Fire, Acoustics, and Structural Detailing of Light-Frame Horizontal Assemblies

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3-Part Series on Light-Frame Interior Detailing

» July 2021 Workshop on Fire, Acoustics, and Structural Detailing of Light-Frame **Interior Walls**

» November 2021 Symposium session on Fire, Acoustics, and Structural Detailing of Light-Frame **Horizontal Assemblies**
  » Will be posted to The Wood Institute prior to December Webinar

» **December 8 Webinar** wrap up on interior floor and wall assemblies
  » Answering follow-up questions, commonly asked questions
  » https://www.woodworks.org/education-event/2021-dec-webinar/
Structural
Acoustics
Fire
Horizontal Assemblies

• A floor or roof assembly required to have a fire resistance rating such as for occupancy separations and fire area separations
• May be constructed with any materials permitted by the construction type
• Occupancy separation: Fire resistance ratings per IBC Table 508.4
• Required to be continuous without vertical openings except as permitted in IBC 712
• Supporting construction required to have same fire-resistance rating as the fire barrier being supported (with exceptions per 711.4)
• Other requirements for openings, penetrations, joints
Fire resistance rating shall not be less than that required for:

- **Building’s construction type – Table 601**
  - 1-hr for III-A, V-A
  - 0-hr for III-B, V-B
- **Separating mixed occupancies – Table 508.4**
- **Separating fire areas – Table 707.3.10**
- **Separating dwelling units – 711.2.4**
  - Not less than 1-hr
  - Except: III-B, V-B with NFPA 13 sprinklers is ½-hr
- **Separating smoke compartments – 709.3**
- **Separating incidental uses – Table 509**
Choosing Fire Rated Assemblies

Common tested assemblies (ASTM E119) per IBC 703.2:

- UL Listings
- Gypsum Catalog
- Proprietary Manufacturer Tests
- Industry Documents: such as AWC’s DCA3

Alternate Methods per IBC 703.3

- Prescriptive designs per IBC 721.1
- Calculated Fire Resistance per IBC 722
- Fire-resistance designs documented in sources
- Engineering analysis based on a comparison
- Fire-resistance designs certified by an approved agency
"The addition of up to 16-3/4 inches of 0.5 pcf glass fiber insulation (R-40), either batt or loose-fill, to any 1- or 2-hour fire resistance rated floor-ceiling or roof-ceiling system having a cavity deep enough to accept the insulation is permitted provided that one additional layer of either 1/2 inch or 5/8 inch type X gypsum board is applied to the ceiling. The additional layer of gypsum board shall be applied as described for the face layer of the tested system except that the fastener length shall be increased by not less than the thickness of the additional layer of gypsum board."

Section 1.12 Gypsum Association’s Fire Resistance Design Manual
"Specified floor-ceiling and roof-ceiling framing sizes or truss dimensions are minimums. Greater joist or truss sizes (depths) shall be permitted to be used in metal- or wood-framed systems."

Section 1.17 Gypsum Association’s Fire Resistance Design Manual

"Thus, larger and deeper trusses can be used under the auspices of the same design number. This approach has often been applied to roof truss applications since roof trusses are usually much deeper than the tested assemblies".

WTCA's Metal Plate Connected Wood Truss Handbook

1. Topping (optional)
2. Flooring - min ¾” plywood
3. Truss – min depth 10”, spaced at 24”oc
4. Bridging/Strongback
5. 2 layers ½” Type X Gyp
6. Insulation (optional) – supported by metal furring or 1x3 wood furring strips at 16” oc. “Equivalent methods that retain insulation above joist bottom flange are acceptable”
Common issues with UL approved assemblies:

- Shallow Floor depth
  - Use prescriptive assemblies: IBC 721.1(3) assembly 21-1.1
  - Or use the calculated method in IBC 722
- Use of Structural Composite Lumber
  - Manufacturer’s ESR shows equivalent fire performance to solid sawn
Exposed Framing Fire Resistance

**IBC 703.3** Alternate Methods for determining fire resistance

Prescriptive designs per IBC 721.1

- **Calculations in accordance with IBC 722**
- Fire-resistance designs documented in sources
- Engineering analysis based on a comparison
- Alternate protection methods as allowed by 104.11

**IBC 722** Calculated Fire Resistance

“...The calculated fire resistance of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/AF&PA National Design Specification for Wood Construction (NDS).”

**NDS Chapter 16** Fire Design of Wood Members

Limited to calculating fire resistance up to 2 hours.

Char rate varies based on endurance required, product type and lamination thickness. Equations and tables provided.

TR10 and NDS commentary are helpful in implementing permitted calculations.
Exposed Framing Fire Resistance

<table>
<thead>
<tr>
<th>Required Fire Resistance (hr.)</th>
<th>Char Depth, $a_{\text{char}}$ (in.)</th>
<th>Effective Char Depth, $a_{\text{eff}}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Hour</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>1½-Hour</td>
<td>2.1</td>
<td>2.5</td>
</tr>
<tr>
<td>2-Hour</td>
<td>2.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Source: 2018 NDS Chapter 16

Image: AWC TR 10

Photo: David Barber, ARUP

https://awc.org/codes-standards/publications/tr10
Are sprinklers required in concealed spaces such as floor and roof cavities in multi-family wood-frame buildings?

The International Building Code (IBC) requires all buildings containing Group R occupancies to have sprinklers throughout, however, the need for sprinklers specifically located in the concealed spaces of floors and roofs is dependent on the type of sprinkler system specified (NFPA 13 or NFPA 13R) and the use of fireblocking and draftstopping.

IBC Requirements:
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 Criteria – IBC 1206

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
<table>
<thead>
<tr>
<th>STC</th>
<th>What can be heard</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Normal speech can be understood quite easily and distinctly through wall</td>
</tr>
<tr>
<td>30</td>
<td>Loud speech can be understood fairly well, normal speech heard but not understood</td>
</tr>
<tr>
<td>35</td>
<td>Loud speech audible but not intelligible</td>
</tr>
<tr>
<td>40</td>
<td>Onset of &quot;privacy&quot;</td>
</tr>
<tr>
<td>42</td>
<td>Loud speech audible as a murmur</td>
</tr>
<tr>
<td>45</td>
<td>Loud speech not audible; 90% of statistical population not annoyed</td>
</tr>
<tr>
<td>50</td>
<td>Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed.</td>
</tr>
<tr>
<td>60+</td>
<td>Superior soundproofing; most sounds inaudible</td>
</tr>
</tbody>
</table>
Choosing Acoustically Rated Assemblies

Common tested assemblies:

**STC:** ASTM E90, per IBC 1206.2

**IIC:** ASTM E492, per IBC 1206.3

- Manufacturers of gypsum, insulation, acoustical products (proprietary tests)
- UL Listings
- Gypsum Catalog
- Industry associations: AWC, APA, others
- Reach out to **WoodWorks**!

Alternate Method: IBC 1206.2 & 1206.3

- Both STC and IIC may be “established by engineering analysis based on a comparison of floor-ceiling assemblies having [STC/IIC] ratings as determined by the test procedures.”
Acoustical Detailing

Figure 1 - Acoustical Progression in Wood Framed Floor / Ceilings
Floor finish has a significant impact on IIC rating

<table>
<thead>
<tr>
<th>Construction Detail</th>
<th>Description</th>
<th>STC</th>
<th>IIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>clg. wt. 3</td>
<td>• 5/8” SHEETROCK Brand FIRECODE C Core Gypsum Panels</td>
<td>59</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>– 2x10” wood joist 16” o.c.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>– RC-1 channel or equivalent 16” o.c.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>– Insulation held up under subfloor by lighting clips</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>– 19/32” T&amp;G wood subfloor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 3/4” LEVELROCK Brand Floor Underlayment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Acoustical Performance**

<table>
<thead>
<tr>
<th>STC</th>
<th>IIC</th>
<th>Test Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>54</td>
<td>RAL-IN04-006/TL04-033</td>
<td>Cushioned vinyl floor, SRM-25, 1” LEVELROCK</td>
</tr>
<tr>
<td>58</td>
<td>55</td>
<td>RAL-IN04-007/TL04-034</td>
<td>Engineered wood-laminate floor SRM-25, 1” LEVELROCK</td>
</tr>
<tr>
<td>59</td>
<td>77</td>
<td>RAL-IN04-005/TL04-032</td>
<td>Carpet with SRM-25, 1” LEVELROCK</td>
</tr>
<tr>
<td>59</td>
<td>52</td>
<td>RAL-IN04-009/TL04-067</td>
<td>Ceramic tile with crack-isolation membrane, SRM-25, 1” LEVELROCK</td>
</tr>
<tr>
<td>58</td>
<td>50</td>
<td>RAL-IN04-013/TL04-100</td>
<td>Cushioned vinyl floor, SRB board</td>
</tr>
<tr>
<td>58</td>
<td>51</td>
<td>RAL-IN04-012/TL04-099</td>
<td>Engineered wood-laminate floor, SRB board</td>
</tr>
<tr>
<td>58</td>
<td>73</td>
<td>RAL-IN04-010/TL04-097</td>
<td>Carpet with SRB board</td>
</tr>
</tbody>
</table>
Acoustical Detailing

Lightweight concrete topping or other similar materials can provide improved acoustical performance, increased durability.
Acoustical Detailing

Adding Noise Absorbers: Batt Insulation

Without Insulation

With Insulation
Decoupled: Acoustical mat - typically installed between subfloor and topping or flooring. Can use multiple decoupling layers in sandwich assembly.
Acoustical Detailing

Decoupled: Resilient Channels

Without Resilient Channels

With Resilient Channels

STC 49

STC 56
Acoustical Detailing

Discontinuous topping at unit partition

Image: USG
Acoustical Detailing

Finish Isolation

Gypsum Wallboard
Baseboard
Acoustical Sealant
GenieMat PMI
Laminate Flooring
GenieMat FF06
3/4" Gypsum Concrete

3/4" O.S.B or T&G Plywood
3 1/2" Insulation
16" Open Web Truss
1/2" Resilient Channel
5/8" Gypsum Wallboard

Credit: Pliteq
Acoustical Considerations for Mixed-Use Wood-Frame Buildings

Steve Sheehy, P.E., LEED-AP, LEED-CI, CT3-D, Parsons Associate

Acoustics are just one aspect of building performance and must be considered in combination with requirements such as fire protection, structural systems and energy efficiency. To determine an optimal design solution, it is critically important to understand how the design and detailing for each individual system affects the others. Specifically, in addition to meeting the appropriate acoustical ratings, the assemblies chosen must achieve the required fire ratings and accommodate the structural and energy needs of the project. Understanding the effects of each performance area enables the design team to more easily navigate the decisions and trade-offs required when evaluating different assembly options.

Multi-Family Housing
Acoustical Expectations

As with any issue of building performance, the acoustics of a mixed-use wood-frame structure can be designed to meet or exceed minimal requirements, depending on the preferences of the developer, buyers, and tenants.

In residential buildings, the International Building Code (IBC) provides a minimum design requirement for unit-to-unit acoustical protection between stories. It requires a Sound Transmission Class (STC) rating or Impact Insulation Class (IIC) rating of 50, unless the “Authority Having Jurisdiction” has its own more stringent requirement, which is overly the case. The International Mechanical Code (IMC) requires a minimum design separation of 12-1/2” for townhouses.

For wood-frame mixed-use buildings, Section 1207 of the 2012 IBC includes the following:

1207.1.1 Sound Transmission Class (STC) Rating. This section shall apply to common walls, partitions, and floor-ceiling assemblies between adjacent dwelling units or between dwelling units and adjacent public areas such as halls, corridors, stairs or service areas.

1207.2 Airborne sound. Walls, partitions, and floor-ceiling assemblies separating dwelling units from each other or from public or service areas shall have a sound transmission class (STC) of no less than 50 for airborne noise when tested in accordance with ASTM E 90. Renovations or openings in constructions assemblies for piping, electrical devices or conduit inspectors shall be sealed, lined, insulated or otherwise treated to maintain the required ratings. This requirement shall not apply to dwelling unit entrance doors; however, such doors shall be tight fitting to the frame and sill.

1207.3 Structure-borne sound. Floor-ceiling assemblies between dwelling units to between a dwelling unit and adjacent public area within the structure shall have an impact insulation class (IIC) rating of not less than 50 (if tested) when tested in accordance with ASTM E 496.
Structural Floor Design

Common Wood Floor Assembly:

• LW Concrete Topping
• Acoustical Mat
• Wood Floor Sheathing
• Wood Trusses/I-joists
• Batt Insulation
• Resilient Channel
• Gypsum Ceiling
Structural Floor Design - Vibration

The code is silent on floor vibration criteria and analysis

<table>
<thead>
<tr>
<th>CONSTRUCTION</th>
<th>L</th>
<th>S or W&lt;sup&gt;f&lt;/sup&gt;</th>
<th>D + L&lt;sup&gt;d, g&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof members:&lt;sup&gt;6&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporting plaster or stucco ceiling</td>
<td>1/360</td>
<td>1/360</td>
<td>1/240</td>
</tr>
<tr>
<td>Supporting nonplaster ceiling</td>
<td>1/240</td>
<td>1/240</td>
<td>1/180</td>
</tr>
<tr>
<td>Not supporting ceiling</td>
<td>1/180</td>
<td>1/180</td>
<td>1/120</td>
</tr>
<tr>
<td><strong>Floor members</strong></td>
<td>1/360</td>
<td>—</td>
<td>1/240</td>
</tr>
<tr>
<td>Exterior walls and interior partitions:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With plaster or stucco finishes</td>
<td>—</td>
<td>1/360</td>
<td>—</td>
</tr>
<tr>
<td>With other brittle finishes</td>
<td>—</td>
<td>1/240</td>
<td>—</td>
</tr>
<tr>
<td>With flexible finishes</td>
<td>—</td>
<td>1/120</td>
<td>—</td>
</tr>
<tr>
<td>Farm buildings</td>
<td>—</td>
<td>—</td>
<td>1/180</td>
</tr>
<tr>
<td>Greenhouses</td>
<td>—</td>
<td>—</td>
<td>1/120</td>
</tr>
</tbody>
</table>

<sup>1</sup> Deflection limits apply to floor vibration.
Where can I find criteria for vibration control for wood members?

- Dolan and Woeste developed some information on controlling vibration published in *Structural Engineer* magazine.
Structural Floor Design - Vibration

IS A "SPRING IN YOUR STEP" CAUSING PROBLEMS?

June 2007 » Feature Article

Annoying vibration is probably the most common performance complaint for light-frame wood floors.

Frank Woeste, Ph.D., P.E., and Daniel Dolan, Ph.D., P.E.

Recommendations to minimize annoying wood-floor vibrations

Annoying vibration is probably the most common performance complaint for light-frame wood floors: Code Council’s 2006 International Residential Code (IRC) intends to address this issue, yet the engineer-of-record for a project may find it challenging to prove that the vibration engineer may be engaged to determine the cause of an annoying vibration. Under the prescriptive provisions of the IRC, While wood floors may qualify as "impossible to fix."
Floor Design: Occupant Comfort

Vibration & Deflection Control

Multi-family floor spans in the 24’-30’ range work well from a layout perspective. Floor design of wood members in this span range are often governed by vibration and/or deflection control, not structural capacity.

Live Load Deflection Chart, Courtesy: Redbuilt
Floor Design: Occupant Comfort

Tools available to designers

Vibration Analysis: FP Innovations
(Spreadsheet available upon request)

Joist Manufacturer’s
Rating Systems

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NOISE AND VIBRATION CONTROL OF LIGHT FRAME WOOD JOIST FLOORS Topped WITH CONCRETE

Lin Hu¹, Mohammad Mohammad² and Sylvain Gagnon³

ABSTRACT: Light frame wood joist floors have reduced sound insulation because of their lightweight nature. The popular solution to the noise transmission problem is to float a 38mm or thicker cementitious topping over the floor. Although this solution efficiently improves sound insulation of light frame floors, it makes normal walk-induced vibrations more perceivable than with the floors without the topping. Currently, more than half of the housing market in Canada is multi-family construction. As more multi-family light frame wood buildings are being built, more and more complaints about excessive feelable vibrations through concrete topped wood joint floors are being received. This paper explains the myths behind this phenomenon, and more importantly, sheds some lights on available solutions.

KEYWORDS: Light frame, multi-family building, wood joist floor, concrete topping, noise control, vibration control
### Structural Floor Design - Vibration

**Determine vibration controlled span using the simple design method, i.e. Vibration controlled span = (EI)L^2/(18.22*(m)^3*(F_a)^0.5)**

#### Floor ID
- O1 - Reactab 2014

#### Floor description
- 5.0' floor at 50' c.c., Bare floor; 5/8' '030 nailed, not in design guide (used 2005 design value of 0.6); 4-400 and use 2010 O.D; and use 2010 O.0 value for IMGC handbook, 2014

#### Results:
- Vibration controlled span = 0.61870297 (6.832 (m)^2*(F_a)^0.5)

#### Input:
- Spacing, s (m)
- 3.64
- 25.08
- 4.60
- 4.26

#### Subfloor:
- Thickness, t (in)
- 0.250 (in)
- 6.35 (mm)

#### Topping:
- Thickness, t (in)
- 0.01 (in)
- 0.25 (mm)

#### Calculations:
- Effective composite bending stiffness:
  - L = 0.233
  - a = 0.128
  - A = 3.01
  - I = 7.4

### Excel Spreadsheet

The Excel spreadsheet shown includes calculations for determining the vibration controlled span based on the floor ID and description details. The spreadsheet contains columns for input parameters such as spacing, material properties, and calculations for effective composite bending stiffness. The results are tabulated for a range of scenarios, including different spans and spacing configurations.
What methods exist for checking floor vibration of light-frame wood structures?

Vibration of light-frame wood floor construction can be a significant occupant comfort issue. However, achieving acceptable levels of floor vibration is not a code requirement. As such, it is possible to design a code-compliant wood floor structure that produces annoying or unacceptable levels of vibration due to standard foot traffic.

A variety of factors can affect a floor’s vibration performance, including:

- Presence of concrete topping or other massing materials
- Thickness/stiffness of floor sheathing
- Stiffness, spacing and span of floor joists/trusses
- Presence, size and spacing of blocking/bridging/strong backs
- Presence of direct-applied ceiling
- Stiffness of joist supporting elements (i.e., beams, bearing walls)
- Presence of partition walls

Several vibration analysis methods have been published, each of which takes into account some or all of these variables.

What constitutes an “acceptable vibration level” is subjective, but level of performance is generally measured by floor frequency. According to an article by Frank Woeste and Dan Dolan, “Occupants are very sensitive to vibrations in the range of 7-10 Hz. In theory, joist designs (or floor system designs) that vibrate well above 7-10 Hz should be judged by the occupants as acceptable simply because they can’t feel the higher frequencies. As a general rule, wider joist spacing (24 inches on center versus 12 inches on center) will produce a higher frequency because deeper members, having a greater bending stiffness (EI), will be required to meet building code deflection requirements.” However, studies by FPInnovations have shown that this approach may be “too simple to differentiate the vibration behavior of the floors with and without concrete topping, and to control vibration in a broad range of light-frame wood joist floors. For example, a long-span light-frame wood/steel floor with a concrete topping can have frequency below 14 Hz, but...
THANK YOU!

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