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Shaft Wall Solutions For Wood-Frame Buildings

Richard McLain, PE, SE • Senior Technical Director • WoodWorks

Wood shaft walls can reduce costs and shorten the construction schedule.

It is fairly common for light wood-frame commercial and multi-family buildings to include shaft walls made from other materials. However, with the heavy use of wood structure in mid-rise construction, many designers and contractors have come to realize that wood-frame shaft walls are in fact a code-compliant means of reducing cost and shortening construction schedule.

A shaft is defined in Section 202 of the 2012 International Building Code (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 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 wood-frame shaft walls under the 2012 IBC. While some of the IBC-referenced section numbers may be different in different editions, none of the main shaft wall provisions have been modified in the 2015 IBC.

Fire Barrier Construction

Shaft enclosures are specifically addressed in IBC Section 713. However, because shaft enclosure walls are 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 sections state that fire barriers can be constructed of any material permitted by the building's type of construction. This means that dimension lumber (light-frame wood construction) or mass timber may be used for shaft wall construction in Construction Types III, IV, and V 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 2015 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 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.*" Per IBC Section 713.4, shaft enclosures are required to have a fire-resistance rating of not less than 2 hours when connecting four or more stories. A fire-resistance rating 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 the 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 of providing 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 fire-resistance rating. 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 ways designers across the country have detailed this condition.

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

Example 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 required fire rating. Unlike fire wall assemblies, fire barriers and shaft enclosures do not specifically require structural stability. However, it is important for the building elements that support the fire barrier to also remain in place for that 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 barrier 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

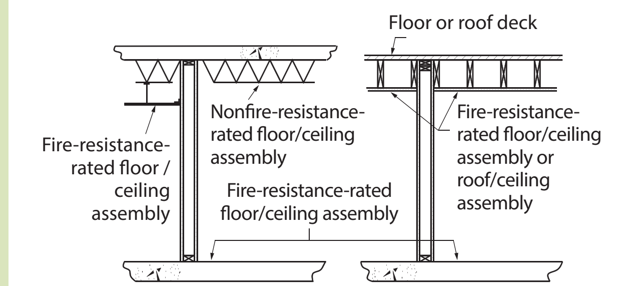
In some instances, confusion comes from looking at IBC Section 707.8, which states the following:

"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.) <u>However</u>, 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 (i.e., when there is no direct contact between wall and underside of floor sheathing). 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.*"

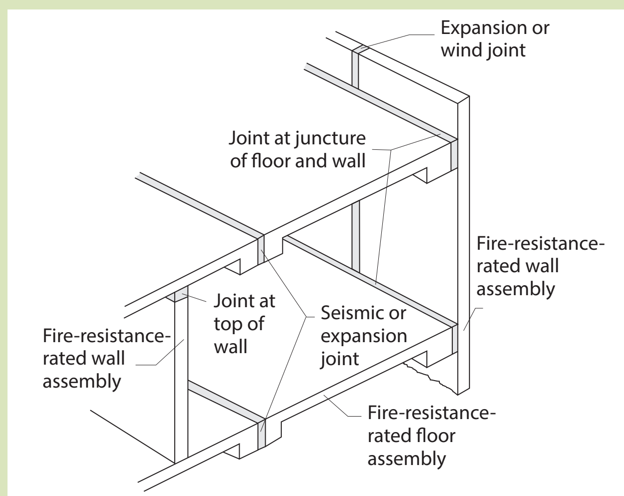
FIGURE 1: IBC Commentary Figure 707.5 – Continuity of Fire Barriers



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 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 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-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 above). 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 a fire-resistance rating 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 service penetrations and therefore do not contradict Section 713.8.

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

IBC Section 714.3 requires that penetrations into or through shaft walls (fire barriers) comply with Sections 714.3.1 through 714.3.3. There are two kinds of shaft wall penetrations to consider: "through penetrations" and "membrane penetrations." These terms, and their firestopping requirements, 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 714.3.2 requires membrane penetrations to comply with Section 714.3.1. 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 fire-resistance rating of the wall penetrated (per Section 714.3.1.2).

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 714.3.1.2 is the most common approach and typically involves the use of a tested, approved firestop system (fire caulk is commonly a component of this firestop 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 1019.2 for exterior egress balconies, Section 1022.7 for interior exit stairways and ramps and Section 1026.6 for exterior exit stairways and ramps.

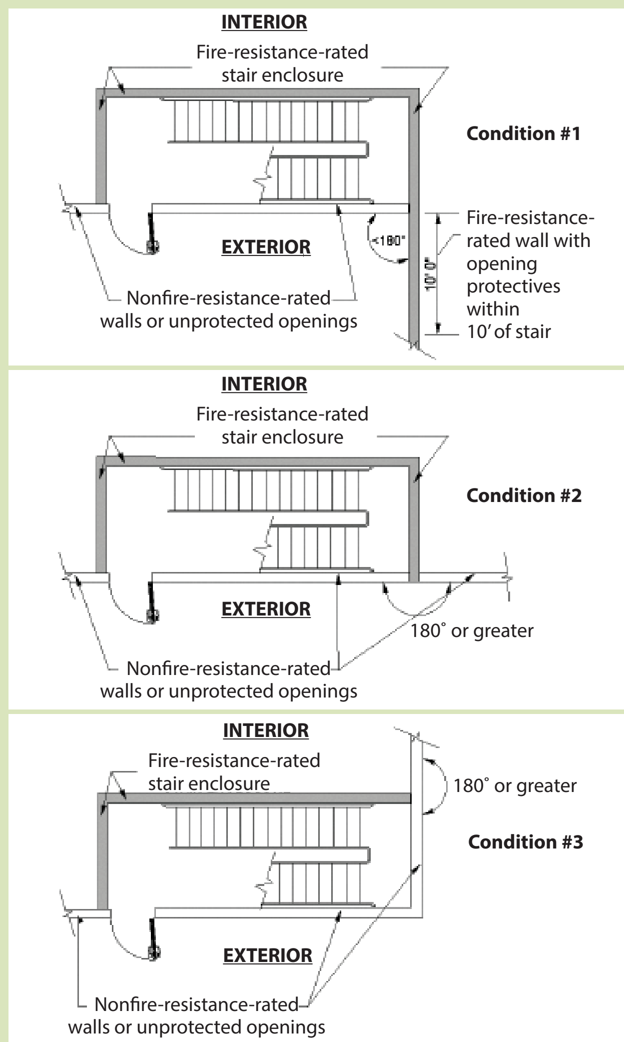
Section 1022.7 Interior exit stairway and ramp exterior walls. *Exterior walls of the interior exit stairway and ramp shall comply with the requirements of Section 705 for exterior walls. Where nonrated walls or unprotected openings enclose the exterior of the stairway and the walls or openings are exposed 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 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 fire-resistance rating requirements for exterior walls. It is important to note that exterior walls with a fire separation distance of greater than 10 feet 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 non-rated 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 feet 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.

Assemblies & 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).

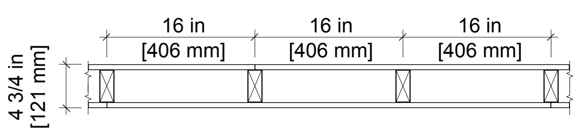
FIGURE 3: IBC Commentary Figure 1022.7(1)



For SI: 1 foot - 304.8 mm, 1 degree - 0.01745 rad.

As noted above, per IBC Section 713.4, shaft enclosures are required to have a fire-resistance rating of not less than 2 hours when connecting four or more stories. A fire-resistance rating 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.

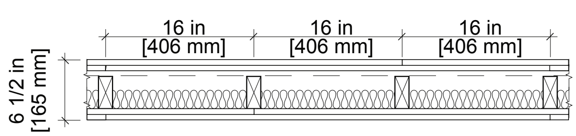
FIGURE 4: UL U305



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

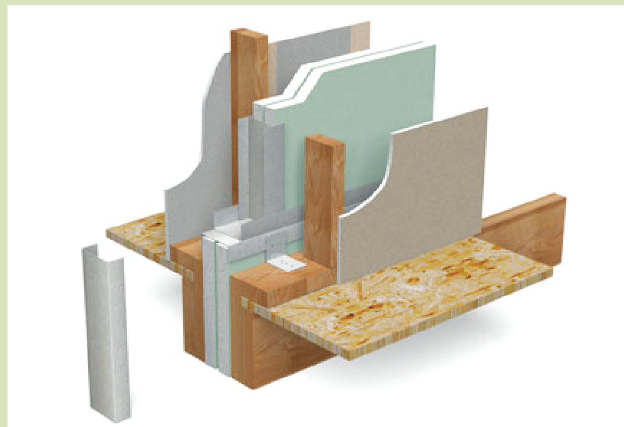
2-Hour Double Wall

- 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*.

Some designers also utilize shaftliner panels. Shaftliner panels are typically thicker than a normal gypsum panel (1-inch-thick is common) and come in sizes that can be installed easily between CH-, CT-, or H-studs (e.g., 24 inches wide and 8 feet to 12 feet 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 fire-resistance rating. 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 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.

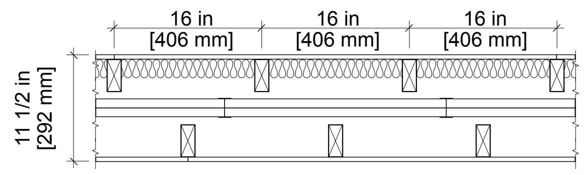
1-Hour Wall with Shaftliner

- UL V455
- UL V433

2-Hour Wall with Shaftliner

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

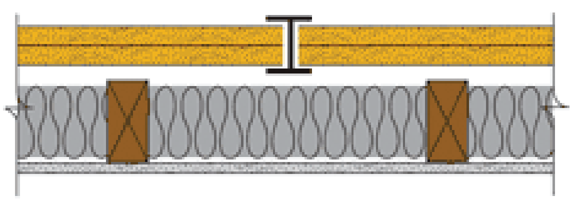
FIGURE 7: UL U336



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 states that their cavity type area separation wall systems have a limiting height of 44 feet and four stories. Another example is assembly UL U375 which allows a total system height up to 66 feet but requires different H-stud clip angle spacing depending on total system height.

FIGURE 8: UL U373



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 space between liner panels and adjacent wood or metal framing.

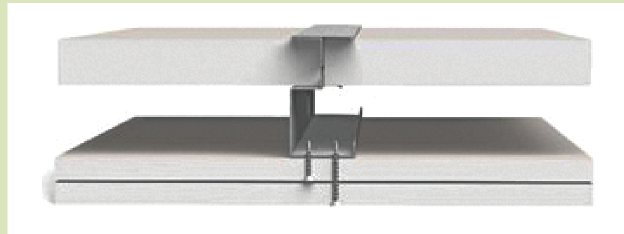
Sound tested with 2" x 4" stud wall with 1/2" (12.7 mm) wallboard or interior panels and 3-1/2" (89 mm) fiberglass insulation in stud space.

Credit: Georgia Pacific

The limiting height of these systems is due to the fact that 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 in the 5 pounds per square foot (psf) to 10 psf range. The 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 in order to determine their capacity against the project's 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 might help in making a wall height work. Additionally, 4-inch-deep and 6-inch-deep CH-stud sections are typically available and would have higher load capacities than the standard 2-1/2-inch-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 installation of control joints in shaftliner panel walls at 30-foot maximum vertical intervals. However, this does not mean that the entire stacked wall height is necessarily limited to 30 feet.

FIGURE 9: UL V433 Shaft Wall with CH-Studs and Shaftliner Panel



Credit: ClarkDietrich

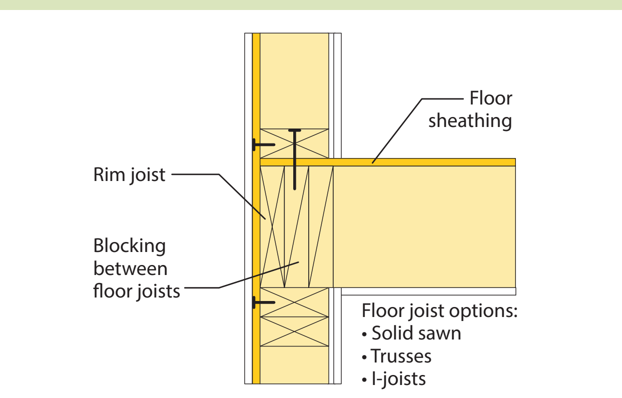
If a proposed shaft wall using shaftliner panels does not meet the total system height limitations, supporting the mass of the wall at intermittent heights off the adjacent floor structure is an option. Maintaining the wall's fire-resistance rating at the support attachment locations is a primary design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

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 above, the main design criteria to consider when detailing this condition is that of fire protection continuity through the floor/ceiling cavity. While local code interpretation varies widely, a variety of 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.)

One method used by designers to demonstrate 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 the American Wood Council'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 inches per hour. It is worth noting that these 2x blocking members are not structural members. Therefore, the nominal char rate of 1.5 inches per hour is applicable rather than the effective char rate (which is slightly higher). The effective char rate, which accounts for the char-effected zone, heat zone stiffness reductions, and rounding of wood member corners, is typically only applied to structural members. See Figure 10 for an example of this detail. The type of floor joist used (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.

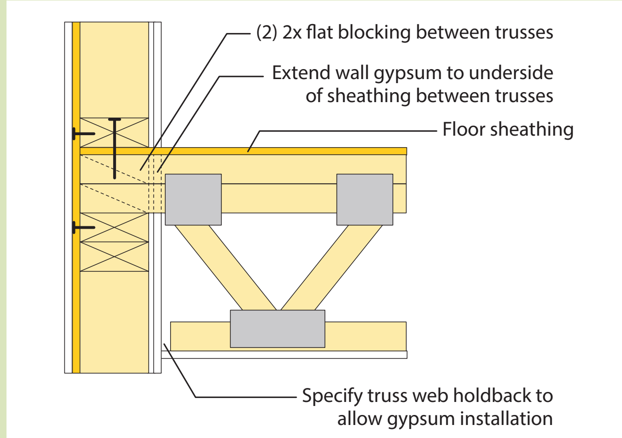
FIGURE 10: Floor-to-Shaft Wall Intersection Detail with Blocking Between Floor Joists



Credit: ClarkDietrich

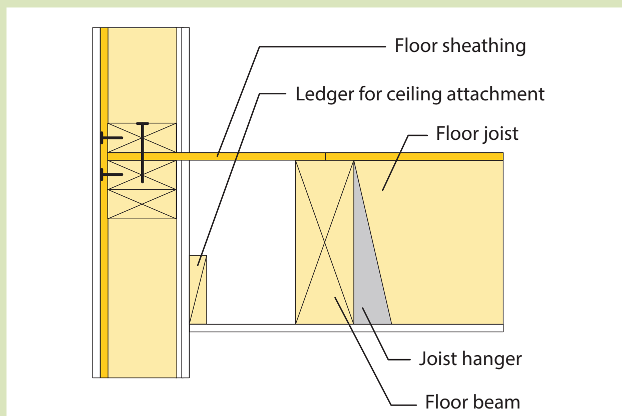
Another option would be to extend the wall gypsum on the floor side of the shaft wall up to the underside of the floor/roof sheathing between the floor/roof joists. This would require interruptions of the gypsum at the joists. However, it is important to consider the structural requirements of the project—i.e., the need for gravity and diaphragm forces to transfer to the shaft wall—in addition to the fire protection detailing. See Figure 11 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 or continuous joint 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 11: Floor-to-Shaft Wall Intersection Detail with Gypsum Extending to Underside of Sheathing between Trusses



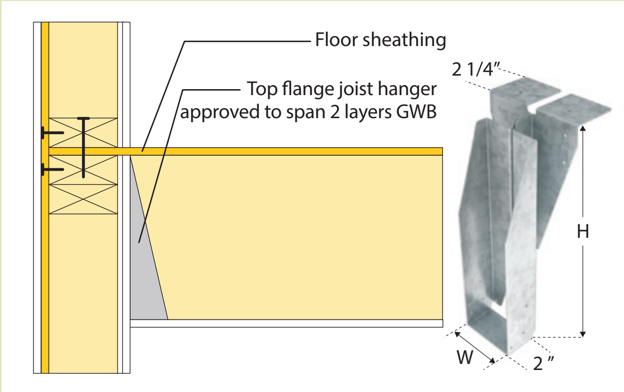
A third option would be to install a floor beam parallel to and just inboard of the shaft wall (12 inches to 24 inches inboard). This beam would be used to support all of the framing perpendicular to the shaft wall such that the only element penetrating the shaft wall is the floor sheathing. This option 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 12 for an example of this detail.

FIGURE 12: Floor-to-Shaft Wall Intersection Detail with Supporting Beam Just Inboard of Wall



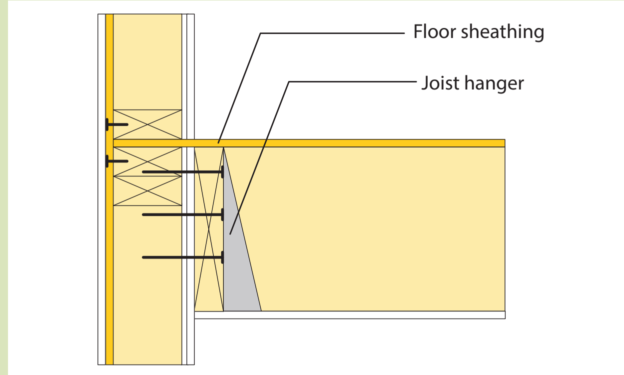
A final option would be to run the gypsum continuously behind the floor joists up to the underside of the floor/roof sheathing. The joists would be hung from the wall with a top flange hanger or face mount hanger capable of spanning over one or two layers of gypsum. See Figure 13 for an example of this 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 13: Floor-to-Shaft Wall Intersection Detail with Hangers Designed to Span Over Gypsum



Right image credit: MiTek Builder Products

FIGURE 14: Floor Framing Ledger Attached to Shaft Wall through Two Layers of Gypsum



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, meaning there would be no membrane penetration needed.

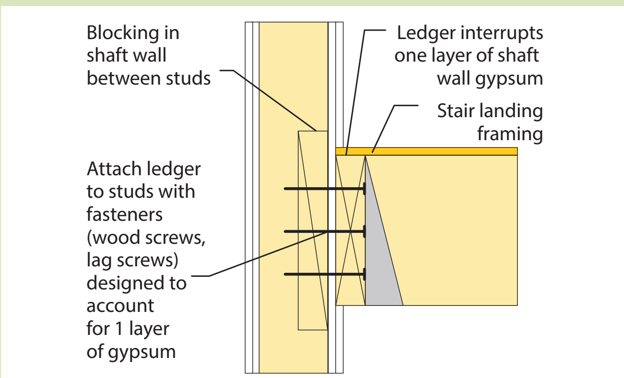
To accomplish this detail, a ledger is typically attached to the shaft wall through the layer(s) of gypsum that extend continuously up the shaft. The stair/landing framing is hung from the ledger and the stair/floor sheathing may or may not extend into the shaft depending on the wall plate elevation. 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. In order to aid in this installation process, in some circumstances, smaller strips of wall gypsum are installed behind the ledger, keeping wall stud location visibility high during fastener install.

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 the eccentricity on the fastener and the compression capacity of the gypsum. In addition to fastener requirements, regardless of the magnitude of loads, construction sequencing is a significant concern. In order to address this, 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. After all of the framing is installed, the remainder of the shaft gypsum is installed. See image above for an example.

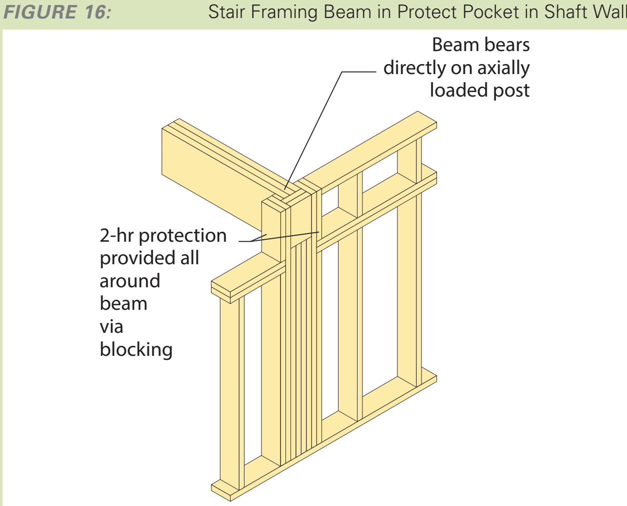
Although this can be done, a few options exist to avoid this potential construction sequencing challenge. One option would be to install blocking and/or a ledger in/on the shaft wall. A ledger interrupting the plane of the membrane of the fire resistance-rated assembly would be considered a membrane penetration and detailed accordingly (Section 714). 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 would be 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 15 for an example of this detail.

FIGURE 15: Stair Framing to Shaft Wall Attachment with Blocking in Lieu of One Continuous Gypsum Layer



If interrupting the shaft wall gypsum is not desired, installing a spanning structural beam just inboard of the shaft wall to support the landing framing is also an option. This would require discrete shaft wall penetration locations. This 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 16 for an example detail.

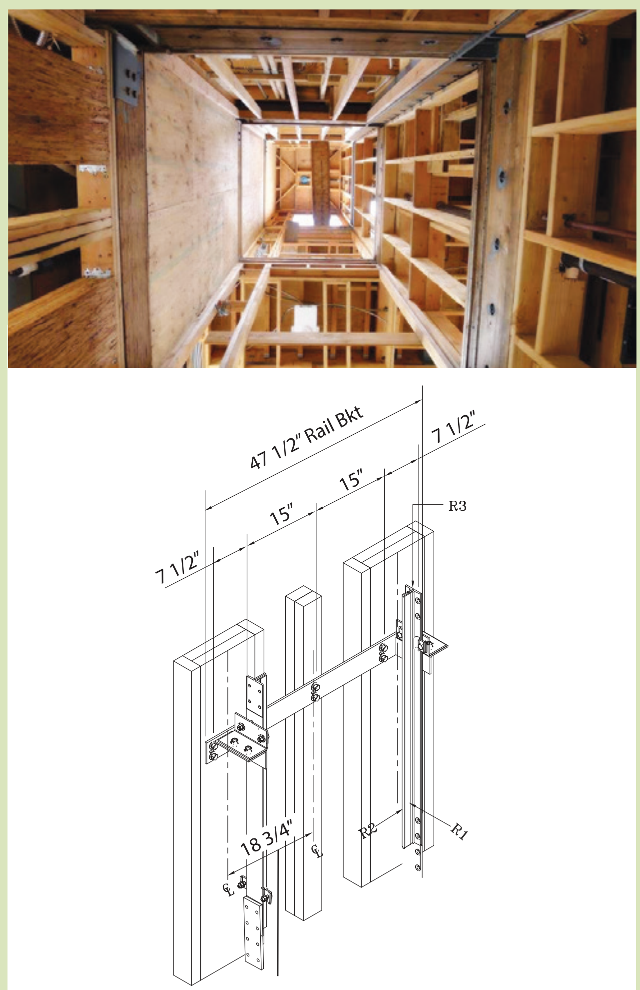
FIGURE 16: Stair Framing Beam in Protect Pocket in Shaft Wall



Elevator Shafts

Many of the same design considerations and wall assembly options that exist for stair shaft walls also apply to elevator shaft walls. Acoustical design considerations are perhaps more pronounced in elevator shaft walls than they are in stair shafts 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. Regardless of the situation, the elevator manufacturer shoul be consulted for input on the proposed detail. See Figure 17 for examples of these options.

FIGURE 17: Example Wood-Frame Elevator Shaft and Rail Bracket Support Posts



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

Wood-frame elevator hoist beam

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 it can be wood. The elevator manufacturer should be consulted to determine the compatibility of their product with different hoist beam options.

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 small enough such that physically getting into the shaft to finish the gypsum is not possible. In order to deal with this situation, a common solution includes framing 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, in addition to the fire protection requirements, the typical floor framing isn't in place on the non-shaft side of the wall to brace it against out-of-plane forces such as external wind pressure. Due to this, hinge effects in the wall framing should be considered. In order to address this condition, a few options exist. One is to use the wall plates as continuous, horizontally spanning members to resist out-of-plane loads. If using this option, the designer should specify that the plates not be jointed in the shaft area. Another option would be 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) would be to shift the wall plate elevation to break the wall studs at the intermediate landing elevations rather than at the typical main floor elevation. See Figure 18 for several examples of this detail.

FIGURE 18A: Stair/Exterior Walls with Options for Bracing Wall Plates at Stud Joints – Option 1

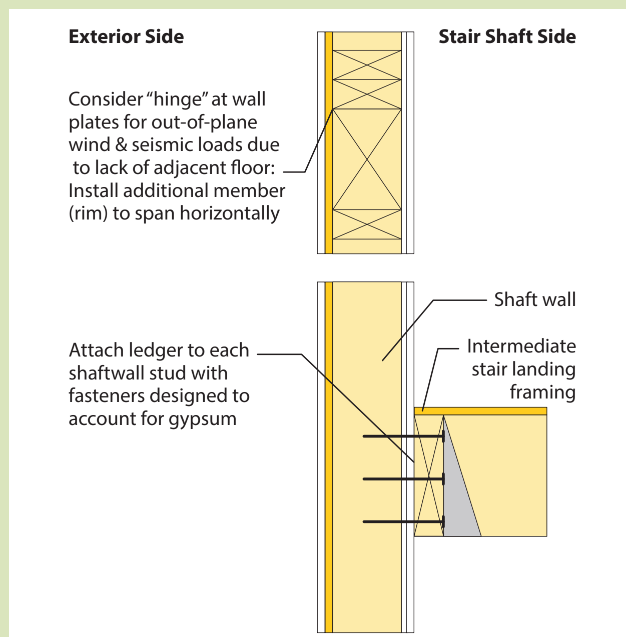
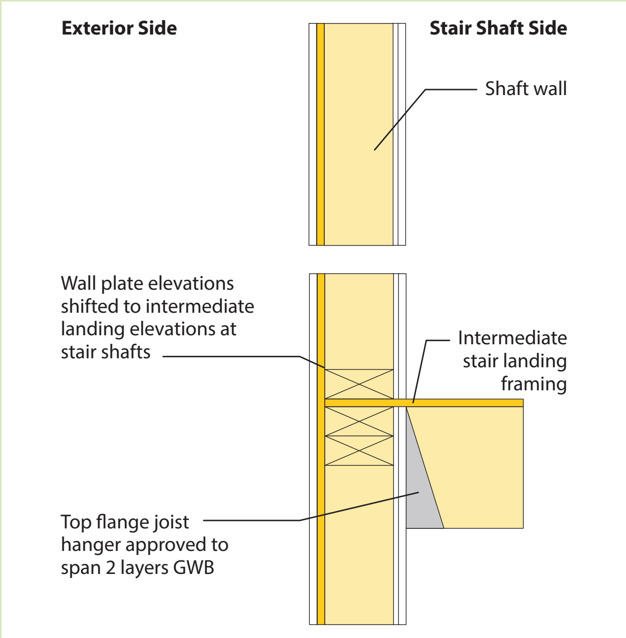


FIGURE 18B: Stair/Exterior Walls with Options for Bracing Wall Plates at Stud Joints – Option 2



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 7-10 – 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 which type of masonry shear wall is being used, the associated 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 7-10 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,

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 originally been slated to be masonry. The estimated cost for two elevator shafts and three stair shafts, each four stories in height, was $266,000.

Dax Brock of Gardner Capital Construction, the general contractor and developer for the project, raised the concept 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 the wood-frame elevator and stair shaft walls are expected to save $176,000 over the original masonry design. In addition to material and labor savings, Brock estimates that the change will reduce the construction schedule by at least three weeks.

Now that he has a code-compliant example of wood-frame shaft walls, Brock says he'll be looking for other opportunities to save costs by implementing this solution.

Masonry shaft wall in wood-frame building

regardless of their relative stiffness. A flexible diaphragm analysis is typically done for light-frame construction. See ASCE 7-10 Section 12.3.1.1 for the diaphragm flexibility check. If accounting for the difference in relative stiffness of the 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 the American Wood Council's Special Design Provisions for Wind and Seismic (SDPWS) discusses this in further detail.

In order to address this requirement of using a lower R factor associated with the masonry walls, as well as to address the requirement of SDPWS Section 4.1.5, many engineers are recognizing the benefits of switching shaft walls to 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 also dealing with issues such as differential movement/shrinkage which 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.

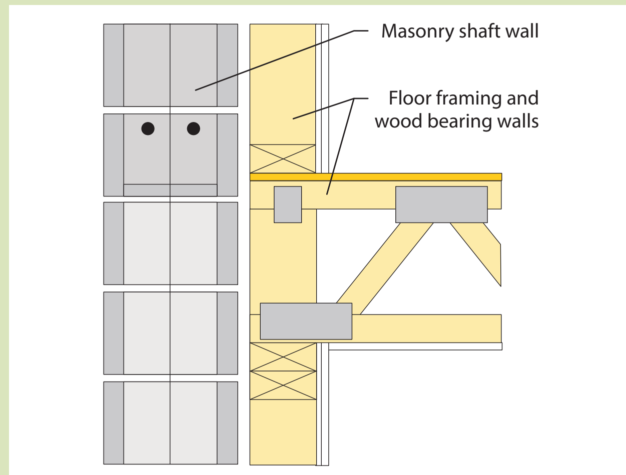
Masonry shaft walls can contribute significantly to the seismic mass of a structure, increasing its required lateral capacity. Masonry is almost three times heavier than wood framing as a wall system—an 8-inch masonry wall with grout and reinforcing at 48-inches on center weighs approximately 44 psf[1] while a 2x6 stud wall with two layers of 5/8-inch 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 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.

Differential Movement

When mixing materials, best detailing practices include consideration of how each of these construction materials will move relative to each other. Wood framing will likely shrink, with the amount varying depending on how the building is detailed, the moisture content of the wood before construction, and the equilibrium moisture content of the site. Masonry will shrink very little if at all (in some instances it can expand) and the differential movement between the wood walls supporting the wood-frame floor and the 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 option for detailing 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 19 for an example of this detail.

FIGURE 19: Masonry Shaft Wall Isolated from Wood Floor Framing by Using Wood Bearing Wall



Cold-Formed Steel Shaft Wall Components

When utilizing cold-formed steel shaft wall studs, either for part of the shaft or the entire shaft, with adjacent wood floor framing, the 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; all of the 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 most likely still occur, many cold-formed steel shaft wall manufacturers do not provide recommendations regarding the differential shrinkage. Given the light gauge of the attachment clips which tie shaftliner H-studs to the 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 while not causing finish damage. 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 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, or to create innovative sculptural buildings. Internationally, mass timber has been used in many multi-story building applications, including shaft walls, for many years.

The four-story Candlewood Suites® at Redstone Arsenal, Alabama, is made entirely from CLT – including the shaft walls.

Photo: LendLease

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

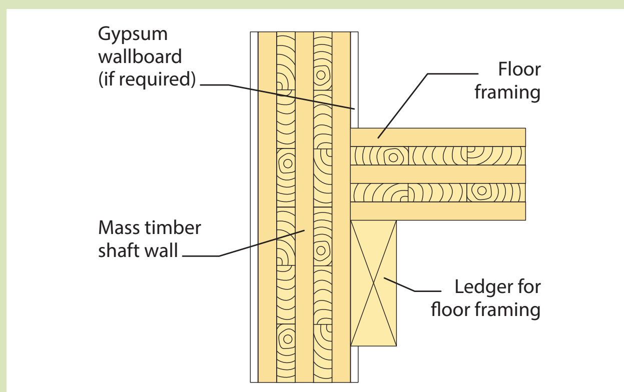
As noted on page 2, mass timber may be used for shaft wall construction in Construction Types III, IV, and V per the construction type definitions in IBC Section 602. Mass timber shaft walls constructed with nail-laminated timber (NLT) panels, typically covered with a layer of wood structural panel (i.e., plywood or OSB) have been permitted in the code for years. However, a popular choice among current building designers has been the use of CLT. The 2015 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 2015 Sections 202 and 2303.1.4.

CLT shaft walls were chosen for the University of Massachusetts (UMass) Design Building in Amherst, MA in part to demonstrate that mass timber building elements can replace traditional building materials for a number of applications, including shafts.

Photo: Alex Schreyer, UMass

In the context of shaft wall construction, the speed of mass timber construction 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.

FIGURE 20: Mass Timber Floor Framing-to-Shaft Wall Attachment



Fire-resistance rating requirements for mass timber shaft walls are the same as those covered above. There are multiple code-compliant methods of demonstrating fire-resistance ratings of mass timber panels for shaft walls and other applications as permitted by IBC Section 703. One such method 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 2015 NDS provides a code-permitted method of calculating up to a 2-hour rating for exposed CLT members.

Another option of determining fire resistance ratings as permitted by IBC Section 703 is through the use of tests conducted according to ASTM E119 or UL 263. In 2012, the American Wood Council sponsored a successful ASTM E119 fire resistance test on a CLT wall at the NGC Testing Services in Buffalo, NY. The wall, consisting of a 5-ply CLT (approximately 6-7/8 inches thick), was covered on each side with a single layer of 5/8" 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 Construction Types III, IV or V where a 1-hour or 2-hour fire-resistance rating is required.

One of the benefits realized from the use of CLT shaft walls at Redstone Arsenal was speed of erection. Each of the shaft walls was a single, 37.5-foot-long piece.

Photo: LendLease

Mass timber shaft walls can be beneficial from a fire barrier continuity perspective as well. Although options exist for meeting code requirements for continuity in a platform-framed floor-to-shaft wall bearing condition, some designers view a continuous shaft wall, traditionally framed with masonry walls, as being 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—while providing the additional benefits mentioned above such as light weight, speed of construction, and better environmental performance. In full-height mass timber shaft wall applications, the adjacent floor framing is typically supported on a ledger attached to the outside face of the mass timber shaft wall.

As shaft walls are also commonly used as shear walls, it is important to consider the lateral load-resisting capabilities of mass timber walls. Although CLT is included in the 2015 IBC as a permitted building material, prescriptive provisions in the SDPWS do not include CLT shear walls or diaphragms; however, an engineering design of CLT to resist wind loads is a fairly straightforward design process. Using CLT components in seismic force-resisting systems is an area of considerable ongoing research. To date, CLT shear wall systems for seismic resistance have been designed using conservative seismic performance factors or using 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 eventual inclusion in the seismic structural design standards used throughout the United States.

For the four-story UMass Design Building, the CLT shaft walls doubled as shear walls, providing lateral load (seismic and wind) resistance.

Photo: Alex Schreyer, UMass

For information on mass timber, the reThink Wood website (www.rethinkwood.com) offers an expanding library of materials on products, research, building examples, and developments related to tall wood buildings.

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 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 exist at assembly intersections. This is a 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 given project.

End Note:

1 Source: ASCE 7-10: Minimum Design Loads for Buildings and Other Structures, Table C3-1

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