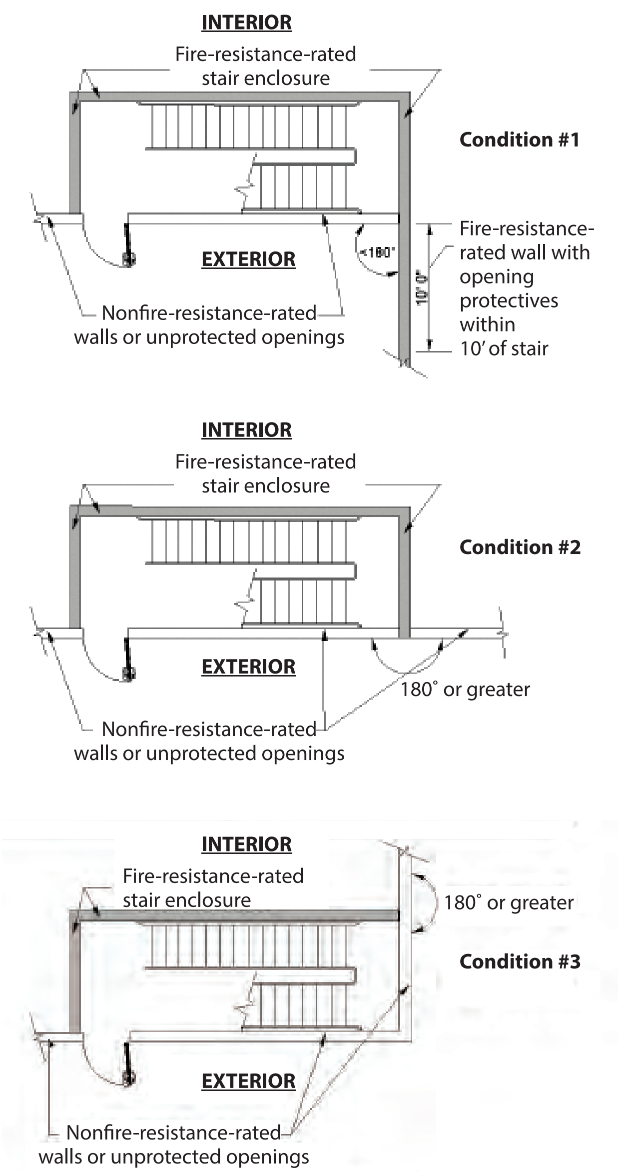
This paper—and most discussion related to shaft enclosure design—is centered on the shaft walls. However, not to be overlooked is the shaft enclosure top. IBC Section 713.12 states that shaft enclosures must extend to the underside of the roof sheathing, extend past the roof assembly, or be capped with construction having the same FRR as either the topmost floor penetrated or the shaft enclosure, whichever is greater. The code commentary to this section provides further narrative on shaft enclosure top construction requirements:

Proper shaft enclosures must include all sides and the top unless the top of the shaft is also the roof of the building. Because the purpose of the shaft is to limit the spread of fire within the building, if the top of the shaft does not extend to or through the underside of the roof sheathing, deck or slab, then the code requires a fire resistance-rated horizontal assembly at the top. The fire-resistance rating for the top of the shaft must not be less than the required fire resistance of the shaft enclosure or the fire-resistance rating of the highest floor penetrated (see IBC Commentary Figure 713.12). The required rating for the top of the shaft that extends to the sheathing or roof deck must be consistent with the requirements of Table 601 and Section 711 for roof construction. The top of the shaft must be constructed using a horizontal assembly (see Section 711) with the proper fire-resistance rating. It is not permissible to simply take a fire barrier, such as the assembly used for the shaft wall, and turn it horizontally.

Assembly Options

Assemblies and Intersections

The first step in detailing shaft wall construction is to select the rated wall assembly that is appropriate for the application. The assembly type chosen will depend on several application-specific constraints, including space available for the wall assembly, accessibility to finish gypsum wallboard, height of the shaft, acoustic needs, and construction efficiency. In some cases, the floor-to-wall intersection detailing necessary for plan approval may affect the type of wall assembly chosen (i.e., single wood wall, double wood wall, shaftliner, or other).



For SI: 1 foot - 304.88 mm, 1 degree - 0.01745 rad

FIGURE 3: IBC Commentary Figure 1022.7(1)

As noted, per IBC Section 713.4, shaft enclosures are required to have an FRR of not less than 2 hours when connecting four or more stories. An FRR of not less than 1 hour is required for shaft enclosures connecting less than four stories. Some options for fire resistance-rated, wood-frame wall assemblies that could be useful for shafts are presented below. This is not intended to be an exhaustive list, but rather a few examples.

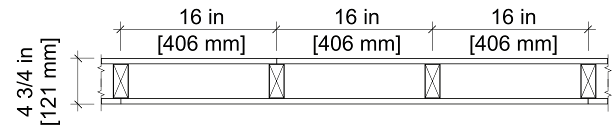


FIGURE 4: UL U305

1-Hour Single Wall

- UL U305
- GA WP 3510
- UL U311
- IBC 2012 Table 721.1(2), Item 14-1.3
- UL U332
- Intertek WPPS 60-01

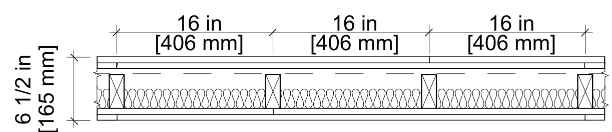


FIGURE 5: UL U334

1-Hour Double Wall

- UL U341

2-Hour Single Wall

- UL U301
- UL U334
- UL W408
- 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
- UL U350
- GA WP 3820

The double wall options provide opportunities for higher acoustically-rated assemblies and/or a way to decouple membrane continuity and structural support. In particular, better acoustical performance may be desired when shaft walls separate the shaft from a residential unit or other occupied space.

For more information on acoustical performance of light-frame wood walls, see the WoodWorks publication, *Acoustical Considerations for Mixed-Use Wood-Frame Buildings*.[2]

Some designers also utilize shaftliner panels. Shaftliner panels are typically thicker than a normal gypsum panel (1-in.-thick is common) and come in sizes that can be installed easily between CH-, CT-, or H-studs (e.g., 24 in. wide and 8 ft to 12 ft long). These studs are cold-formed steel sections that hold the shaftliner panels together and eliminate the need for gypsum panel joint finishing. They are attached to and laterally supported by adjacent wood-frame walls with cold-formed steel clip angles. Some assemblies are tested with the supporting wood structure (UL U375) and others are not (GA ASW 1000). This is an important distinction to make when discussing continuity and structural support. Even if included in the tested wall assembly, the wood walls are usually assumed not to be providing part of the wall's FRR. The 1-hour or 2-hour rating can typically be accomplished solely with the shaftliner panels. If tested with a supporting wood structure, only lateral bracing of the shaftliner panels is assumed. The weight of the panels is carried through the panels to the foundation unless specifically detailed otherwise.

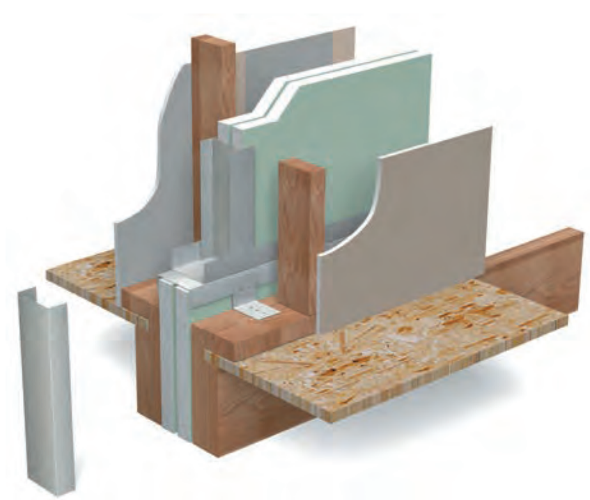


FIGURE 6: Shaftliner wall assembly with wood wall on each side *Credit: ClarkDietrich*

Assemblies such as UL U336 have an option for a single wood-frame wall supporting a double shaftliner gypsum membrane. A second wood wall could be used on the other side of the double gypsum membrane to support floor framing (i.e., stair and landing framing). Alternatively, only one wood wall could be used (on the non-shaft side) and the gypsum membrane could face the inside of the shaft. This allows structural support of the main floor and roof framing to occur without penetrating the membrane.

1-Hour Wall with Shaftliner

- UL V455
- UL V433

2-Hour Wall with Shaftliner

- UL U336
- UL U373
- UL U375
- UL V455
- UL V433
- GA ASW 1000

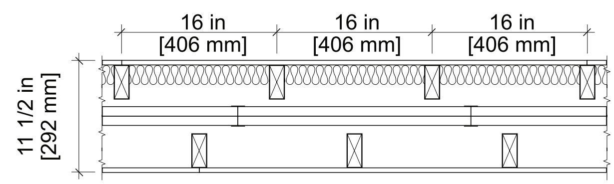


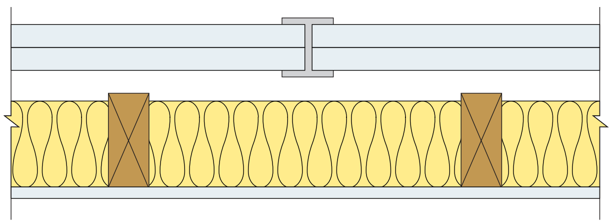
FIGURE 7: UL U336

When selecting shaft wall assemblies, a common question is whether shaft wall FRRs are required from both wall faces or just one. This may come up when using mass timber shaft wall assemblies where the designer wants exposed mass timber on the shaft side, and finish materials on the non-shaft side for acoustics and other reasons (or when any nonsymmetrical shaft wall assembly is used). Although the general function of the shaft wall may be seen as needing to prevent a fire that starts in the main floor area of a building from advancing into the shaft enclosure (as opposed to preventing a fire that starts in the shaft enclosure from spreading to the main floor area), the code requirements clearly state that shaft walls must be rated for the required fire endurance from both faces.

IBC 703.2.1 notes that *"Interior walls and partitions of nonsymmetrical construction shall be tested with both faces exposed to the furnace, and the assigned fire-resistance rating shall be the shortest duration obtained from the two tests conducted in compliance with ASTM E119 or UL 263."* Additionally, the code commentary to section 713.4 states: *"The intent is that fire resistance-rated shaft enclosure walls must be rated for fire exposure from both sides. That is, they must be symmetrical assemblies or assume the rating of the least-rated side."*

Height Limitations on Walls With Shaftliner Panels

A common question that arises when utilizing shaftliner panels is that of limiting heights, both floor-to-floor and overall, of the shaftliner panel system. Many shaftliner manufacturers publish maximum floor-to-floor heights and/or maximum system height limitations. An example is the System Design Considerations chapter of United States Gypsum's *Gypsum Construction Handbook*, which says their cavity-type area separation wall systems have a limiting height of 44 ft and four stories. Another example is assembly UL U375, which allows a total system height up to 66 ft but requires different H-stud clip angle spacing depending on total system height.



59 STC Sound Transmission

Test Reference: RAL TL 10-290

Two layers 1" (25.4 mm) shaftliner inserted in H-studs 24" (610 mm) o.c., min. 3/4" (19 mm) air spacing between liner panels and adjacent or wood metal framing

Sound tested with 2"x4" stud wall with 1/2" (12.7 mm) wallboard or interior panels and 3-1/2" (89 mm) fiberglass insulation in stud space

FIGURE 8: UL U373
Credit: Georgia Pacific

Shaftwall

FIGURE 9: UL V433 shaft wall with CH-studs and shaftliner panel *Credit: ClarkDietrich*

These systems have height limits because they are designed to be non-load bearing walls. As the self-weight of the wall assembly accumulates throughout the height of the wall, axial stresses on the non-load bearing steel studs could increase to the point where they become inadequate, creating a need for a limiting height. Also, these walls are generally designed for a minimal internal horizontal pressure, typically at least 5 pounds per square foot (psf). Prescriptive allowable height tables published by the manufacturer can potentially be increased when the project's structural engineer analyzes the cold-formed steel stud sections to determine their capacity against actual loading conditions. Most CH-stud manufacturers provide structural section properties for their products that can be used for this purpose. Most of these sections are available in 25-gauge and 20-gauge options,so using the slightly thicker 20-gauge option could potentially make a taller wall height work. Additionally, 4-in.-deep and 6-in.-deep CH-stud sections are typically available and would have higher load capacities than the standard 2-1/2-in.-deep option. The wall stud and system manufacturer should be consulted for input on options that exceed their published allowable height tables.

Some manufacturers recommend installing control joints in shaftliner panel walls at 30-foot maximum vertical intervals. However, this does not mean the entire stacked wall height is necessarily limited to 30 ft.

If a proposed shaft wall using shaftliner panels does not meet the total system height limitations, supporting the mass of the wall at intermittent heights off the adjacent floor structure is an option. Maintaining the wall's FRR at the support attachment locations is a primary design objective if choosing this option.

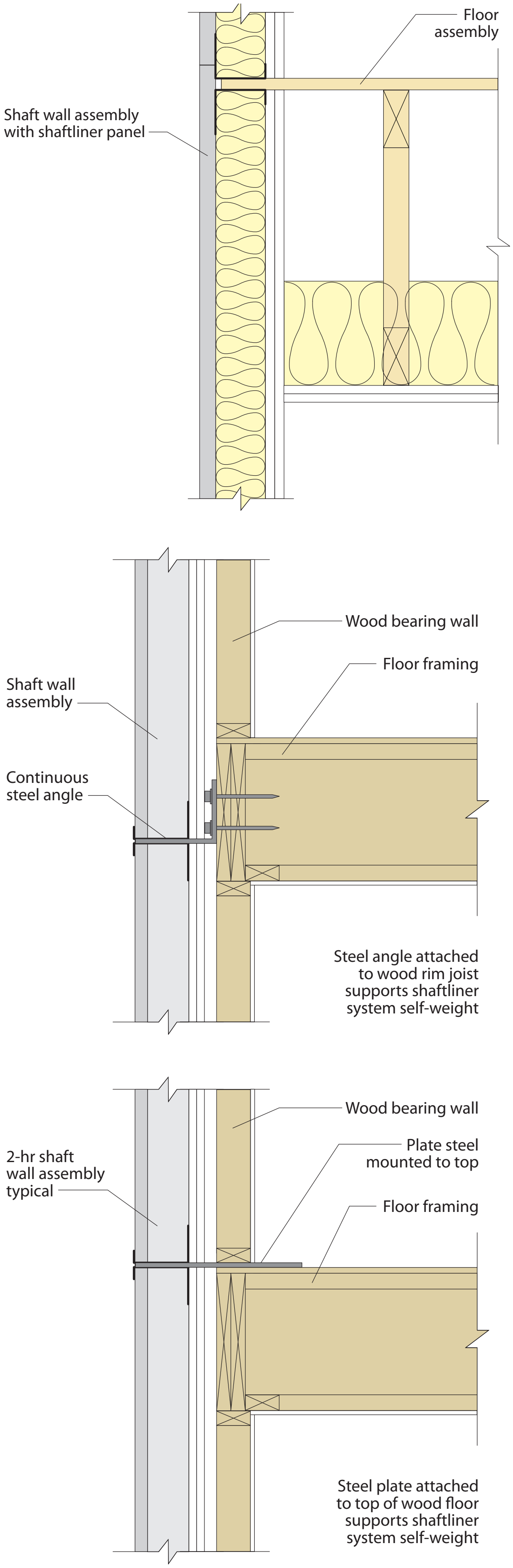


FIGURE 10: Options for non-bearing shaft liner wall assembly gravity load support

Detailing Floor-to-Wall Intersections

Once the typical wall assembly for the shaft has been selected, the detail at the floor-to-shaft intersection should be addressed. The look of this detail will depend on the floor joist type and bearing condition. To varying degrees (depending on the detail used), the shaft wall will need to be interrupted to allow attachment of the adjacent floor/roof framing and sheathing. As indicated, the main design criteria to consider is fire protection continuity through the floor/ceiling cavity.

While local code interpretation varies widely, several detailing concepts have arisen across the country as possible solutions to this floor-to-shaft wall issue, as illustrated by the options described below. The local building official will have the final say on a given detail's acceptability. It is often prudent to have a discussion with the building official regarding items such as this early in the project's design phase. If assistance is desired, contact your local WoodWorks technical expert to gain a better understanding of regional variations and detailing preferences. (For contact information, visit www.woodworks.org/project-assistance.)

For more information on floor-to-exterior wall intersection detailing in wood-frame construction, see the American Wood Council (AWC) publication, *DCA 3: Fire-Resistance-Rated Wood-Frame Wall and Floor/Ceiling Assemblies.*[3]

One method of demonstrating continuity of the shaft wall through the floor or roof cavity is having the wall gypsum stop at the underside of the floor framing and installing wood blocking in the floor cavity, aligned with the gypsum above and below. The concept is that each 2x wood block provides approximately 1 hour of protection. This rationale is codified through IBC Section 722.1, which references Chapter 16 of AWC's National Design Specification® (NDS®) for Wood Construction for calculated fire resistance of exposed wood members and decking.

NDS Chapter 16 indicates that the nominal char rate of a number of wood products, including solid sawn lumber, is 1.5 in. per hour. It is worth noting that these 2x blocking members are not structural members. Therefore, the nominal char rate of 1.5 in. per hour is applicable rather than the effective char rate (which is slightly higher). The effective char rate, which accounts for the char-affected zone, heat zone stiffness reductions, and rounding of wood member corners, is typically only applied to structural members. See Figure 11 for an example of this detail. The type of floor joist (e.g., solid sawn, I-joist, truss) will have an impact on this detail. Blocking between joists should fit tight to all joist components in the plane of the wall (top and bottom chords and web if applicable). Some designers will rely on the rated floor/ceiling assembly as contributing to the overall intersection's rating, thereby potentially reducing the need for one of the two plies of blocking between joists.

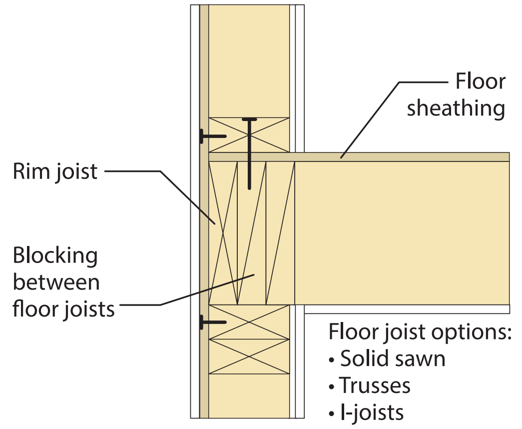


FIGURE 11: Floor-to-shaft wall intersection with blocking between floor joists

Another option is to extend the wall gypsum on the floor side of the shaft wall up to the underside of the floor/roof sheathing between the floor/roof joists. This requires interruptions of the gypsum at the joists. However, it is important to consider the structural requirements of the project—i.e., the need for gravity and diaphragm forces to transfer to the shaft wall—in addition to the fire protection detailing. See Figure 12 for an example of this detail. The joist is simply a structural penetration, which is allowed in shaft wall construction. Notice there is no cavity created in this application. As noted, Section 713.8 does require that penetrations be protected with an approved firestop system at the joist/membrane interface.

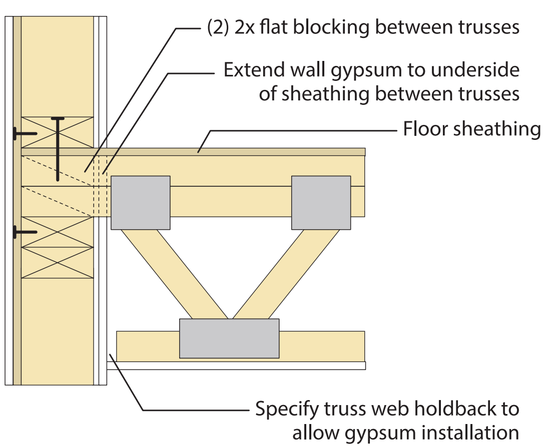


FIGURE 12: Floor-to-shaft wall intersection with gypsum extending to underside of sheathing between trusses

A third option is to install a floor beam parallel to and just inboard of the shaft wall (12 in. to 24 in. inboard). This beam would support all of the framing perpendicular to the shaft wall such that the only element penetrating the shaft wall is the floor sheathing. This option is only feasible if the length of the shaft wall is such that a reasonable beam size can still be used. Walls or beams parallel to and just beyond the ends of the shaft are used to support the ends of the above-mentioned beam. See Figure 13 for an example of this detail.

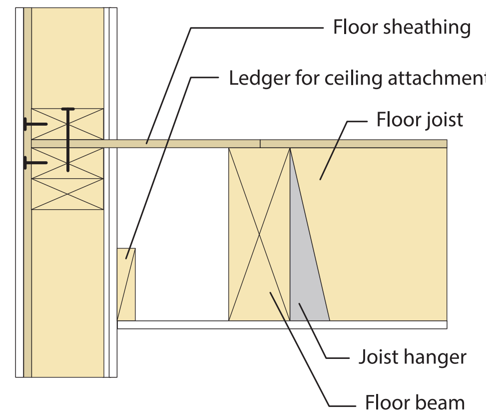


FIGURE 13: Floor-to-shaft wall intersection with supporting beam just inboard of wall

A final option is to run the gypsum continuously behind the floor joists up to the underside of the floor/roof sheathing. The joists are hung from the wall with a top flange hanger or face mount hanger capable of spanning over one or two layers of gypsum. See Figure 14 for an example of this detail. This semi-balloon-frame detail is not uncommon in exterior wall-to-floor intersections in Type III construction projects. Therefore, in those circumstances, extending this detail to the shaft walls can often be an easy choice.

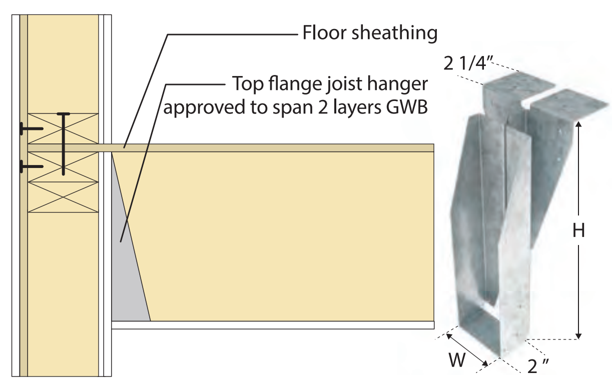


FIGURE 14: Floor-to-shaft wall intersection with hangers designed to span over gypsum
Credit (image on the right): MiTek Builder Products

Shaft Wall Applications

The three main types of shafts in commercial and multi-family construction are elevators, stairs, and mechanical. Some of the following principles apply to all of these shafts, while some are unique to each.

Stair Shafts

Many variables go into detail selection of shaft walls, particularly at floor-to-shaft intersections. Stair shafts are unique when compared to elevator shafts and mechanical shafts in that they have framing within the shaft (stair and landing framing) that needs to be accommodated.

Once the typical wall assembly and main floor-to-shaft wall detail have been selected, the next detailing considerations involve attaching the stair framing—stringers and landing framing—to the shaft walls. Many of the same considerations for main floor-to-wall detailing exist at this stair framing-to-wall detail. The difference is that a break/joint in the wall studs is typically not present at the stair and intermediate landing framing-to-wall attachment. Due to this, it is common to run both layers of wall gypsum up the face of the wall and attach the stair and landing framing to the shaft wall through the wall gypsum, which means there is no membrane penetration needed.

To accomplish this detail, a ledger is typically attached to the shaft wall through the layer(s) of gypsum that extend continuously up the shaft. The stair/landing framing is hung from the ledger and the stair/floor sheathing may or may not extend into the shaft depending on the wall plate elevation. Note that this configuration requires special attention to design of the fasteners attaching the ledger to the wall. It also requires careful attention during ledger fastener installation to ensure that the fasteners are centered in the wall studs. For easier installation, smaller strips of wall gypsum can sometimes be installed behind the ledger, keeping wall stud location visibility high during fastener install.

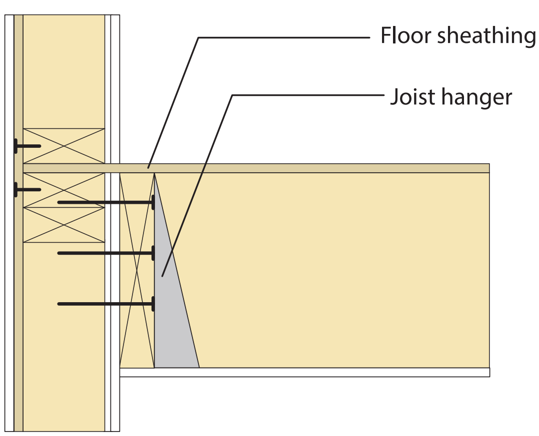


FIGURE 15: Floor framing ledger attached to shaft wall through two layers of gypsum

Stair landing framing attached to shaft wall through two layers of gypsum prior to landing beam hanger installation

Fasteners installed through gypsum wallboard can be large and difficult to accommodate when supporting larger loads because of eccentricity on the fastener and compression capacity of the gypsum. In addition to fastener requirements, regardless of the magnitude of loads, construction sequencing is a significant concern. Some contractors will begin by installing a strip (or strips) of moisture-resistant gypsum wallboard only where the structure will attach to the shaft wall, and wait to install the rest of the shaft gypsum after all the framing is installed. See image above for an example.

Although this can be done, a few options exist to avoid this potential construction sequencing challenge. One option is to install blocking and/or a ledger in/on the shaft wall. A ledger interrupting the plane of the membrane of the fire resistance-rated assembly is considered a membrane penetration and must be detailed accordingly (Section 714). In this scenario, blocking would be installed in the wall to provide fire protection continuity (through charring calculations per NDS Chapter 16). If the shaft wall rating is 2 hours, another variation on this detail is to run one layer of gypsum wallboard continuously between the ledger and shaft wall framing while providing one layer of 2x blocking in the wall, in line with the ledger, to complete the 2-hour rating continuity. See Figure 16 for an example of this detail.

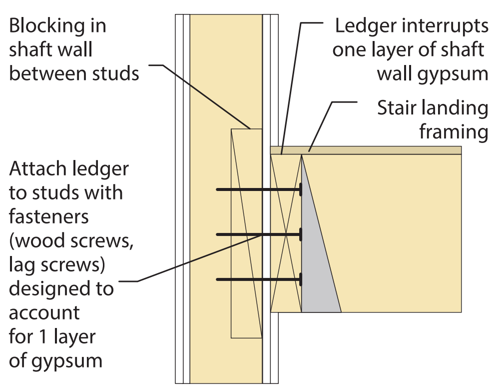


FIGURE 16: Stair framing to shaft wall attachment with blocking in lieu of one continuous gypsum layer

An alternative to interrupting the shaft wall gypsum is to install a spanning structural beam just inboard of the shaft wall to support the landing framing. This option requires discrete shaft wall penetration locations. The beam penetrating the shaft wall could be oversized to provide 2 hours of protection through char rates, or it could be installed in a fire-protected beam pocket in the shaft wall. See Figure 17 for an example.

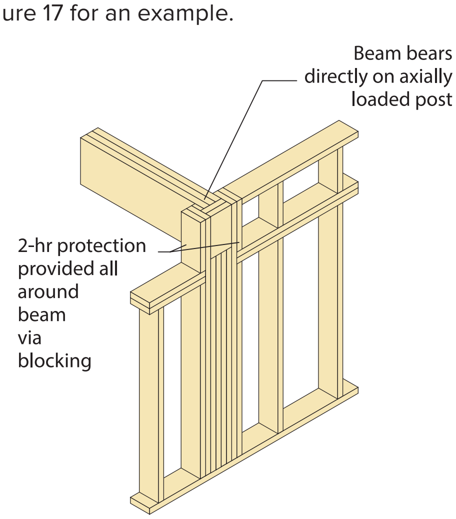


FIGURE 17: Stair framing beam in protected pocket in the shaft wall

Credit: Jeff Morrow

CLT was used for stair framing and shaft walls at the Candlewood Suites Hotel at Redstone Arsenal, AL

In addition to framing the stair shaft walls with wood, there is also opportunity for wood-frame stairs and landings. IBC Section 1011.7 notes that stairs may be constructed with materials that are permitted for the construction type of the building. This indicates that, where the use of combustible materials is not limited—i.e., Types III and V construction—light wood framing can be used to frame stairs and landings. Heavy timber framing can be used to frame stairs in Type IV buildings, which allow heavy timber for all interior framing including floors.

There are no specific FRR requirements for stair and landing framing. This is corroborated in the code commentary to Section 1011.7:

In keeping with the different levels of fire protection provided by each of the five basic types of construction designated in Chapter 6, the materials used for stairway construction must meet the appropriate combustibility/noncombustibility requirements indicated in Section 602 for the particular type of construction of the building in which the stairway is located. This is required whether or not the stair is part of the required means of egress. Any structure supporting the stairway and the stairway enclosure must be fire-resistance rated consistent with the construction type; however, the stairway components inside the enclosure need only comply with the material limits for the type of construction.

The presence of wood stair and landing framing (and other combustible materials) may affect the need for sprinkler protection within the shaft. See NFPA 13 Section 8.15.2 for additional information.

In mid-rise structures, the use of the horizontal building provision (for podium or pedestal-style buildings) in IBC Section 510.2 is common. When the building above the podium is Type III, IV or V wood-frame construction, the portion of the stair shaft and framing above the podium can therefore be framed in wood. However, a common question is whether stair framing below the podium may also be framed with wood. To address this, it is useful to look at the wording of Section 510.2:

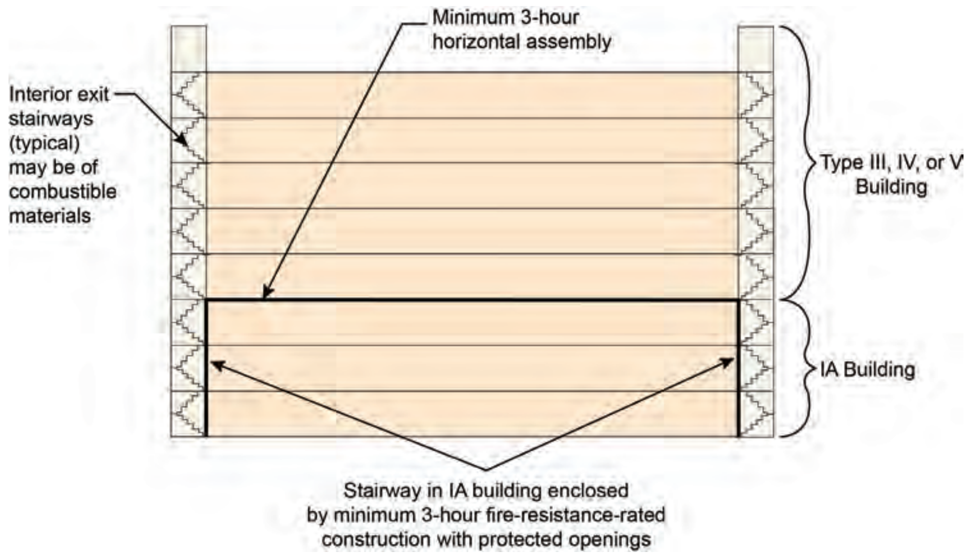


FIGURE 18: IBC 2021 allows combustible stair framing in the podium level(s) of Type III, IV or V buildings

510.2 Horizontal building separation allowance.
A building shall be considered as separate and distinct buildings for the purpose of determining area limitations, continuity of fire walls, limitation of number of stories and type of construction where all of the following conditions are met ...

One of the conditions in Section 510.2 is that the building below the horizontal assembly be of Type I-A construction. Type I-A is required to be framed with noncombustible materials and no exceptions to this exist in IBC Section 603 that would apply to stair and/or floor framing. Based on these code sections, previous versions of the IBC have required that stair construction below the podium be framed with non-combustible materials, even though the stair framing in the building above the podium is wood-framed and they share a common shaft enclosure. However, in recognition of this common design scenario, the 2021 IBC was changed to allow combustible stair framing in the podium level(s) of buildings where the building above the podium is of Type III, IV or V construction. Item 4 in Section 510.2 of the 2021 IBC contains the new allowances, as illustrated in Figure 18.

Example of wood stair framing below the podium in a mid-rise project

Elevator Shafts

Many of the same design considerations and wall assembly options that exist for stair shaft walls also apply to elevator shaft walls, though acoustical design considerations are perhaps more pronounced in elevator shaft walls than stair and mechanical shafts. The distinguishing factor in elevator shafts is design of the rail supports. In some instances, elevator rails are attached to the structure at each floor level. In others, the rails can attach at any elevation in the shaft. For the former option, a rim joist is typically implemented in the adjacent floor framing for rail bracket attachment. These rim joists provide backing to bolt the connecting plates to the shaft. Additional blocking and strapping are provided around the perimeter of the shaft to transfer the elevator's horizontal forces into the floor diaphragm. To compensate for shrinkage of the wood framing, the bracket attaching the elevator rail to the connecting plate must be vertically slotted at each floor level. For the latter situation, vertical wood posts composed of wood members oriented with their wide face parallel to the wall are typically used for rail bracket attachment. Mass timber elevator shaft walls are also a viable solution and provide ample rail attachment opportunities. Regardless of the situation, the elevator manufacturer should be consulted for input on the proposed detail. See Figure 19 for examples of these options.

Credit: Aberthaw Construction


Mass timber elevator shaft walls at 90 Arboretum Drive in Newington, NH

Credits: Dann Brunn Architecture (top); Savaria (bottom)

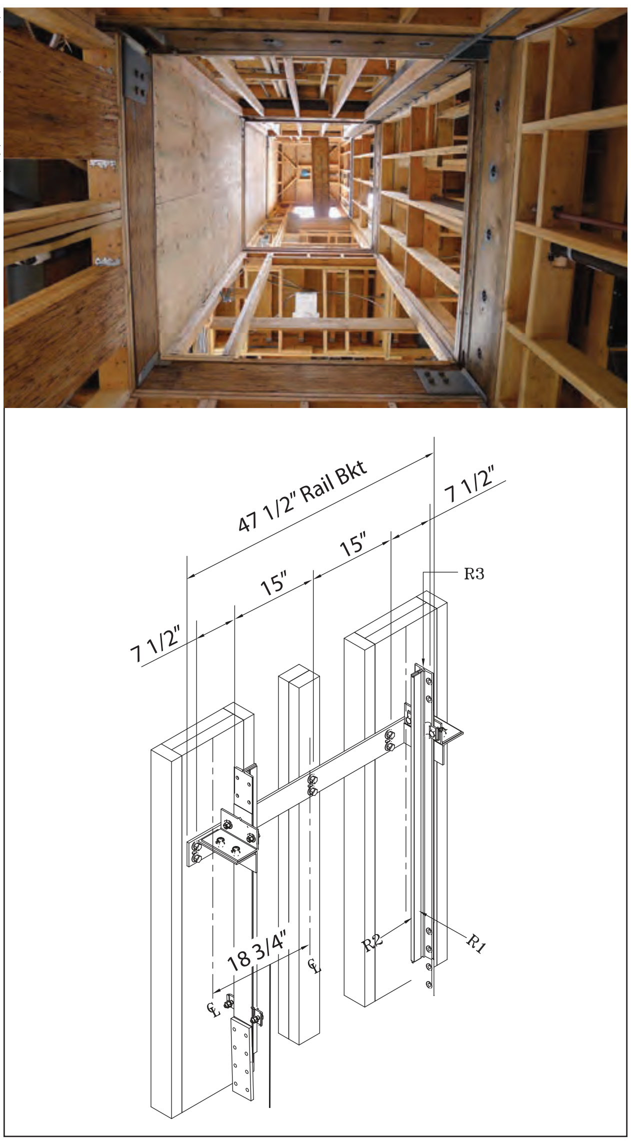


FIGURE 19: Example wood-frame elevator shaft and rail bracket support posts

Most elevator shafts are required to have a hoist beam at the top for installation safety purposes. The location and required load resistance is specified by the elevator manufacturer. In masonry and steel-frame shafts, the hoist beam is typically a structural steel wide flange beam. In wood-frame elevator shafts, the hoist beam can be structural steel or, in some situations, wood. The elevator manufacturer should be consulted to determine the compatibility of their product with different hoist beam options.


Wood-frame elevator hoist beam

Stair shaft wall stud joints at exterior wall

Mechanical Shafts

Many of the same design considerations and wall assembly options that exist for stair and elevator shaft walls also apply to mechanical shaft walls. The main difference is that mechanical shafts are often so small that physically getting into the shaft to finish the gypsum is not possible. To address this, a common solution is to frame some or all sides of the shaft with shaftliner panels, using one of the options presented above.

Other Shaft Design Considerations

Unbraced Joints in Wall Studs at Shafts

When a shaft wall is also an exterior wall, there are considerations beyond the additional fire protection requirements. Because an exterior wall doesn't include floor framing on the outer (non-shaft side) of the wall to brace it against out-of-plane forces such as external wind pressure, hinge effects in the wall framing should be considered. Several options exist to address this. One is to use the wall plates as continuous, horizontally-spanning members to resist out-of-plane loads. With this option, the designer should specify that the plates not be jointed in the shaft area. Another option is to install a structural rim member between the plates with the purpose of spanning horizontally and resisting out-of-plane loads. A third option (only applicable to stair shafts) is to shift the wall plate elevation to break the wall studs at the intermediate landing elevations rather than the typical main floor elevation. See Figure 20 for examples of this detail.

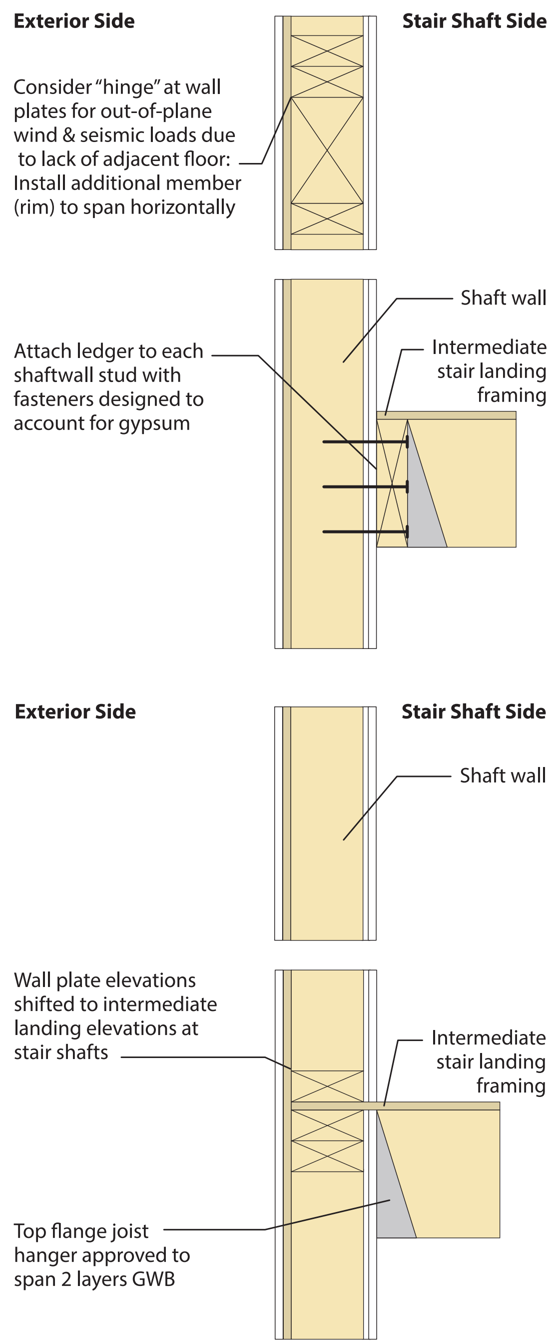


FIGURE 20: Two options for bracing wall plates at stud joints on exterior stair/elevator walls

Masonry Shaft Walls

In some regions of the country, masonry shafts are commonly used in buildings that are otherwise wood-frame. In addition to acting as shaft enclosure walls, these masonry walls are often used as shear walls. While this is common practice, there are several issues with mixing masonry shear walls at the shafts with an otherwise light-frame wood shear wall structure, notably seismic compatibility of the systems and differential shrinkage. While fire-resistive continuity may not be particularly onerous for the masonry shaft wall, detailing for load transfer and material movement may more than make up for this ease.

Seismic Compatibility

ASCE 7-16 – Minimum Design Loads for Buildings and Other Structures, Table 12.2-1, lists design coefficients and factors for seismic force-resisting systems. This table does not include a lateral load-resistance combination for both light-frame wood shear walls and masonry shear walls. Each is categorized separately and they have significantly different seismic-resistance properties. The seismic response modification coefficient, R, of light-frame wood-sheathed shear walls is 6.5, while the R of masonry shear walls can vary from 2 (ordinary reinforced masonry shear walls) to 5 (special reinforced masonry shear walls). Regardless of masonry shear wall type, the lower R of masonry shear walls will produce higher seismic forces when compared to a wood shear wall system. When using more than one type of lateral force-resisting system in the same force direction, ASCE 7-16 Section 12.2.3.3 requires the following:

Section 12.2.3.3 R, C_d, and Ω_0 Values for Horizontal Combinations. *The value of the response modification coefficient, R, used for design in the direction under consideration shall not be greater than the least value of R for any of the systems utilized in that direction. The deflection amplification factor, C_d, and the over strength factor, Ω_0, shall be consistent with R required in that direction.*

Exception: Resisting elements are permitted to be designed using the least value of R for the different structural systems found in each independent line of resistance if the following three conditions are met: (1) Risk Category I or II building, (2) two stories or less above grade plane, and (3) use of light-frame construction or flexible diaphragms. The value of R used for design of diaphragms in such structures shall not be greater than the least value of R for any of the systems utilized in that same direction.

Unless the conditions of the above exception are met, the lower R factor of the masonry shear walls would need to be used throughout the building for the loading direction being considered, even for design of the wood shear walls.

Wood shear walls and masonry shear walls also have inherently different stiffness properties. When using a flexible diaphragm analysis, the diaphragm forces are distributed to vertical-resisting elements based on their tributary area, regardless of their relative stiffness. A flexible diaphragm analysis is typically done for light-frame construction. See ASCE 7-16 Section 12.3.1.1 for the diaphragm flexibility check. If accounting for the difference in relative stiffness of vertical-resisting elements (shear walls) in separate lines of resistance is desired, a semi-rigid or rigid diaphragm analysis would be required. Section 4.2.5 of AWC's *Special Design Provisions for Wind and Seismic* (SDPWS) discusses this in further detail.

Masonry shaft wall in a wood-frame building

Masonry shaft walls can contribute significantly to the seismic mass of a structure, increasing its required lateral capacity. Masonry is almost three times heavier than wood framing as a wall system—an 8-in. masonry wall with grout and reinforcing at 48-in. on center weighs approximately 44 psf[4] while a 2x6 stud wall with two layers of 5/8-in. gypsum on each face weighs approximately

16 psf—and seismic forces are directly tied to structure mass. SDPWS Section 4.1.5 specifically states that wood-frame diaphragms in structures more than one story in height shall not resist seismic forces generated by masonry or concrete walls. Although there are exceptions to this, the basic principles of seismic design indicate that mixing masonry and wood-frame systems for lateral resistance is generally not a good idea.

Because of the requirement to use a lower R factor with masonry walls, and the requirement of SDPWS Section 4.1.5, some engineers choose to design the shaft walls in wood. This reduces the seismic forces (lower wall mass) and allows the entire building's lateral system to use an R of 6.5, while addressing issues such as differential movement/shrinkage that can occur between a wood-frame floor and its supporting masonry shaft wall. Switching to wood shaft walls may also be beneficial from the perspective that it eliminates the need for two construction trades and has the potential to speed the construction schedule and reduce cost.

Switch to Wood-Frame Shaft Walls Saved this Team $176,000

When the design team and general contractor for the Gala at Oakcrest project, a four-story, 135,000-square-foot multi-family wood-frame building in Euless, Texas, needed to reduce construction costs, stair and elevator shaft wall construction became a focus of discussion. Although the project was otherwise wood-frame, the shaft walls had been envisioned in masonry. The estimated cost for two masonry elevator shafts and three stair shafts, each four stories in height, was $266,000.

Dax Brock of Gardner Capital Construction, the project's developer and general contractor, raised the idea of using wood-frame shafts. Both the design team and building jurisdiction were unfamiliar with wood-frame shaft walls, and WoodWorks provided support to help them understand how the code requirements could be met. The proposed change was accepted by the building department, and Brock estimated that the wood-frame elevator and stair shaft walls would save $176,000 over the original masonry design. In addition to material and labor savings, he said the change would reduce the construction schedule by at least three weeks. Now that he has a code-compliant example of wood-frame shaft walls, Brock said he'd be looking for other opportunities to save costs by implementing this solution.

Differential Movement

When mixing materials, best detailing practices include consideration of how each construction material will move relative to the others over time. Wood framing will likely shrink, with the amount varying based on how the building is detailed, moisture content of the wood before construction, and equilibrium moisture content of the project. Masonry will shrink very little if at all (it can also expand) and the differential movement between wood walls supporting a wood-frame floor and masonry shaft wall may cause floors to slope, finishes to be damaged, or issues at door thresholds.

If using masonry shaft walls in a wood-frame building, the best way to avoid issues is to isolate the wood framing from the masonry shaft walls, meaning the masonry shaft wall is not used for lateral load resistance. See Figure 21 for an example of this detail.

For more information on detailing wood-to-masonry shaft walls (and other material interfaces) to accommodate differential movement, see the WoodWorks publication *Accommodating Shrinkage in Multi-Story Wood-Frame Structures*.[5]

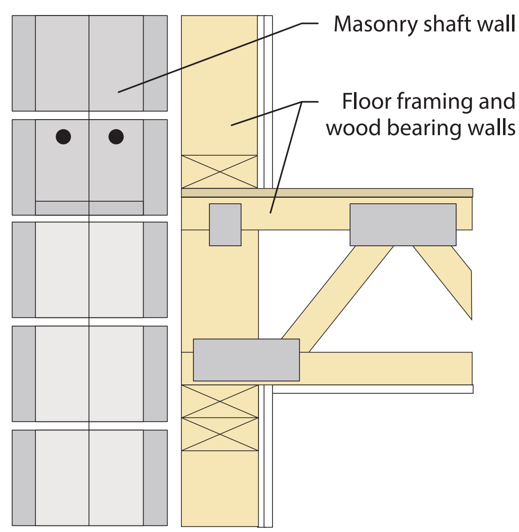


FIGURE 21: Masonry shaft wall isolated from wood floor framing with wood bearing wall

Cold-Formed Steel Shaft Wall Components

When utilizing cold-formed steel shaft wall studs, either for part or all of the shaft, with adjacent wood floor framing, differential shrinkage between the wood and shaft walls should be considered. It is important to note that longitudinal shrinkage in wood (i.e., along the length of the studs) is negligible; shrinkage is concentrated at the wall plates and floor depth. The less wood oriented perpendicular to grain in those areas, the less potential shrinkage. Detailing the floor-to-wall connection with this in mind, and implementing moisture management best practices during construction, will help minimize but not eliminate wood shrinkage.

Knowing that a small amount of wood shrinkage in the floor depth will likely occur, many cold-formed steel shaft wall manufacturers nonetheless do not provide recommendations regarding the differential movement. Given the light gauge of the attachment clips that tie shaftliner H-studs to wood wall framing, it would be reasonable to assume that the horizontal leg of the clip angles could slightly flex if needed to accommodate a small amount of shrinkage without damaging finishes. Alternatively, vertical slotted holes in the clip angles could allow vertical differential movement while maintaining lateral wall stability. The light-gauge clip manufacturer should be consulted for the amount of differential movement each clip can accommodate.

Mass Timber

Mass Timber Shaft Walls

One of the exciting trends in U.S. building design is the growing use of mass timber—i.e., large solid wood panel products such as cross-laminated timber (CLT) and nail-laminated timber (NLT)—for floor, wall and roof construction. While the 2021 IBC prescriptively allows mass timber buildings up to 18 stories (see *Shaft Walls in Tall Mass Timber Buildings* below), the majority of taller wood structures in the U.S. are in the six to 12-story range. Some of these projects have proposed the use of mass timber shaft walls, but they are more common in low- and mid-rise projects.

Because of their strength and stability, mass timber products offer a carbon-friendly alternative to steel, concrete, and masonry for many applications. They can be used on their own, in conjunction with other wood systems, or in hybrid structures with steel or concrete. Unless desired for aesthetic, biophilic or other value-add reasons, mass timber is not necessarily a good substitute for light wood-frame construction, only because dimension lumber framing offers such a compelling combination of structural performance, cost, and environmental advantages where permitted by code.

As noted under *Fire Barrier Construction*, mass timber may be used for shaft walls in Types III, IV, and V construction based on the definitions in IBC Section 602. Mass timber

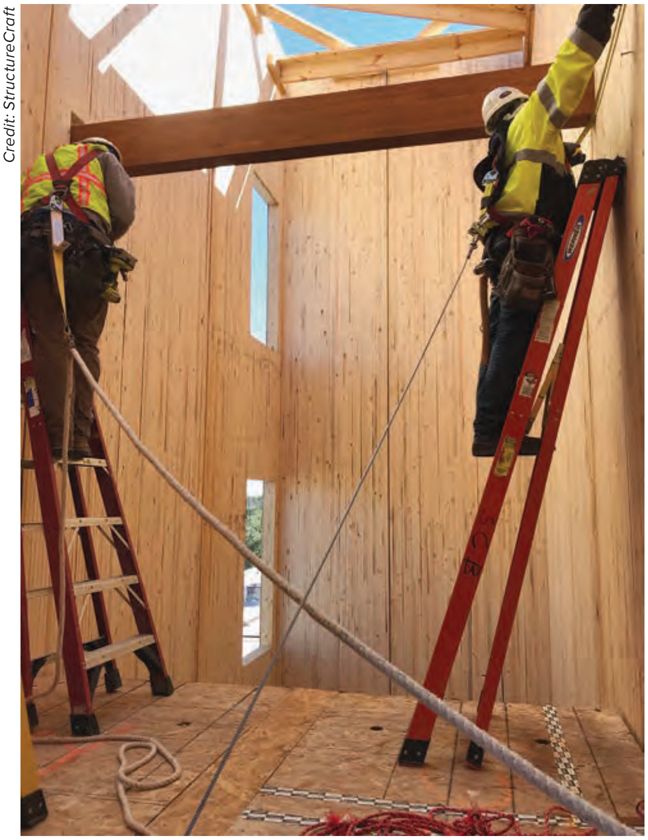
Credit: Aberthaw Construction

Mass timber shaft walls at 90 Arboretum Drive, a three-story office building in Newington, NH shaft walls constructed with NLT panels, typically covered with a wood structural panel (i.e., plywood or oriented strand board) have been permitted in the code for years. Dowel-laminated timber (DLT) panels have become a common alternative to NLT and can also be used in shaft wall applications. CLT is another option. The 2018 IBC recognizes CLT products manufactured according to the ANSI/APA PRG-320: Standard for Performance-Rated Cross-Laminated Timber. When manufactured according to this standard, CLT is an approved building material per IBC Section 2303.1.4.

In the context of shaft wall construction, the speed of mass timber installation is especially attractive. Because materials come premanufactured as large solid panels, it is possible to construct an entire shaft in a day or less, simply by placing four mass timber panels, one for each wall of the shaft.

Fire-resistance rating requirements for mass timber shaft walls are the same as those covered earlier in this paper. There are multiple code-compliant methods of demonstrating FRRs of mass timber panels for shaft walls and other applications as permitted by IBC Section 703. One is to use calculations in accordance with IBC Section 722. IBC Section 722.1 states that the fire resistance of exposed wood members and decking shall be permitted in accordance with Chapter 16 of the NDS. Chapter 16 of NDS provides a code-permitted method of calculating up to a 2-hour rating for exposed mass timber members, including CLT.

Credit: StructureCraft



DLT shaft walls at the Magdalena Hotel in Austin, TX

Credit: Alex Schreyer

CLT shaft walls at the John W. Olver Design Building at the University of Massachusetts (UMass – Amherst)

Credit: SA+R Architects

Mass timber shaft walls at the University of Denver's Burwell Center for Career Achievement

Credit: Jeff Morrow

At the Candlewood Suites hotel at Redstone Arsenal, each of the shaft walls was a single, 37.5-foot-long CLT panel.

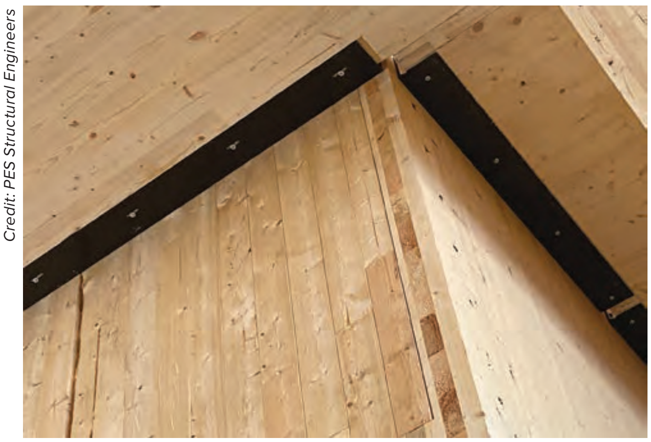
Another option is to use fire tests conducted according to ASTM E119 or UL 263 per IBC 703.2.1. In 2012, AWC sponsored a successful ASTM E119 fire-resistance test on a CLT wall at NGC Testing Services in Buffalo, NY. The wall, consisting of 5-ply CLT (approximately 6-7/8 in. thick), was covered on each side with a single layer of 5/8-in. Type X gypsum wallboard. The wall was loaded to the maximum load attainable by the NGC Testing Service equipment. It was then exposed to a standard fire that reached over 1,800 degrees Fahrenheit in the first 90 minutes of exposure. While only seeking a 2-hour rating as required by building code provisions, the test specimen lasted 3 hours and 6 minutes. This test, along with a series of CLT wall and floor tests conducted by FPInnovations, was used to substantiate the performance of CLT, leading to its recognition in the 2015 IBC. As such, this assembly is now a viable option for shaft walls in Types III, IV or V construction where a 1-hour or 2-hour FRR is required. Other ASTM E119 fire tests have since been conducted on exposed and protected mass timber wall assemblies, with results of up to a 2-hour rating.

For more information on the design of mass timber assemblies for FRRs, see the WoodWorks publication, *Fire Design of Mass Timber Members: Code Applications, Construction Types and Fire Ratings.*[6]

Mass timber shaft walls have been successfully used in all-mass timber structures with glue-laminated timber (glulam) post-and-beam construction, as well as light-frame hybrid projects where wood-frame bearing walls support mass timber floor and roof panels. They have also been used in buildings where the remainder of the structure—i.e., roof, floors and all other walls—are wood-frame construction. Each of these conditions create unique floor-to-shaft wall intersection details that should be carefully thought out.

Mass Timber Shaft Walls in Mass Timber Buildings

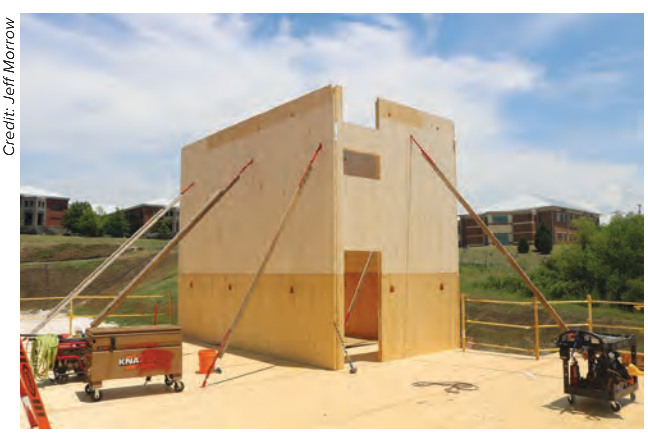
To streamline installation crews and limit the number of active trades on a jobsite, it may be cost efficient to use mass timber shaft walls in an otherwise fully mass timber building. Examples include the John W. Olver Design Building at the University of Massachusetts in Amherst, MA, Candlewood Suites at Redstone Arsenal, AL, 90 Arboretum Drive in Newington, NH, and the University of Denver's Burwell Center for Career Achievement in Denver, CO.



Credit: PES Structural Engineers

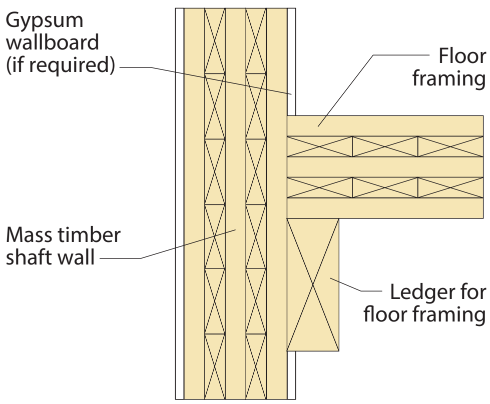
CLT floor panel supported on CLT shaft wall by steel ledger angle

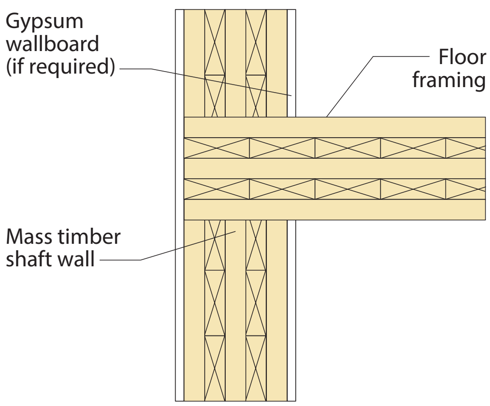
Mass timber shaft walls can also be beneficial from a fire barrier continuity perspective. Although options exist for meeting code requirements for continuity in a platform-framed floor-to-shaft wall bearing condition, some view a continuous shaft wall, traditionally framed with masonry walls, as superior. Mass timber shaft walls provide the option of being continuous; it is not uncommon to use a single CLT panel for a three- or four-story full-height shaft wall, or with heights of one or two stories but wall joints offset from the floor elevation. In full-height mass timber shaft wall applications, the adjacent floor framing is typically supported on a ledger or steel angle attached to the outside face of the mass timber shaft wall.



Credit: Jeff Morrow

CLT shaft walls with joint above floor line allows wall to bypass floor





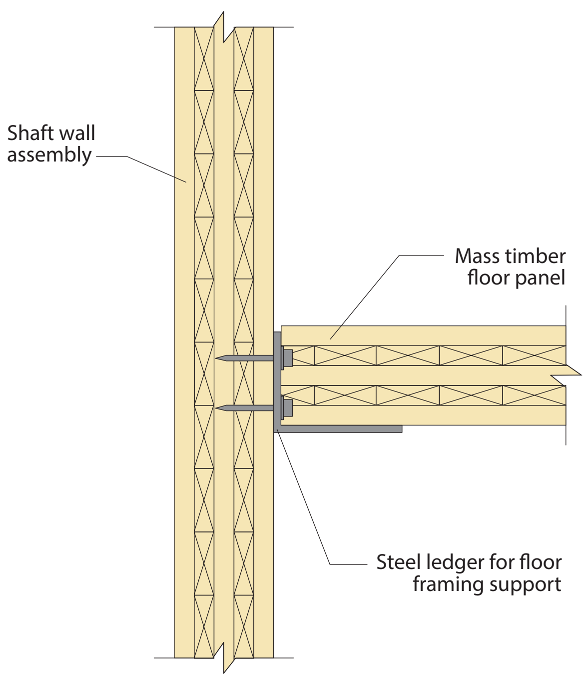


FIGURE 22: Mass timber floor framing-to-mass timber shaft wall detailing options

When using mass timber as a shaft wall, especially when one or both faces will be left exposed, there are several unique fire-resistance detailing conditions to consider. The difference between joints and intersecting assemblies was discussed earlier and, although two mass timber shaft walls that intersect (i.e., at wall corners) do not create a joint, they still need to prevent the passage of hot gases and smoke. To accomplish this at abutting and intersecting panels, a sealant is usually required. For example, Section 703.7 of the 2021 IBC includes a new requirement for the use of sealants or adhesives at abutting panel edges in Types IV-A, IV-B, and IV-C construction. The reason statement for this change notes the following:

The US CLT manual recommends a bead of construction adhesive [at abutting panels]. Construction adhesive or other sealant can be used to prevent air flow. When a wall or horizontal assembly serves as the separation between two atmospheres, a fire creates differential pressure where heated gasses raise the pressure and work to drive fire and hot gasses through the structure. Voids that are not properly sealed can serve as a conduit for air movement during a fire, so abutting edges and intersections are recommended to be sealed to address the topic.

As noted, penetrations and openings in mass timber shaft walls require firestopping. When exposed mass timber shaft walls are used, the impact of these firestopping systems on the aesthetics of the wall should be considered and discussed with the firestop manufacturer and building owner. Similarly, access holes for inspections, as shown below, require firestopping considerations.

CLT shaft wall base anchorage inspection holes at the Burwell Center for Career Achievement

Another consideration when using mass timber as an exposed shaft wall is acoustics. An exposed 5-ply, 6-7/8-in.-thick CLT wall panel has a Sound Transmission Class (STC) rating of 38. Wall assemblies that separate dwelling units from public or service areas are required to have an STC rating of 50 per IBC 1206.2. Due to this requirement, designers of mass timber shaft walls in multi-family and hospitality occupancies (and others) typically cover one or both faces with materials that improve the assembly's acoustic performance.

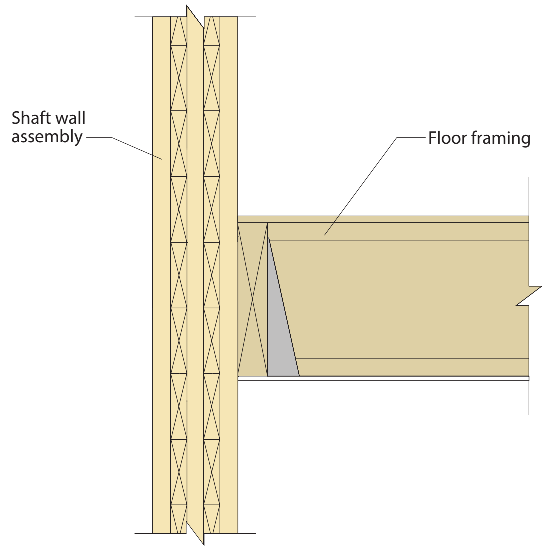
For more information on the acoustic performance of mass timber assemblies, see the WoodWorks publication, *Acoustics and Mass Timber: Room-to-Room Noise Control*[7] and the accompanying *Inventory of Acoustically-Tested Mass Timber Assemblies*.[8]

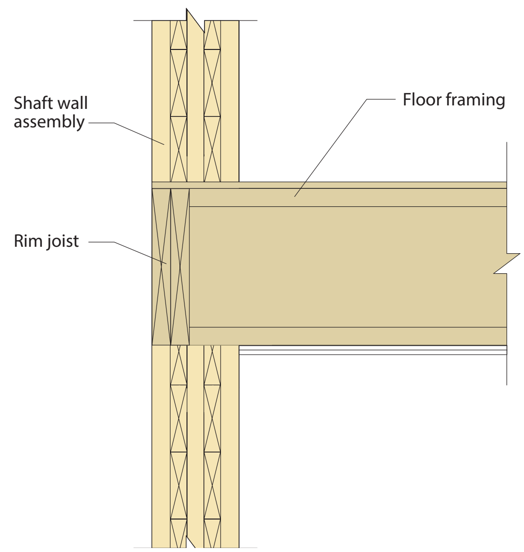
Mass Timber Shaft Walls in Wood-Frame Buildings

When mass timber shaft walls are used in place of masonry shaft walls in light wood-frame buildings, the motivator is often installation speed—which is measured in hours for mass timber vs. weeks for masonry. Wessex Woods, a four-story affordable senior housing project in Portland, ME, is one such example. Avesta Housing estimates that using CLT instead of masonry shaft walls saved about $75,000, largely in labor costs but also because heated tents weren't needed for a masonry install in Maine's cold climate.

Credit: Avesta Housing

CLT shaft wall installation at Wessex Woods, an affordable housing project in Portland, ME





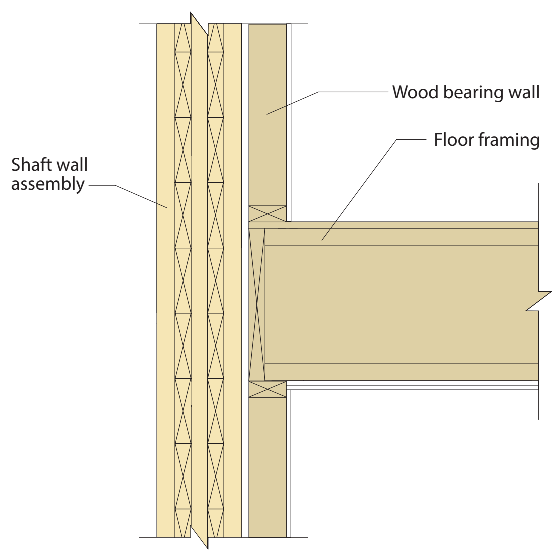


FIGURE 23: Options for light-frame floor framing to mass timber shaft wall assembly details

Credit: Avesta Housing

CLT shaft wall installation at Wessex Woods

Mass timber shaft walls in wood-frame buildings require the same considerations as those mentioned for mass timber shaft walls in mass timber buildings (FRRs, firestopping systems at penetrations, acoustics, etc.). Floor-to-shaft wall intersections typically rely on a wood ledger or wood stud wall adjacent to the mass timber shaft wall to support the floor/roof framing. Although wood-frame floor/roof construction can be platform framed on the mass timber shaft wall, this isn't common because of the construction efficiencies created by installing shaft walls in two or more story lifts per panel.

A wood bearing wall adjacent to the mass timber shaft wall might be used to improve acoustical performance of the shaft wall assembly, or to isolate the floor structure from the shaft wall for another reason (i.e., to avoid using the mass timber shaft wall as a shear wall). If using the platform-framed condition (i.e., wood floor framing is platform framed on the mass timber shaft wall or an adjacent wood stud wall), the floor-to-wall intersection detail could follow the same strategies discussed in the section, *Detailing Floor-to-Wall Intersections*.

Wood-Frame Shaft Walls in Mass Timber Buildings

Many of the wood-frame floor-to-wood-frame shaft wall intersection considerations mentioned above also apply when using mass timber floors and wood-frame shaft walls. However, there are several distinctions. First, it is important to recall that fire barriers are required to *"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 space, such as the space above a suspended ceiling."*

In the wood-frame floor construction conditions discussed above, it was noted that the fire barrier's FRR should extend through the depth of the floor structure up to the underside of the floor sheathing. However, a mass timber floor panel is acting as a *"slab or deck"* and there are usually no dropped ceilings that create concealed spaces, so by definition, a shaft wall that extends to the underside of a mass timber floor panel (and starts again on top of the mass timber floor panel) meets the code's continuity requirements. The mass timber floor panel in a platform-framed floor-to-shaft wall condition is not penetrating the shaft wall. This condition is prescriptively permitted by IBC per the fire barrier continuity requirements.

The chosen shaft wall assembly will have an impact on the floor-to-wall intersection detailing options. If the shaft wall is wood-frame and acting as a bearing wall to support the CLT floor panel, the floor panel will usually be platform framed. There are several detailing options for maintaining the code's continuity requirements for the wall through the floor depth, and these should also satisfy the supporting construction requirements.

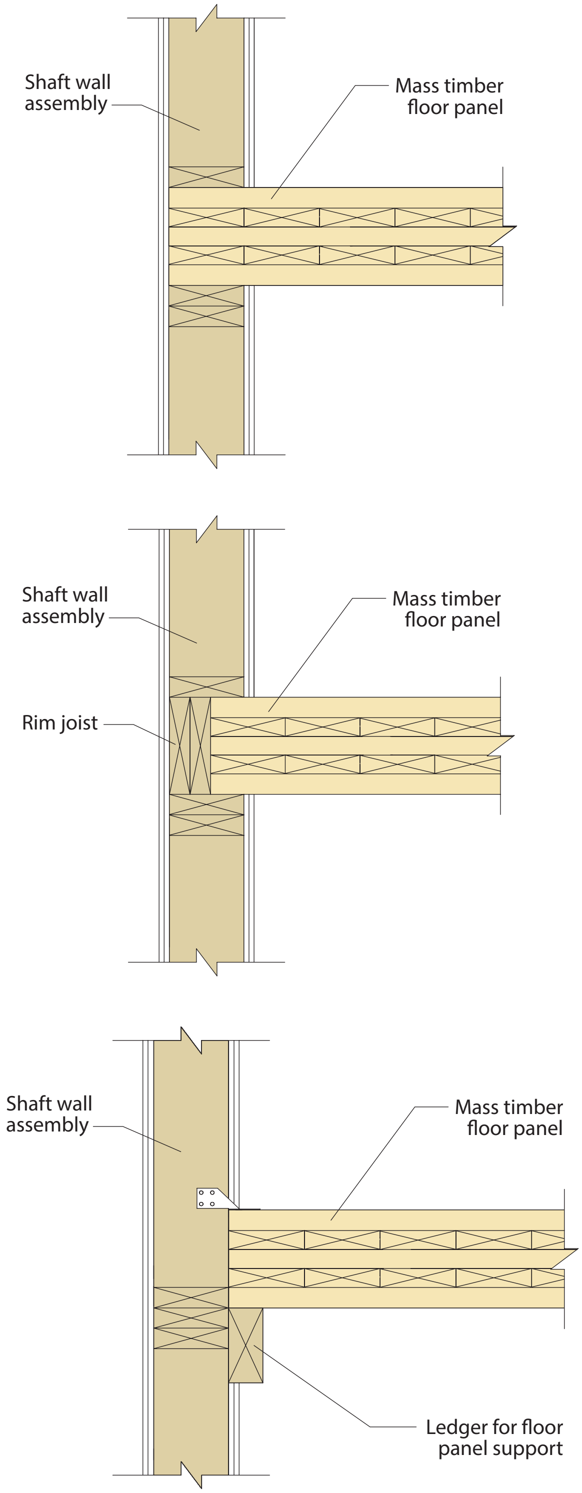


FIGURE 24: Options for mass timber floor panel to light-wood frame shaft wall details

Additional considerations include adequate CLT bearing area and ledger size for the required FRR of the wall assembly

When used in Types III, IV-HT and V construction, mass timber floor panels are generally required to have an FRR of no more than 1 hour. However, some panels may be able to achieve a 2-hour rating even if not required by code. Currently, over a dozen 5-ply CLT (or 2x6 DLT/GLT) floor panels have been fire tested per ASTM E119 and have achieved a 2-hour rating with the ceiling side of the panel exposed.[9] Although not a code requirement (per the definition of fire barrier continuity), demonstrating that the floor panel has an FRR that matches the shaft wall could be advantageous. An alternative would be to hold the mass timber floor panel back from the face of stud and install wood blocking, matching the depth of the mass timber floor panel, in the plane of the shaft wall. This blocking could be considered sacrificial blocking, using the rationale discussed earlier in this document.

Credit: WoodWorks

Mass timber floor panel bearing on light wood-frame shaft wall

Non-Wood Shaft Walls in Mass Timber Buildings

It is also common for shaft walls in mass timber buildings to be framed with non-wood materials—such as steel stud walls or concrete walls. In some cases, these shaft walls also function as shear walls, providing the building's vertical lateral force-resisting system. In other instances, they are designed to be isolated from vertical and lateral forces. Each circumstance creates unique detailing considerations.

If using a steel stud shaft wall, a platform-framed condition like the ones described above could be used. Shaftliner panels are another alternative, but generally require vertical support at each floor level due to their low axial capacity and loads associated with their self-weight. Shaftliner wall assemblies could be used in a platform-framed condition with a mass timber floor panel, with the floor panel extending out to be flush with the shaftliner panel on the shaft side of the wall. Alternatively, the mass timber floor panel could be held back approximately 1-in., with a strip of shaftliner panel (or 2 layers of 1/2-in. or 5/8-in. gypsum) installed to cap off the end of the mass timber floor slab. If the shaft has limited space, this may require installing the gypsum on the end of the floor panel before installing the panel. A third option is to hold the end of the floor panel back so it is entirely outside the plane of the shaft wall. In this case, the shaft wall could be supported by a flat steel plate that cantilevers out over the top of the floor panel, or by a steel angle attached to the end of the floor panel. Regardless of which detail is used, it is important to recall that the IBC does not require shaft walls to bypass the floor structure. By definition, a platform-framed shaft wall-to-mass timber floor panel intersection detail is acceptable. Discussing the proposed floor-to-shaft wall details with the Authority Having Jurisdiction early in the design process will also help clarify their requirements.

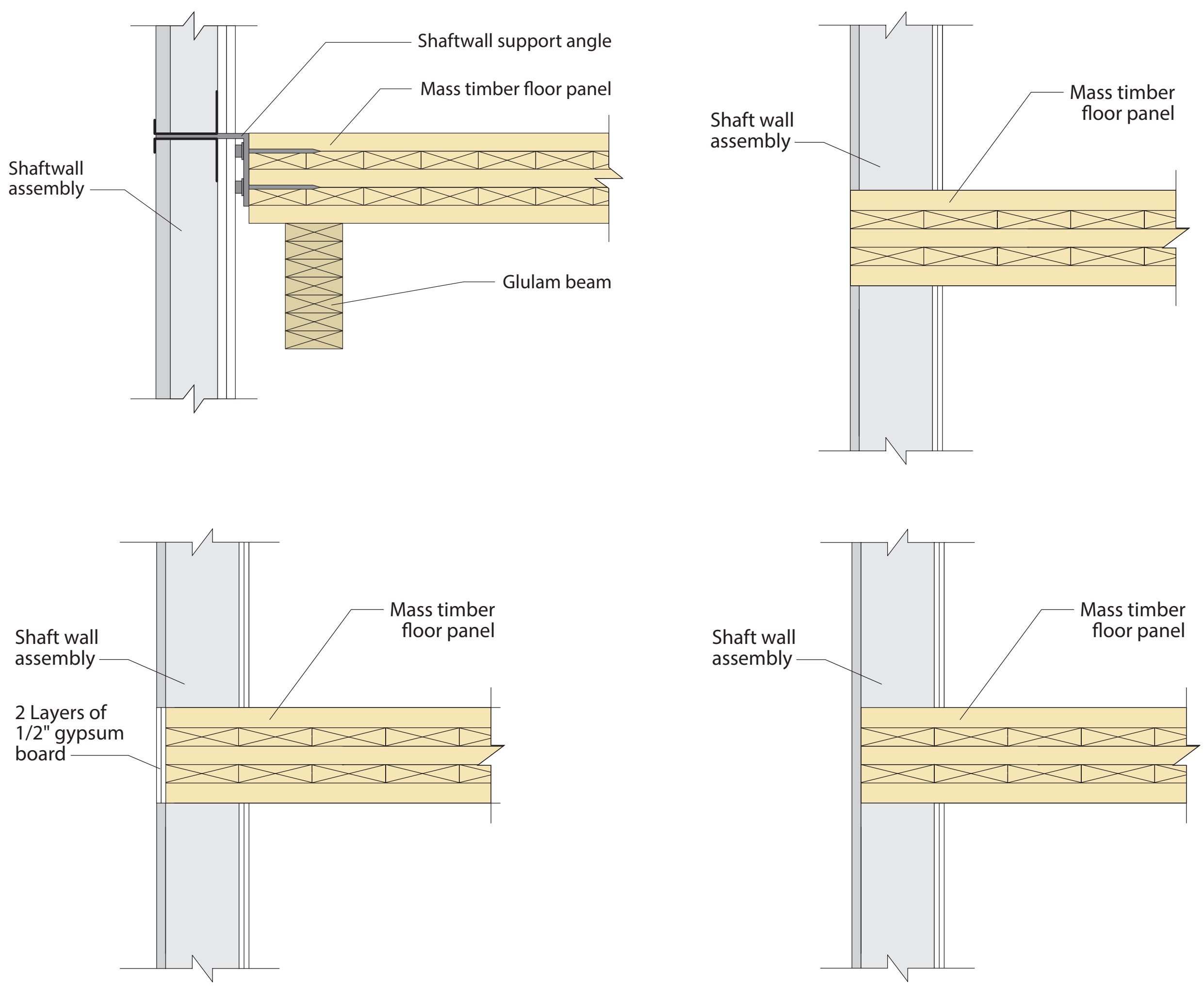


FIGURE 25: Options for attaching non-wood shaft walls to mass timber floor panels

Credit: Harbor Bay Real Estate

Credit: naturallywood.com

Concrete shaft walls and shear walls at INTRO (above) and Brock Commons Tallwood House (below)

Mass timber is often fabricated with exceptionally tight tolerances for overall size, as well as size and locations of holes, notches and any other alterations, and can be constructed to within as little as +/- 1/16-in. of the specified dimensions. While this is extremely beneficial when connecting mass timber members to each other, it presents a challenge when attaching mass timber elements to other materials, such as concrete shaft walls with allowable tolerances that may be much larger. To maximize constructability, it is essential to consider these different tolerances during design and not in the field. Common solutions include allowing for a gap between members of differing materials and providing built-in adjustability in the connection itself. While these are relatively straightforward to incorporate during the design phase, fixes in the field can be much more involved, time-consuming and costly.

For more information on connections between mass timber and concrete shaft walls, and other wood-related connections, browse the WoodWorks CAD/Revit tool and accompanying *Index of Mass Timber Connections,*[10] and the publication, *Mass Timber Connections Index: Optimal Connection Considerations.*[11]

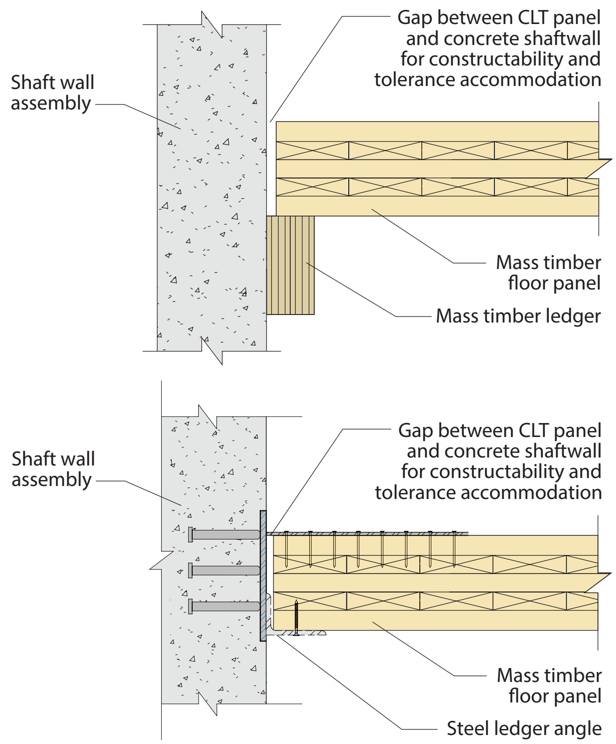


FIGURE 26: Leaving a gap between materials is a common way to accommodate different tolerances and material movements

Shaft Walls in Tall Mass Timber Buildings

As noted, changes to the 2021 IBC have created opportunities for wood buildings that are much larger and taller than prescriptively allowed in past versions of the code. The result is three new construction types—Type IV-A, IV-B and IV-C—which are based on the previous Heavy Timber construction type (renamed Type IV-HT), but with additional fire protection requirements.

In these new construction types, mass timber may be used for shaft walls with one exception. Section 602.4 notes that mass timber interior exit and elevator hoistway enclosures are permitted in buildings up to 12 stories or 180 ft. Noncombustible materials are required for shaft walls in buildings greater than 12 stories or 180 ft.

When used as shaft walls in Type IV-B or IV-C buildings, mass timber must be covered on both faces with noncombustible materials, as noted in IBC Section 602. Mass timber shaft walls in Type IV-B will usually require noncombustible protection providing 80 minutes of duration, which can be accomplished with two layers of 5/8-in. Type X gypsum wallboard. Mass timber shaft walls in Type IV-C will usually require noncombustible protection providing 40 minutes of duration, which can be accomplished with one layer of 5/8-in. Type X gypsum wallboard.

In addition to requirements specific to shaft walls, all mass timber elements used in tall wood buildings require specific FRRs, which are achieved in part with noncombustible materials. For more information on this and the use of mass timber shaft walls in tall wood buildings, see the WoodWorks publication, *Shaft Wall Requirements in Tall Mass Timber Buildings*.[12]

Other Mass Timber Shaft Wall Considerations

As shaft walls are also commonly used as shear walls, it is important to consider the lateral load-resisting capabilities of mass timber walls. Prescriptive provisions for CLT shear walls and diaphragms were first introduced in the 2021 SDPWS. To date, CLT shear wall systems for seismic resistance have been designed using conservative seismic performance factors or advanced performance-based seismic design procedures. Further research into CLT's use as a lateral force-resisting system is underway. The results should make it easier to design CLT shear wall systems for seismic resistance, and provide the data necessary for its inclusion in the seismic structural design standards used in the United States.

Credit: Alex Schreyer

CLT shaft walls doubled as shear walls at the John W. Olver Design Building, providing lateral load (seismic and wind) resistance.

For a collection of current materials on mass timber building design, engineering and construction, download the Mass Timber Design Manual[13] jointly published by WoodWorks and Think Wood.

Conclusion

Shaft wall assembly and detail selection should be carefully considered regardless of the material being used. The IBC provides ample opportunities for wood-frame and mass timber shaft walls that should be explored before making an assumption that other materials are necessary in an otherwise wood-frame structure. A variety of detailing options also exist for assembly intersections. This is positive as it allows for flexibility in shaft wall solutions and enables the designer and building official to explore options and determine the most appropriate solution for a project.

End Note:

[1] Copyright 2020, International Code Council, Inc., Washington, D.C. Information from the IBC has been reproduced with permission. All rights reserved. www.iccsafe.org

[2] *Acoustical Considerations for Mixed-Use Wood-Frame Buildings,* WoodWorks www.woodworks.org/resources/acoustical-considerations-for-mixed-use-wood-frame-buildings/

[3] *DCA 3 - Fire-Resistance-Rated Wood-Frame Wall and Floor/Ceiling Assemblies,* American Wood Council https://awc.org/codes-standards/publications/dca3

[4] ASCE 7-16: Minimum Design Loads and Associated Criteria for Buildings and Other Structures, Table C3-1

[5] *Accommodating Shrinkage in Multi-Story Wood-Frame Structures,* WoodWorks www.woodworks.org/resources/accommodating-shrinkage-in-multi-story-wood-frame-projects/

[6] *Fire Design of Mass Timber Members: Code Applications, Construction Types and Fire Ratings,* WoodWorks www.woodworks.org/resources/fire-design-of-mass-timber-members-code-applications-construction-types-and-fire-ratings/

[7] *Acoustics and Mass Timber: Room-to-Room Noise Control,* WoodWorks www.woodworks.org/resources/acoustics-and-mass-timber-room-to-room-noise-control/

[8] *Inventory of Acoustically-Tested Mass Timber Assemblies,* WoodWorks www.woodworks.org/resources/inventory-of-acoustically-tested-mass-timber-assemblies/

[9] *Inventory of Fire Resistance-Tested Mass Timber Assemblies,* WoodWorks www.woodworks.org/resources/inventory-of-fire-resistance-tested-mass-timber-assemblies-penetrations/

[10] WoodWorks CAD/Revit tool and accompanying *Index of Mass Timber Connections*, www.woodworks.org/cad-revit/

[11] *Mass Timber Connections Index, Optimal Connection Considerations,* WoodWorks www.woodworks.org/resources/mass-timber-connections-index-optimal-connection-considerations/

[12] *Shaft Wall Requirements in Tall Mass Timber Buildings,* WoodWorks www.woodworks.org/resources/shaft-wall-requirements-for-tall-mass-timber-buildings/

[13] *Mass Timber Design Manual,* WoodWorks and Think Wood www.woodworks.org/resources/mass-timber-design-manual/

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