Sound Transmission in Wood Floor and Roof Trusses

Overview

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SBCA has been the voice of the structural building components industry since 1983, providing educational programs and technical information, disseminating industry news, and facilitating networking opportunities for manufacturers of roof trusses, wall panels and floor trusses. SBCA endeavors to expand component manufacturers’ market share and enhance the professionalism of the component manufacturing industry.
Introduction

- Controlling sound transmission in buildings through wall, floor and ceiling assemblies is an important serviceability issue.
- Noise from both environmental sources and adjacent occupancies can affect occupant comfort and privacy.
- This presentation explores the fundamentals of sound transmission in buildings and some methods commonly used to reduce sound transmission in assemblies constructed with wood trusses.
Key Definitions

• **CEILING ATTENUATION CLASS (CAC)** – A measure for rating the performance of a ceiling system as a barrier to airborne sound transmission through a common plenum between adjacent closed spaces.

• **DECIBEL** – A logarithmic unit used to measure the intensity of a sound. The decibel scale ranges from 0 (soundless) to approximately 190. See Table 2 for decibel levels of common sounds.

• **IMPACT INSULATION CLASS (IIC)** – An integer rating of how well a building floor attenuates impact sounds such as footsteps.

• **NOISE REDUCTION COEFFICIENT (NRC)** – Measurement of the ability of a material to absorb sound energy in the frequency range of 250 Hz to 2,000 Hz. NRC values range from 0 to 1, 0 meaning perfect reflection of noise and 1 meaning perfect absorption of noise.
Key Definitions

• **OUTSIDE INSIDE TRANSMISSION CLASS (OITC)** – Measurement, expressed in decibels, of the ability of a partition to attenuate sounds ranging between 80 and 4,000 Hz. OITC values are often lower than STC values and are used to gauge performance in low-frequency sensitive areas.

• **SOUND ABSORPTION** – The process by which a material or structure takes in sound energy as opposed to reflecting it. A portion of the absorbed energy is converted to heat and is “lost” and the rest is transmitted through the absorbing body.

• **SOUND TRANSMISSION CLASS (STC)** – An integer rating of how well a building partition such as an interior wall, floor/ceiling, door, window, or exterior wall attenuates airborne sounds ranging between 125 and 4,000 Hz. The STC value approximates the decibel reduction provided by that particular partition.
The speed and quality at which sound travels depends greatly on the medium through which it travels, whether wood, metal, or air. Sound waves can bounce off surfaces and squeeze though small openings in a building. While sound mitigation is less of a concern within detached residential structures, it is more significant in multi-use structures such as apartment buildings. Soundproofing design can be complex – there is no one size fits all solution, and code required STC and IIC values are just one aspect to be considered.
Background

• IBC Section 1207 (2015) requires:
  – **Minimum STC Rating of 50** for wall and floor/ceiling assemblies separating dwelling units
    • Requirement is reduced to 45 if field tested in accordance with ASTM E90
  – **Minimum IIC rating of 50** for floor/ceiling assemblies separating dwelling units or between a dwelling unit and a public or service area
    • Requirement is reduced to 45 if field tested in accordance with ASTM E492

STC > 50 required

STC & IIC > 50 required
Two main qualities are important when dealing with soundproofing:
  – Intensity, or how loud a sound is, is commonly measured in decibels (dB)
  – Frequency, or how high- or low-pitched a sound, is measured in Hertz (Hz)

While typical human hearing ranges between 20 – 20,000 Hz, sounds around 1,000 – 5,000 Hz are perceived as louder even though the actual sound energy may be the same.

STC testing roughly centers on the range of frequencies where human hearing is most sensitive.
Background – STC Rating Testing

• STC testing in accordance with ASTM E90 yields a curve showing sound transmission loss at 16 standard frequencies ranging between 125 – 4,000 Hz, which are then averaged to find the STC value.
• However, because the actual sound transmission loss can vary widely across the range, the STC value can often be misleading.
• Certain products may excel at limiting high frequency noise, but lack the ability to reduce low frequency noise and vice versa.
  – Full STC test results can help determine whether an assembly is well suited for the types of noise the assembly is expected to experience
Background – STC Rating Testing

• Low frequency noises such as home theater subwoofers or passing aircraft can be very distracting and annoying, especially if left completely unmitigated.
• However, as STC value only tests frequencies down to 125 Hz (for IIC – 100 Hz), there is no provision in the building codes for limiting lower frequency noises.
• Furthermore, reducing low frequency noise is much more difficult than reducing high or middle frequency noise.
• The most effective means of reducing low frequency noise is to increase the mass of the system, which is often not practical or cost effective in wood construction.
Analysis

• The table below demonstrates the level of privacy provided by different STC values.

• Partitions with an STC > 50 are considered well soundproofed.

<table>
<thead>
<tr>
<th>STC Rating</th>
<th>Privacy Afforded</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Normal speech easily understood</td>
</tr>
<tr>
<td>30</td>
<td>Normal speech audible, but not intelligible</td>
</tr>
<tr>
<td>35</td>
<td>Loud speech audible and fairly understandable</td>
</tr>
<tr>
<td>40</td>
<td>Loud speech audible but not intelligible</td>
</tr>
<tr>
<td>45</td>
<td>Loud speech barely audible</td>
</tr>
<tr>
<td><strong>50</strong></td>
<td><strong>Shouting barely audible</strong></td>
</tr>
<tr>
<td>55</td>
<td>Shouting inaudible</td>
</tr>
</tbody>
</table>
Analysis

• Another helpful way to understand STC ratings is in terms of the approximate decibel reduction a particular partition will provide over a reasonable range of frequencies.
  – For example, a floor with STC = 50 would be able to reduce the sound of a garbage disposal on one story to the volume of a whisper on the story below.
• The table at right lists common sounds and their decibel levels.

<table>
<thead>
<tr>
<th>Sound Source</th>
<th>Decibel Level (at source)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold of Human Hearing</td>
<td>0</td>
</tr>
<tr>
<td>Breathing</td>
<td>10</td>
</tr>
<tr>
<td>Rustling Leaves</td>
<td>20</td>
</tr>
<tr>
<td>Whispering</td>
<td>30</td>
</tr>
<tr>
<td>Moderate Rainfall</td>
<td>50</td>
</tr>
<tr>
<td>Conversation or AC unit at 100ft</td>
<td>60</td>
</tr>
<tr>
<td>Vacuum Cleaner</td>
<td>70</td>
</tr>
<tr>
<td>Garbage Disposal/Blender</td>
<td>80</td>
</tr>
<tr>
<td>Lawnmower or Shouting</td>
<td>90</td>
</tr>
<tr>
<td>Motorcycle or Drum Set</td>
<td>100</td>
</tr>
<tr>
<td>Chainsaw or Jackhammer</td>
<td>110</td>
</tr>
<tr>
<td>Live Rock Music</td>
<td>120</td>
</tr>
<tr>
<td>Air Raid Siren</td>
<td>130</td>
</tr>
<tr>
<td>Airplane Takeoff</td>
<td>140</td>
</tr>
<tr>
<td>Jet Takeoff (at 75 feet)</td>
<td>150</td>
</tr>
<tr>
<td>12 Gauge Shotgun</td>
<td>160</td>
</tr>
</tbody>
</table>
Analysis

• It can be difficult and tedious to determine the exact STC or IIC of a particular partition assembly
• Common practice is to add the STC or IIC values of each individual component to approximate the performance of the entire system.
• This may include, but is not limited to:
  – Sheathing type and thickness
  – Insulation
  – Furring
  – Truss depth and spacing

Fig 46a - Adding sound absorbing insulation increases the STC four points in this wall.
Analysis

• Testing has been done on commonly used wall and floor/ceiling assemblies to determine more exact STC and IIC values.

• It is worthwhile to compare the calculated values of an assembly to a similar assembly that has established test data.

• The table at right lists common building materials and their STC and IIC values.

<table>
<thead>
<tr>
<th>Product Description</th>
<th>STC</th>
<th>IIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic wood floor consisting of wood joist(I-joist, solid-sawn, or truss), 3/4” decking, and 5/8” gypsum wallboard attached directly to ceiling</td>
<td>36</td>
<td>33</td>
</tr>
<tr>
<td>Cushioned vinyl or linoleum</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Non-cushioned vinyl or linoleum</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1/2” parquet flooring</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3/4” Gypcrete® of Elastizel®</td>
<td>7-8</td>
<td>1</td>
</tr>
<tr>
<td>1-1/2” lightweight concrete</td>
<td>7-8</td>
<td>1</td>
</tr>
<tr>
<td>1/2” sound deadening board (USG)</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Quiet-Cor® underlayment by Tarkett, Inc.</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Enkasonic® by American Enka Company</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Sempafloor® by Laminating Services, Inc.</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>R-19 batt insulation</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>R-11 batt insulation</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3” mineral wool insulation</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Resilient channel</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Resilient channel with insulation</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Extra layer of 5/8” gypsum wallboard</td>
<td>0-2</td>
<td>2-4</td>
</tr>
<tr>
<td>Carpet and padding</td>
<td>0</td>
<td>20-25</td>
</tr>
</tbody>
</table>
Analysis

• Component manufacturers will typically list the STC and IIC values for products which are intended to aid in soundproofing.

• It should be noted that the additive approach to determining STC and IIC values should be used only as an estimate and should not be considered a substitute for lab or field testing conforming to the appropriate ASTM standards.

Figure 1. Plan view of a simple double stud partition. (a) Adding dry wall will actually lower its sound isolation if it creates a triple (b) or quadruple (c) wall. A mass-spring-mass arrangement Figure 1. Plan view of a simple double stud partition. (a) Adding dry wall will actually lower its sound isolation if it creates a triple (b) or quadruple (c) wall. A mass-spring-mass arrangement allows the best use of materials and space. Additional dry wall at the outer faces (d) increases attenuation dramatically.
Analysis – Floor Trusses

• When dealing with floor systems, IIC is often the most critical value to consider.
• Common complaints about noise through ceilings include walking, moving furniture, and dropping objects, all of which are considered impact sounds.
• A floor or ceiling assembly’s ability to limit sound transmission depends most on the types of insulation, sheathing, flooring, and subflooring, rather than the type of joist or truss used.
Analysis – Floor Trusses

• Unfortunately, standard materials such as gypsum board and hard flooring don’t offer much IIC value, and it is not always possible to include higher IIC value materials like carpeting on the floor above.

• Thus, the best way to reduce impact noise is to use specialized acoustic products like resilient channels and special acoustic underlayments.

Source: Maxxon
Analysis – Floor Trusses

• The picture at right shows a floor/ceiling system that is well soundproofed with several different measures in place.
• Using several soundproofing techniques is key because some measures are effective at reducing only certain types of noise.
• For example:
  – Batt insulation is effective for absorbing airborne sounds, but ineffective against structural/impact noise.
  – Carpeting with a thick layer of padding is excellent at reducing impact noise, but inadequate against airborne noise.

Source: Maxxon
Analysis – Roof Trusses

• While floor systems deal mainly with impact noises, roof systems deal mainly with external and environmental noises.

• Structures near airports or highways will require higher STC and IIC ratings, and certain outside noises such as aircraft may have very low frequencies, which can be very difficult to mitigate.

• This may require resilient channels, greater amounts of insulation, or other soundproofing products to achieve.
Analysis – Roof Trusses

• As with floor truss systems, sheathing and insulation materials matter far more than the structural members at reducing sound transmission in roof systems.
• Roof coverings with increased mass such as concrete decking or clay tile shingles are most effective at reducing outside noise.
• However, even assemblies with lighter roof coverings such as metal roofing can be effective when combined with sound insulating materials such as plywood and rigid foam insulation.
Analysis – Roof Trusses

• Sound transmission can also be reduced in the roof/ceiling plane.
• The techniques used in managing floor/ceiling sound transmission also work well here.
• Some good strategies for roof/ceiling sound reduction include:
  – Resilient channels
  – Adding proper insulation
Analysis – Canadian Code Provisions

• The National Building Code of Canada is somewhat similar to the IBC on the subject of sound transmission.

• According to the Canadian code:
  – STC measurements are to be made in accordance with ASTM E90 and IIC measurements are to be made in accordance with ASTM E492.
  – The STC limit for “partywalls” or walls separating units within multifamily dwellings is 50, same as the IBC.

• The Canadian code, however, does not have requirements for IIC ratings of assemblies.
Conclusion

• Limiting sound transmission in structures is a complex topic
• Although the building code gives minimum requirements for both STC and IIC in partitions, there is often a need for additional considerations depending on the structure’s location and intended use.
• In the case of wood floor and roof trusses, the trusses themselves are not critical to the level of soundproofing offered by the floor or roof system.
• Proper installation, planning and the use of soundproofing materials are essential for an ideally soundproofed system.
Design Considerations

- There are multiple approaches a designer can take to reduce the sound transmission through floors and roofs.
- Each method is not completely effective and should, in almost all cases, be implemented with at least one of the other methods to adequately reduce all types of sound.
- See [DrJ Best Practices](#) for a step by step guide to potential design solutions.

Step 1 – Increase Mass

- The concept here is fairly simple. The more massive an object is, the more difficult it is to shake or vibrate.
- Making a floor/ceiling system thicker or adding extra layers of building material can increase mass and thus reduce sound transmission.
- Although this method is effective at reducing all types of sound, it is often not cost effective.
References

• *National Building Code of Canada*; National Research Council Canada; 2015
• *Metal Plate Connected Wood Truss Handbook*; Wood Truss Council of America, 2002
• *National Design Standard for Metal Plate Connected Wood Truss Construction*; Truss Plate Institute, 2014