



Structure, Fire & Acoustics Shouldn't Exist in Separate Silos for Mid-Rise

Bruce Lindsey

WoodWorks – Wood Products Council



Credit: Greg Folkins

Structure and Fire & Life Safety



Credit: Greg Folkins

Can't Live in Separate Bubbles

Structure and Fire & Life Safety

In any project, but particularly wood-frame mid-rise construction, efficiency in structural framing layout, assembly selection and detailing must also account for “architectural” requirements such as:

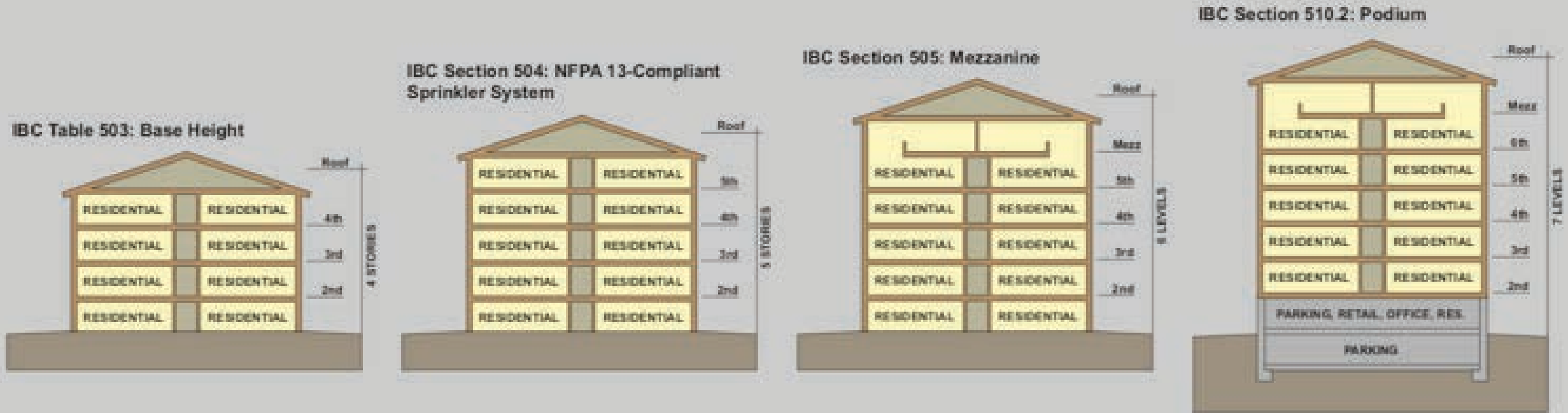
- Fire-resistance ratings
- Acoustics
- Materials permitted (construction type)

In other words, you’re not just an architect or engineer anymore



Credit: Brett Drury

Evolution of Mid-Rise



Through the lens of Type III and Type V mid-rise projects, we will take a look at a few common design & detailing issues and how to design holistically

Type III Exterior Walls – FRT

Type III Construction - IBC Section 602.3:

Fire-retardant-treated wood framing complying with Section 2303.2 shall be permitted within exterior wall assemblies of a 2-hour rating or less

What does this FRTW requirement include?

- Wall Framing (Studs & Plates) – Yes
- Headers – Yes
- Wall Sheathing – Yes
- Floor sheathing - ?
- Rim Joist- ?
- Floor Joists- ?



Credit: WoodWorks

Type III Exterior Walls – FRT

Long Span Headers in Type III

When a multi-ply 2x is inadequate due to load and span, what are the options?

- FRT EWP availability?
- Non-FRT wood options?
- Non-combustible materials?



Credit: WoodWorks

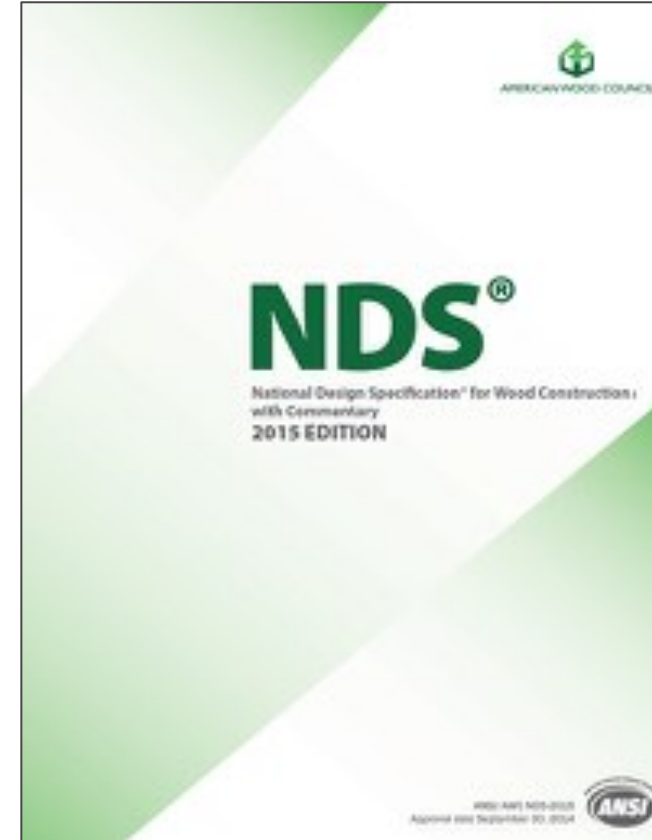
Type III Exterior Walls – FRT

Structural Impacts of using FRTW



FRT Wood Design Values

NDS 2.3.4: Adjusted design values, including adjusted connection design values, for lumber and structural glued laminated timber pressure-treated with fire retardant chemicals shall be obtained from the company providing the treatment and redrying service.



FRT Wood Design Values

FRT manufacturers provide reduction values in literature, ICC ESR's, etc.

Example FRT manufacturer's ESR reduction values:

TABLE 2—DESIGN VALUE ADJUSTMENT FACTORS FOR PYRO-GUARD® TREATED LUMBER

[illegible]

FRT Wood Design Values

Shear wall capacity reduction typically handled by increasing sheathing thickness

When fire-retardant-treated plywood is used in a shear wall, the thickness must be one standard size thicker than that determined in the tabulated allowable shear values contained in Section 4.3 of ANSI/AWC Special Design Provisions for Wind and Seismic (SDPWS) or as shown in the tables referenced in Section 2306.3 of the IBC (2306.4 of the 2009 and 2006 IBC). Thickness to be used for FRT plywood compared to untreated plywood shear walls are shown below:

FRT Plywood Thickness (inches)	Untreated Plywood Thickness (inches)
$\frac{3}{8}$	$\frac{5}{16}$
$\frac{7}{16}$	$\frac{3}{8}$
$\frac{15}{32}$	$\frac{7}{16}$
$\frac{1}{2}$	$\frac{15}{32}$

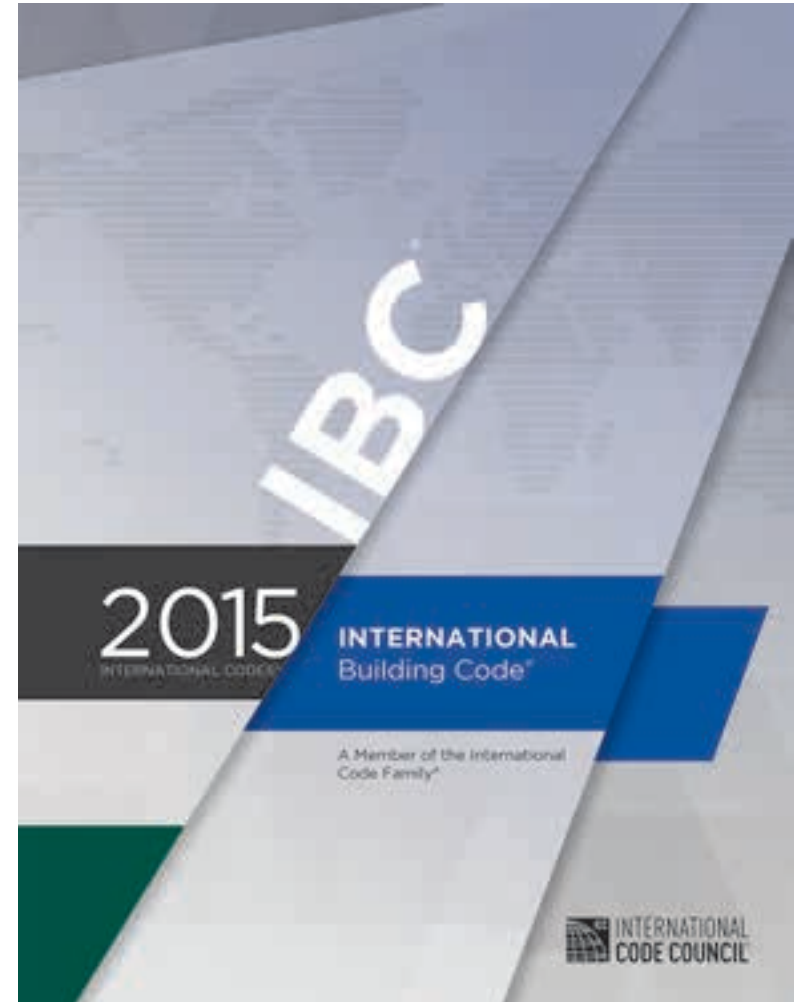
Accommodating Wood Shrinkage

Credit: Greg Folkins



Shrinkage Code Requirements

2304.3.3 Shrinkage. Wood walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the building official shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems, or other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternative, such systems shall be designed to accommodate the differential shrinkage or movements.



Shrinkage Design Considerations



Image: Schaefer



Shrinkage Design Considerations

Wood is orthotropic, meaning it behaves differently in its three orthogonal directions: Longitudinal (L), Radial (R), and Tangential (T)

- Longitudinal shrinkage is negligible
- Can assume avg. of radial & tangential or assume all tangential

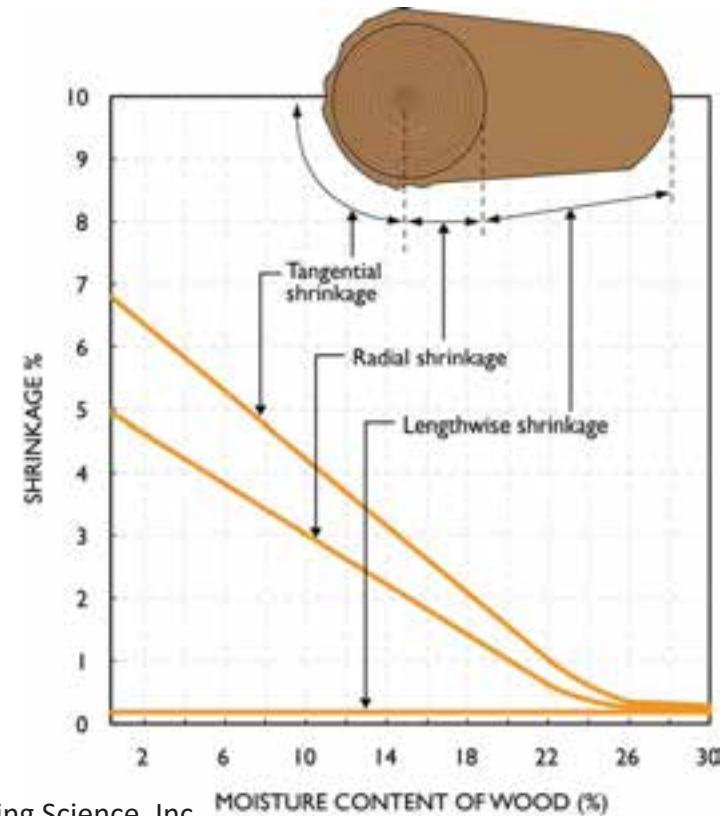
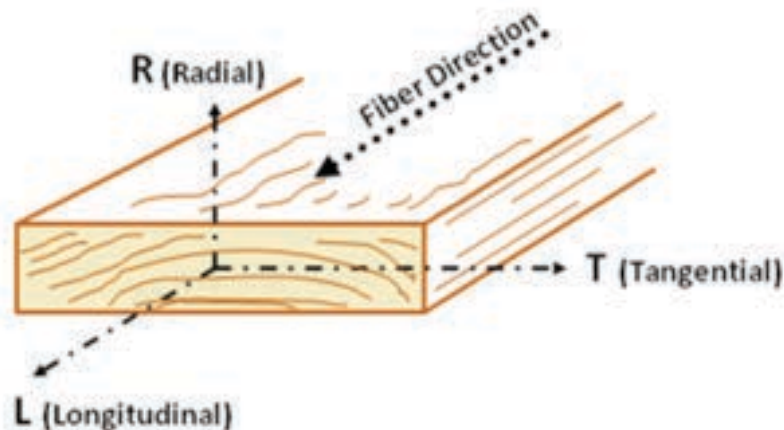


Image: RDH Building Science, Inc.

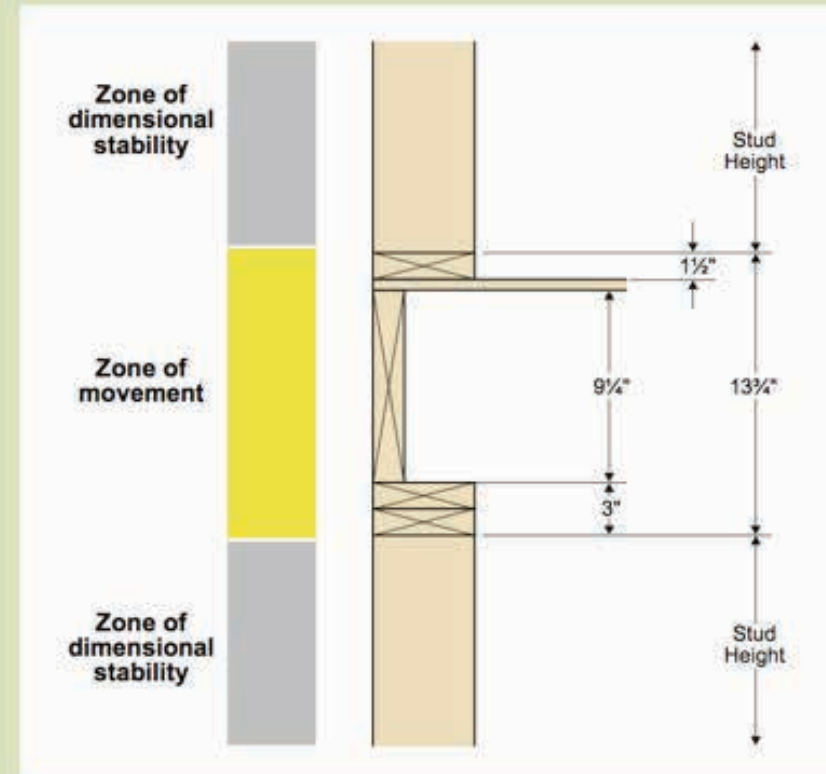
Shrinkage Calculations – Cross Grain Wood

Shrinkage occurs in cross-grain, but not longitudinal, wood dimensions

- Primarily in horizontal members
- Wall plates
- Floor/rim joists
- Engineering judgement required when determining what to include in shrinkage zone
- Should Sheathing, I-Joists, Trusses, other products manufactured with low MC be included?

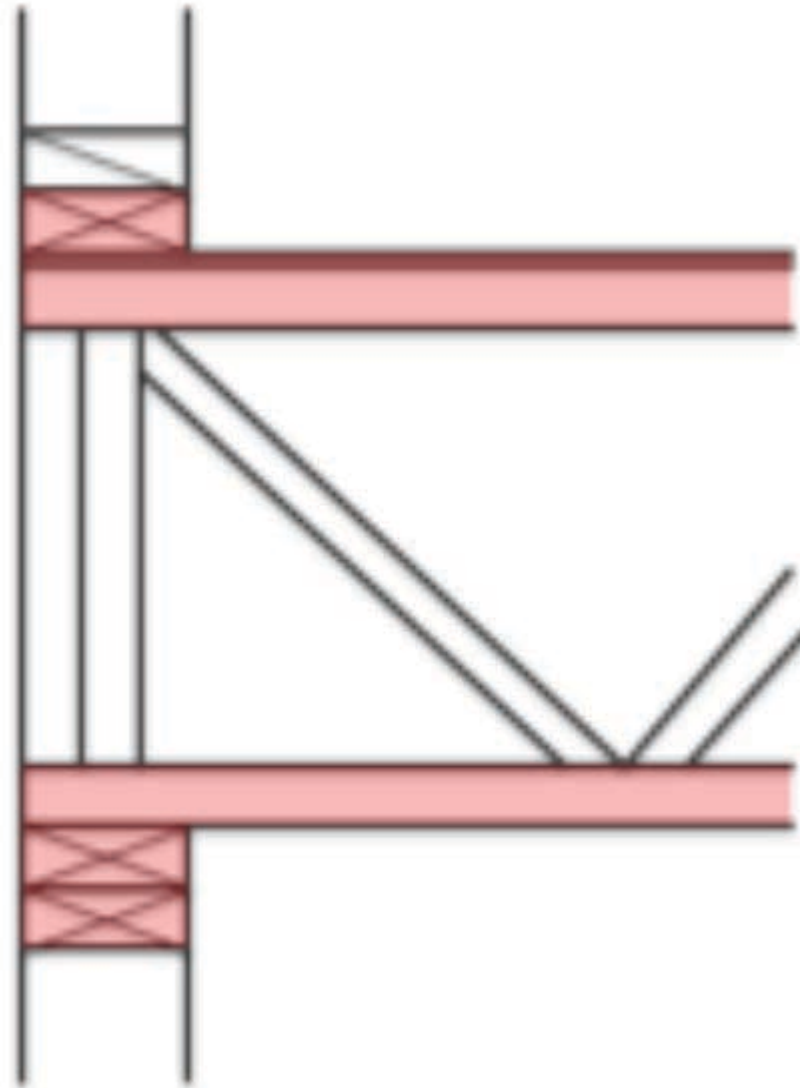
FIGURE 5:

Shrinkage zone in platform-framed detail



Shrinkage Calculations – Cross Grain Wood

In parallel chord trusses, only chords contribute to shrinkage, vertical and diagonal webs don't



Shrinkage Calculations – Running the Numbers

Simplified Method:

$$S = 0.0025 \text{ in} * \text{inch of cross grain wood} * \% \text{ MC change}$$

Example: 13.75" shrinkage zone

Installed MC = 19%

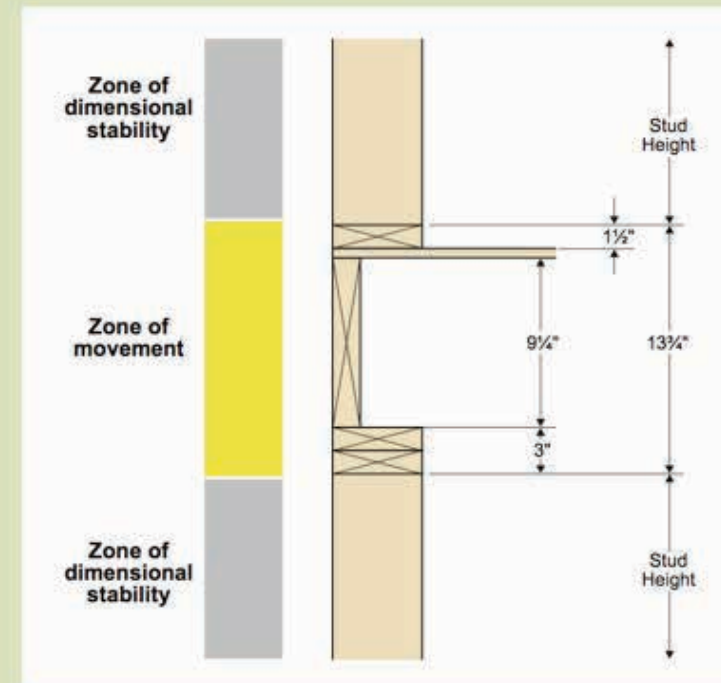
EMC = 12%

$$S = (0.0025)(13.75'')(12-19) = \mathbf{-0.24''}$$

(note: Negative value due to loss in cross section)

FIGURE 5:

Shrinkage zone in platform-framed detail



Differential Movement – MEP

MEP main runs often start at base or top of structure, extend throughout height, with horizontal tees at each floor.

Horizontal tees often installed in wood stud partitions



Differential Movement - MEP

Wood framing shrinks, vertical MEP runs remain stationary or expand with thermal fluctuations

Differential movement should be allowed for

Helpful to wait as late as possible after wood framing is erected to install MEP

Note anticipated wood shrinkage at each level on construction documents – MEP contractor should provide methods of accommodating



Differential Movement - MEP

- Vertically slotted holes in studs allow differential movement
- Verify structural adequacy of studs

GAP REQUIRED ABOVE & BELOW FOR DIFFERENTIAL MOVEMENT, SEE GENERAL NOTES FOR ANTICIPATED SHRINKAGE OF WOOD STRUCTURE. CONSULT w/ MEP ENGINEER FOR ANTICIPATED MOVEMENT OF CONDUIT OR PIPE

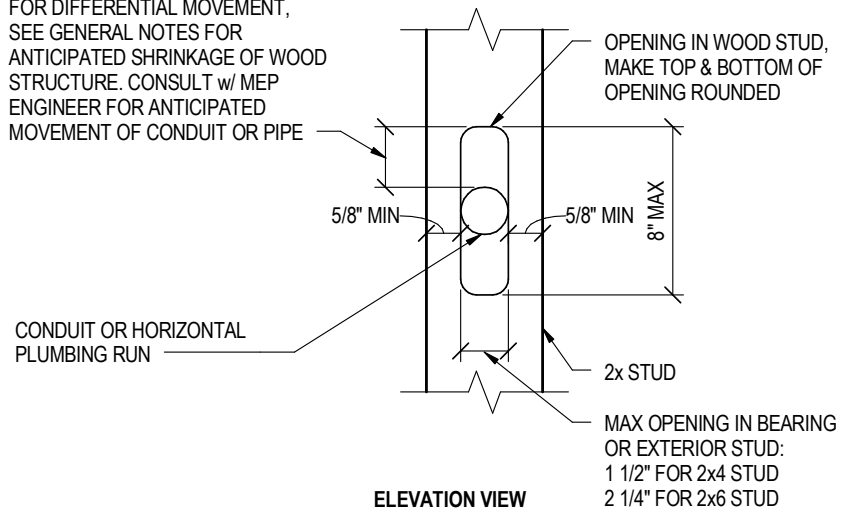


Image: Schaefer



Image: Louisiana-Pacific Corporation

NOTE: ENGINEER SHALL REVIEW LOADING CONDITIONS ON WALL FOR ALLOWABLE SIZE OF PENETRATION

Vertical Stacks – Compensation Devices Installed



Shrinkage Resource

Code provisions, detailing options, calculations and more for accommodating differential material movement in wood structures

Free resource at [woodworks.org](https://www.woodworks.org)

Accommodating Shrinkage in Multi-Story Wood-Frame Structures

Richard McLean, MS, PE, SE, Technical Director, WoodWorks • Doug Daniels, PE, Principal, Schaeffer

In wood-frame buildings of three or more stories, cumulative shrinkage can be significant and have an impact on the function and performance of finishes, openings, mechanical/electrical/plumbing (MEP) systems, and structural connections. However, as more designers look to wood-frame construction to improve the cost and sustainability of their mid-rise projects, many have learned that accommodating wood shrinkage is actually very straightforward.

Wood is hygroscopic, meaning it has the ability to absorb and release moisture. As the occurs, it also has the potential to change dimensionally. Knowing how and where wood shrinks and swells helps designers detail their buildings to minimize related effects.

Wood shrinkage occurs perpendicular to grain, meaning that a solid sawn wood stud or floor joist will shrink in its cross-section dimensions (width and depth). Longitudinal shrinkage is negligible, meaning the length of a stud or floor joist will essentially remain unchanged. In multi-story buildings, wood shrinkage is therefore concentrated at the wall plates, floor and roof joists, and rim boards. Depending on the materials and details used at floor-to-wall and roof-to-wall intersections, shrinkage in light-frame wood construction can range from 0.06 inches to 0.5 inches per level.

This publication will describe procedures for estimating wood shrinkage and provide detailing options that minimize its effects on building performance.

Wood Science & Shrinkage

Understanding the cellular structure of wood allows us to understand how moisture and wood interact and identify the paths that moisture typically travels. Within wood, moisture is present in two forms: (1) free water in cell cavities, and (2) bound water in cell walls. Simplistically, wood's cellular structure can be imagined as a bundle of drinking straws held together with a rubber band, with each straw representing

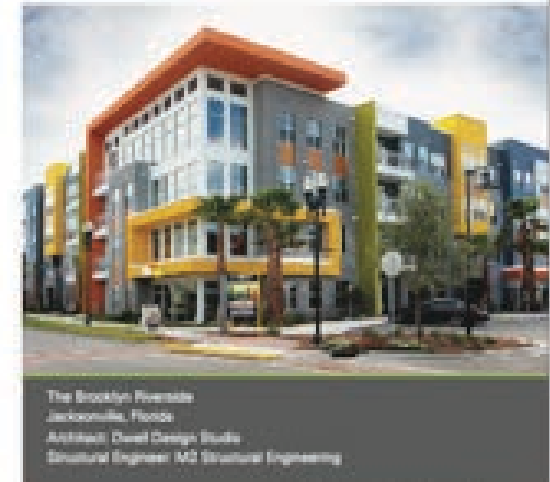


Photo: Richard Woods, Stone Mountain

a longitudinal cell in the wood. Water can be free water stored in the straw cavity or bound water absorbed by the straw walls. At high moisture contents, water exists in both locations. As the wood dries, the free water is released from the cell cavities before the bound water is released from the cell walls. When wood has no free water and yet the cell wall is still saturated, it is said to be at its fiber saturation point (FSP). Imagine a sponge that has just been taken out of a bucket filled with water. As the sponge is lifted from the bucket, water comes out of the pores. When the sponge is squeezed, more water comes out of the pores. The moment when no water can be squeezed out of the sponge but yet it still feels damp is analogous to the FSP. The moisture retained in the sponge is the bound water and water that has been squeezed out is the free water.

Acoustical Design

Noise

Acoustics

Sound Pollution



Whatever you call it, it all comes down to one thing:

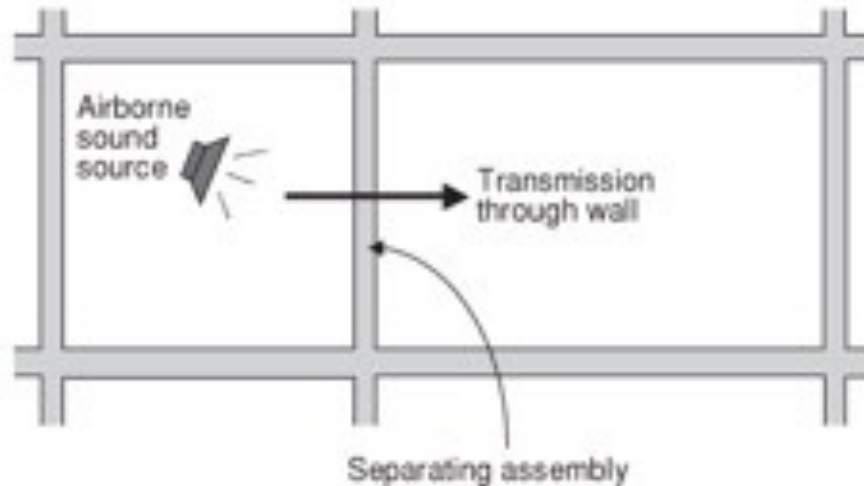
Occupant Comfort

Acoustical Design

Air-Borne Sound:

Sound Transmission Class (STC)

- Measures how effectively an assembly isolates air-borne sound and reduces the level that passes from one side to the other
- Applies to walls and floor/ceiling assemblies

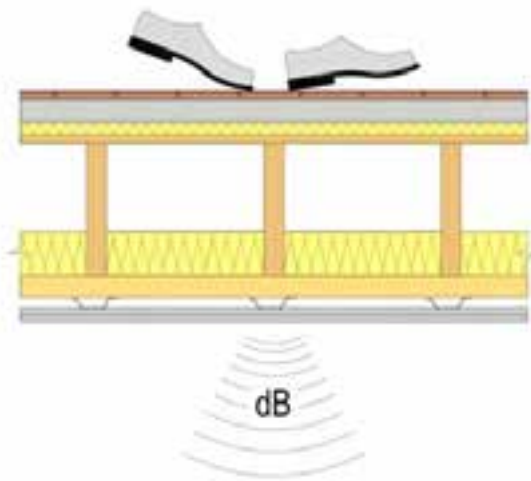


Acoustical Design

Structure-borne sound:

Impact Insulation Class (IIC)

- Evaluates how effectively an assembly blocks impact sound from passing through it
- Only applies to floor/ceiling assemblies



Acoustical Design

Code requirements only address residential occupancies:

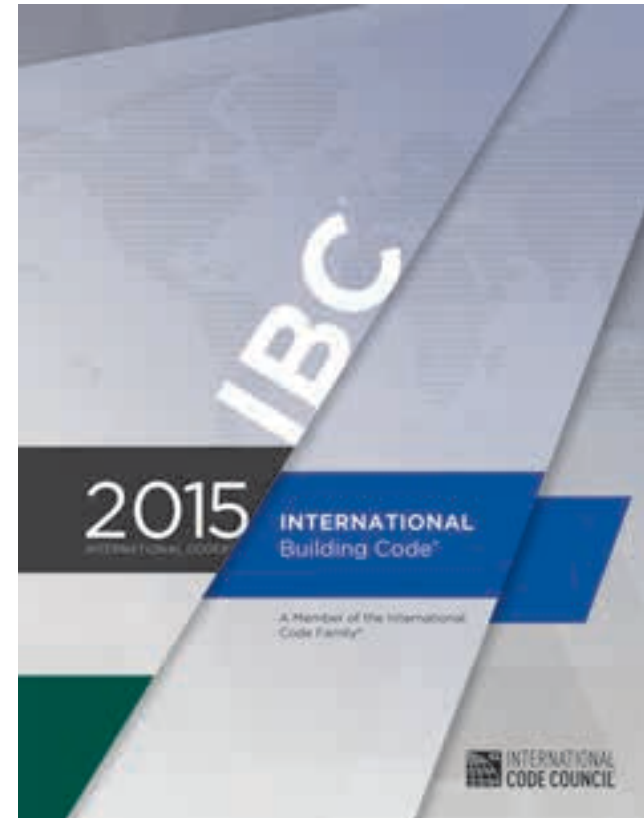
For unit to unit or unit to public or service areas:

Min. STC of 50 (45 if field tested):

- Walls, Partitions, and Floor/Ceiling Assemblies

Min. IIC of 50 (45 if field tested) for:

- Floor/Ceiling Assemblies

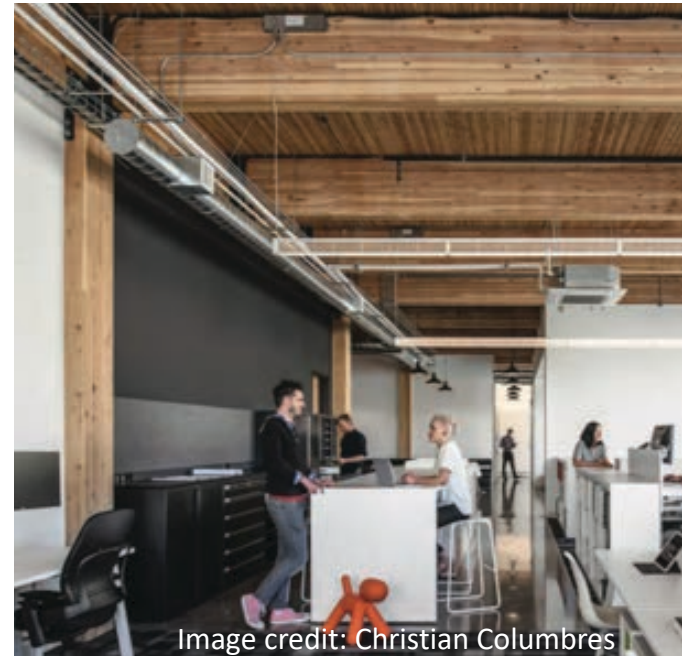


Acoustical Design

When does structure impact the acoustical performance of a wall or floor assembly?

Regardless of the structural materials used in a wall or floor ceiling assembly, there are 3 effective methods of improving acoustical performance:

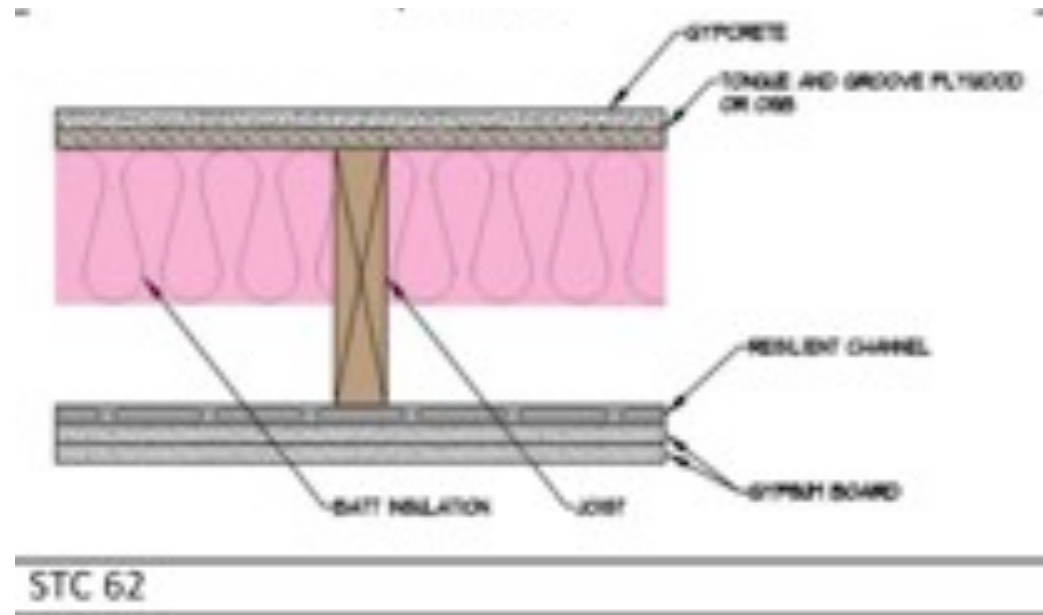
1. Add Mass
2. Add noise barriers
3. Add decouplers



Acoustical Design

What does this look like in typical wood-frame construction:

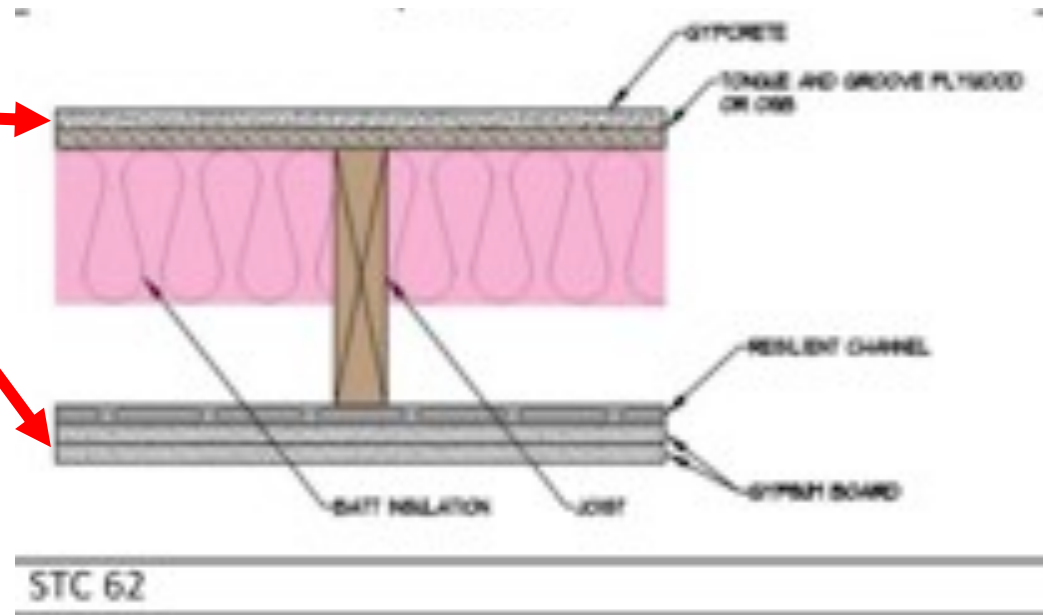
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Acoustical Design

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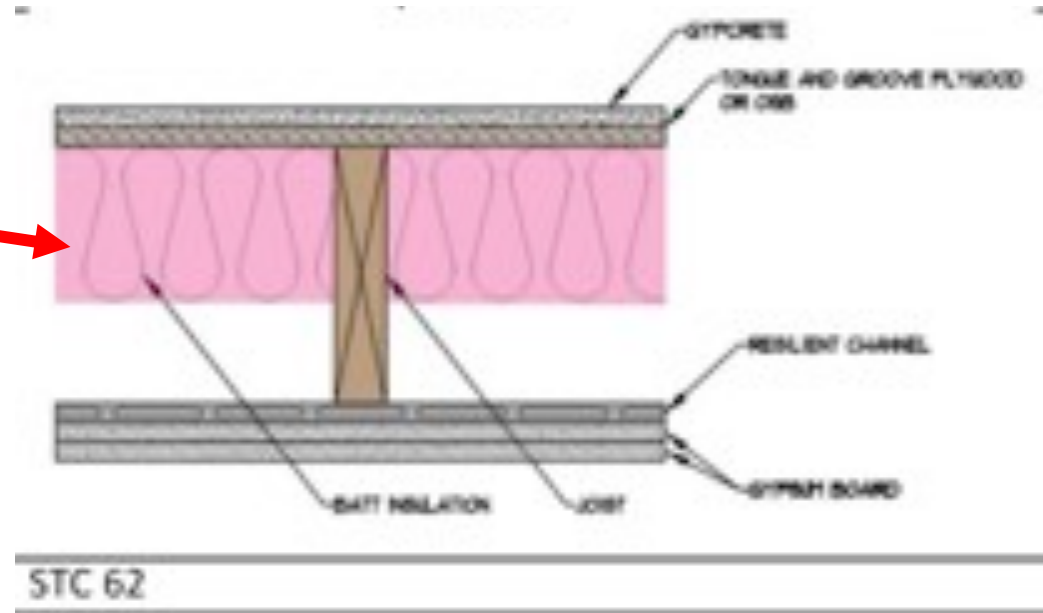
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Acoustical Design

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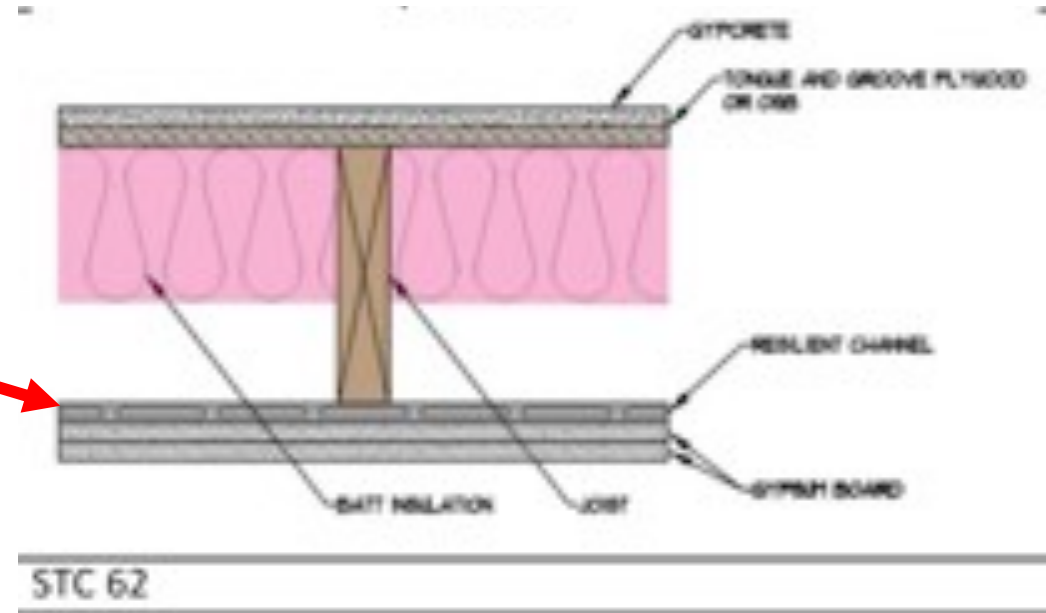
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Acoustical Design

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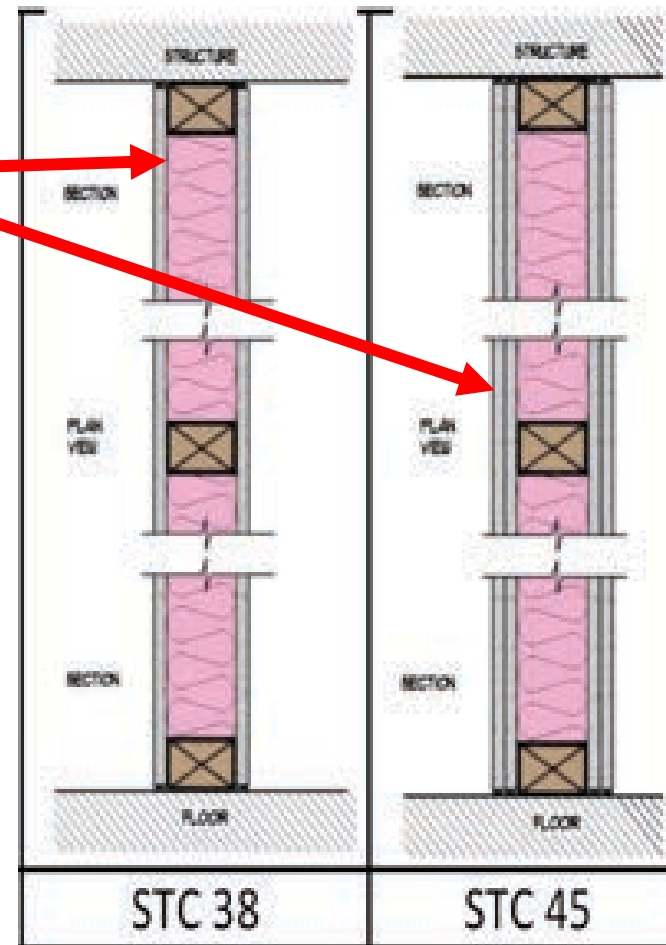
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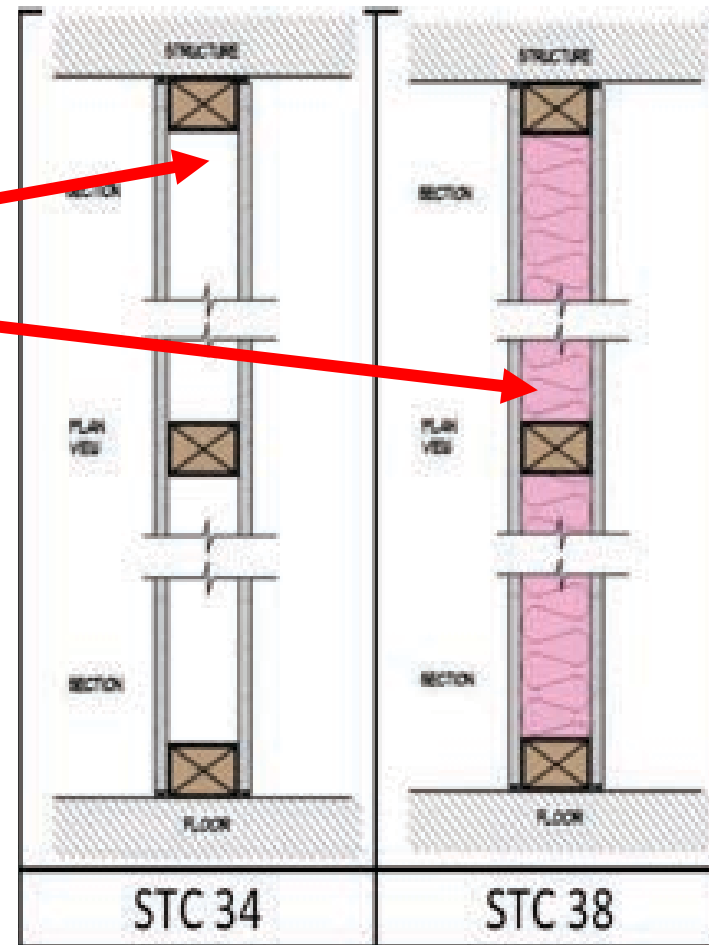
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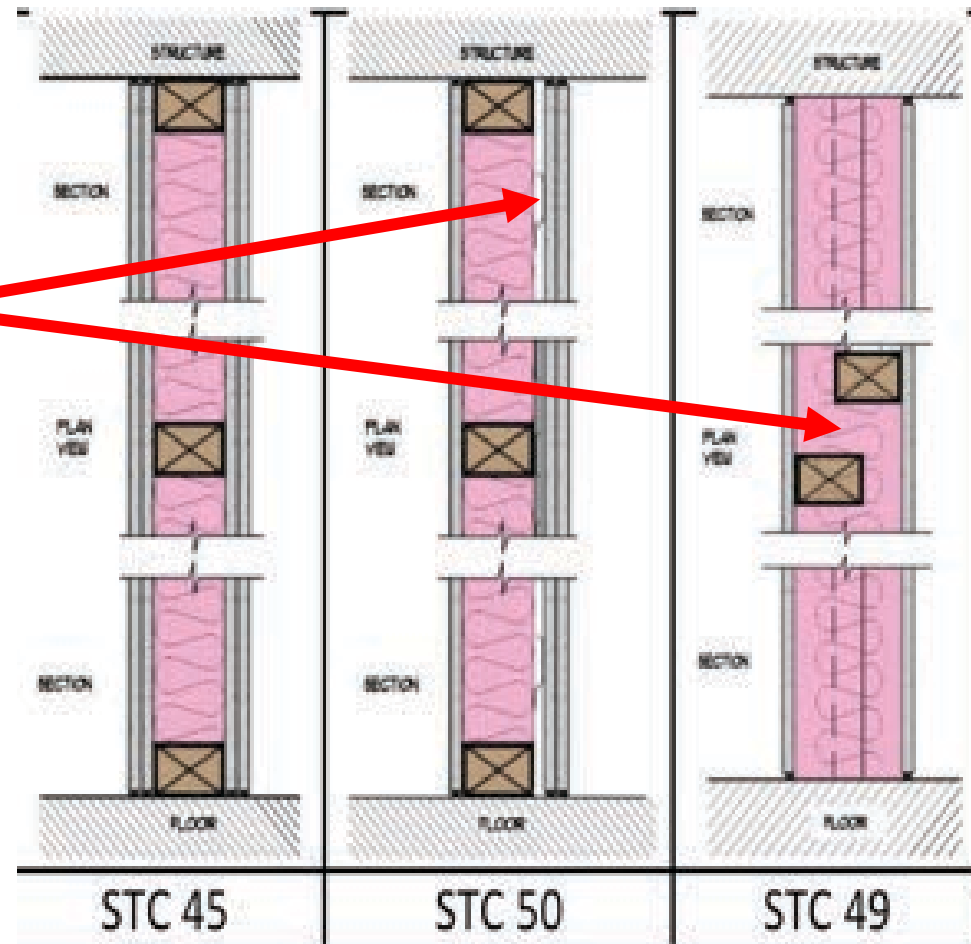
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Acoustical Design

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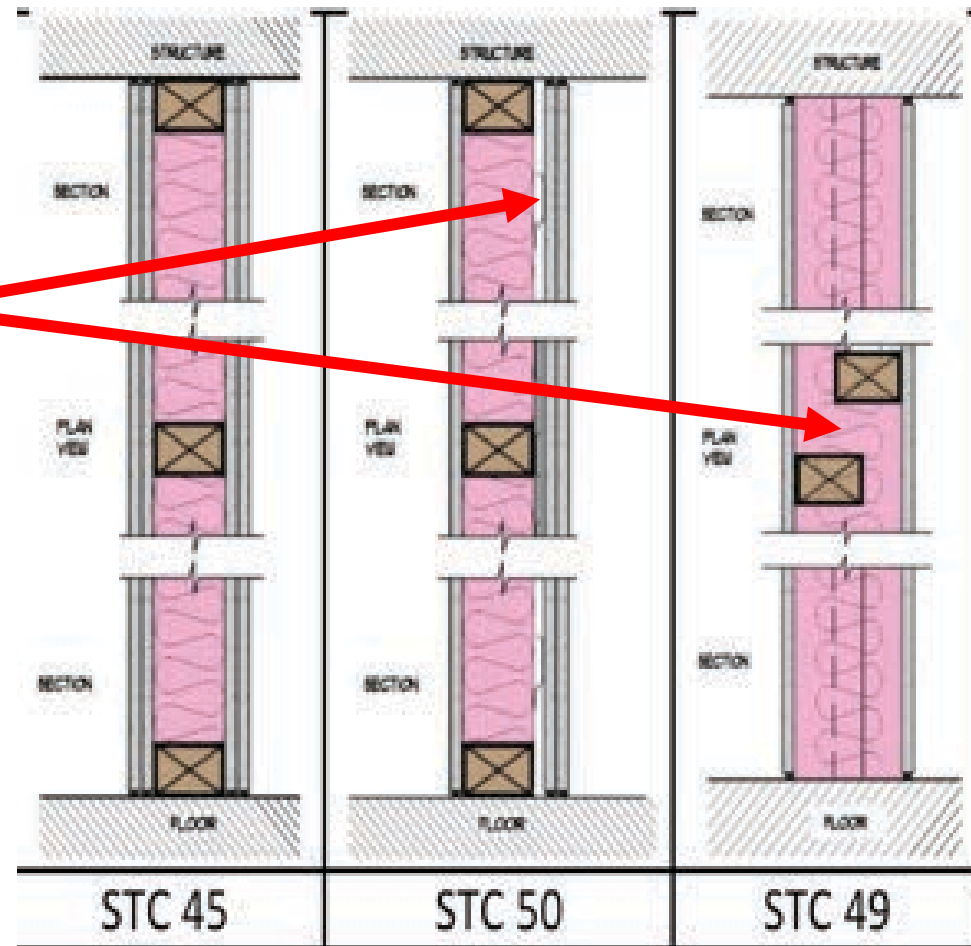


Acoustical Design

What does this look like in typical wood-frame construction:

1. Add Mass
2. Add noise barriers
3. Add decouplers

Make sure that structural elements don't defeat the purpose of these, especially decouplers



Acoustical Design

- My interior, acoustically rated wall also needs to be a shearwall (think unit demising wall)
- Can I add wood structural panels to an acoustically tested wall?

Yes, but placement is very important!

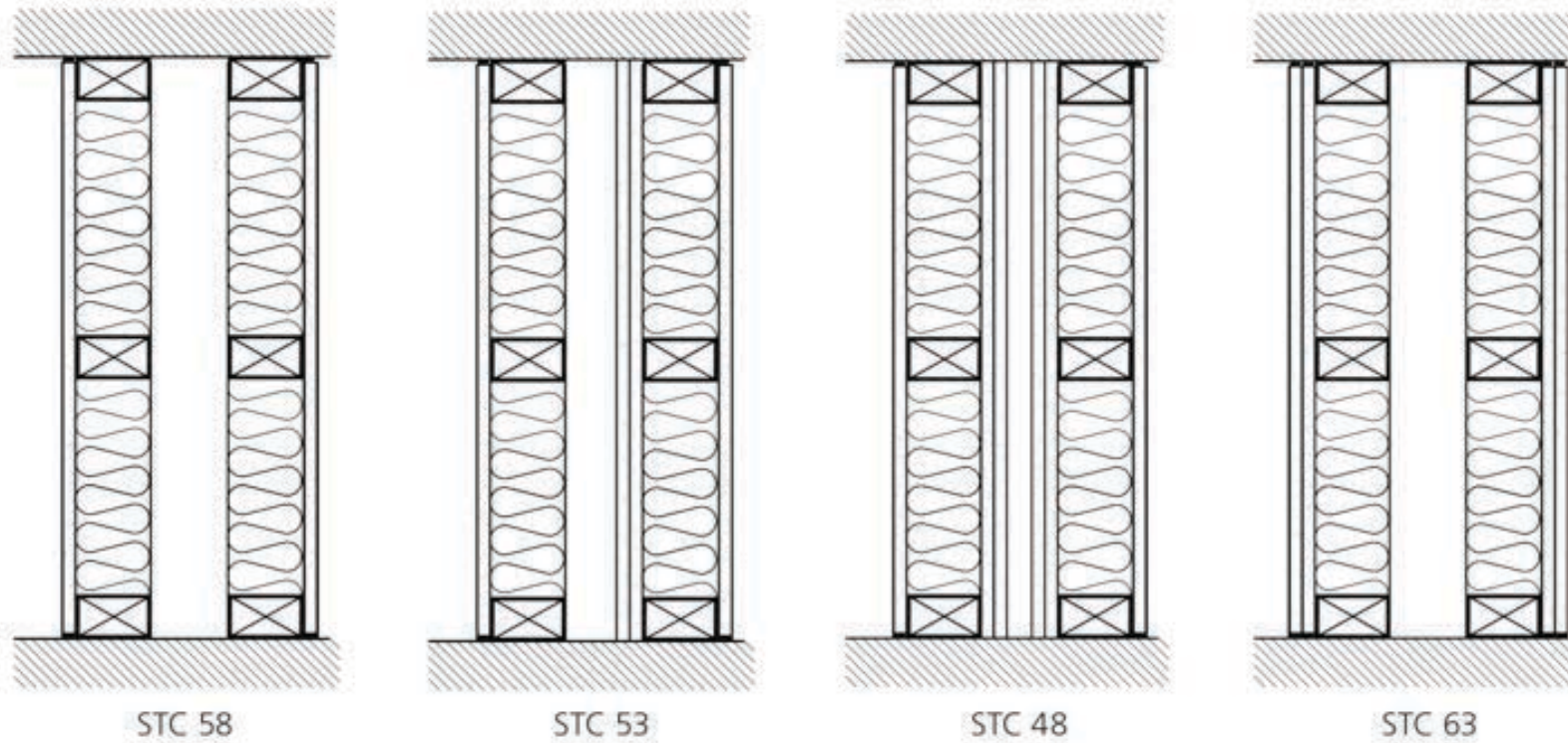


Credit: WoodWorks

Acoustical Design

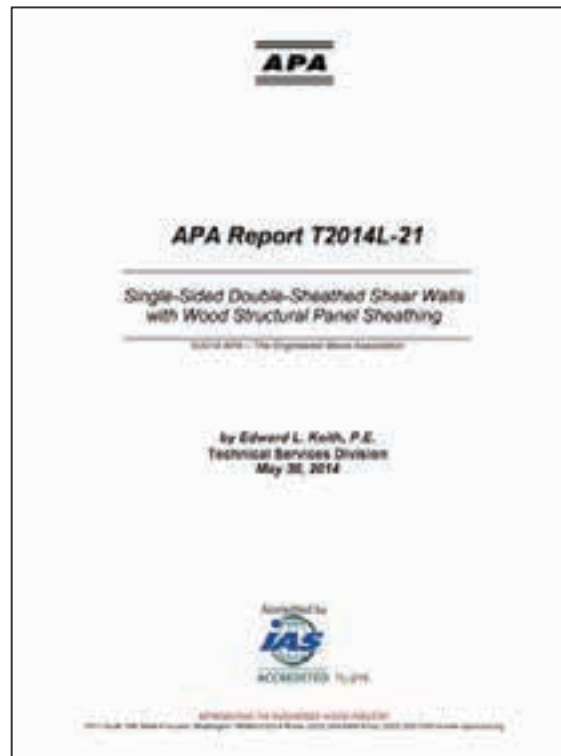
FIGURE 6

Effect of Sheathing Placement on Acoustical Performance (Plan View)



Acoustical Design

- For walls with resilient channels, put WSP on opposite side of wall
- For highly loaded shearwalls, can use double layer of sheathing on same side of wall



Acoustical Design

- Staggered stud wall condition:
- Blocking bridges finish on one side of wall to studs on opposite side, defeats purpose.
- Solution: use flat blocking in wall (wide face against WSP)



QUESTIONS?

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Credit: Brett Dury





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