Research Report

Sound Transmission in Wood Floor and Roof Trusses

SRR No. 1601-03

Structural Building Components Association (SBCA)

August 29, 2016

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Introduction:

Controlling sound transmission in buildings through wall, floor and ceiling assemblies is important for the comfort level and enjoyment of building occupants as they live, work and play in these buildings. Noise from areas surrounding individual living or working spaces that makes its way into that space can reduce the enjoyment of that space and adversely affect the health and wellbeing of the occupants. Environmental noise such as nearly roadways, airports and playgrounds contribute to the noise levels in a building. Likewise, noise transmitted through walls, ceilings and floors of adjacent occupancies, offices and residences can cause a decrease in the comfort of the occupants as well as privacy concerns. This report aims to explore the methods one can use 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.

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.

Background:

The science of sound and how it interacts with the environment is fairly well understood. Sound is a vibration through any medium. The medium through which sound travels, be it brick, steel, wood or simply air, has a great effect on the sound's behavior. Additionally, sound waves can bounce off surfaces and squeeze though small openings, allowing them to travel great distances in some cases. The two most useful descriptions of sound are the sound's intensity and frequency. Intensity, or how loud a sound is, is commonly measured in decibels. Frequency, or how high- or low-pitched a sound, is measured in Hertz (Hz). Both measures are important to understand when dealing with soundproofing.

Sound mitigation within residential structures is typically not a major concern except in purpose-built rooms such as home theaters. Limiting sound transmission in multi-use structures such as apartment buildings, however, is and should be a sizeable concern. Infiltrating noises from neighbors or the environment can be very annoying and distracting and can go so far as to affect productivity within a space. The International Building Code (*IBC*) provides guidance on limiting sound transmission though walls, ceilings and floors. Section 1207 of the 2015 *IBC* states that wall and floor/ceiling assemblies separating dwelling units must meet a Sound Transmission Class (STC) rating of 50, or 45 for field tested assemblies (tested in accordance with *ASTM E90*). The same code states that floor/ceiling assemblies between dwelling units or between a dwelling unit and a public or service area in a structure must have an Impact Insulation Class (IIC) rating of at least 50, or 45 for field tested assemblies (tested in accordance with *ASTM E492*).

Controlling and limiting sound within structures is very difficult since doing so depends on a number of project specific variables. There are little to no solutions for sound transmission that can be effectively applied in all situations. The complexity of the issue means more than just the code required STC and IIC values of a product or system should be considered. Correct soundproofing design takes a great deal of care and thought by the building designer or engineer to be done correctly.

Analysis:

So what does the code specified STC or IIC rating of 45 or 50 equate to in real world terms? How much privacy does a code compliant building offer? Table 1 below demonstrates the level of privacy provided by different STC values. Partitions having an STC greater than 50, as suggested by the code requirements, are widely considered to be well soundproofed.

STC Rating	Privacy Afforded
25	Normal speech easily understood
30	Normal speech audible, but not intelligible
35	Loud speech audible and fairly understandable
40	Loud speech audible but not intelligible
45	Loud speech barely audible
50	Shouting barely audible
55	Shouting inaudible

Table 1: Privacy Afforded by Different STC Ratings[1]

Another helpful way to understand the effectiveness of various STC ratings is to think about it in terms of the approximate decibel reduction that a particular partition will provide. For example, a floor/ceiling system with STC = 50 should decrease sounds by approximately 50 decibels over a reasonable range of frequencies. See Table 2 for some example of recognizable sounds and their associated decibel levels. A floor with STC = 50 for example would be able to reduce the sound of a garbage disposal on one story to the volume of a whisper on the story below.

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

Table 2: Approximate Decibel Levels of Recognizable Sounds.

Determining STC and IIC Values

Determining the exact STC and/or IIC of a particular partition assembly can be difficult and tedious. Common practice is to take an additive approach to estimating the values of a partition assembly. The STC values of each individual component

[1] 2012 *ASD/LRFD Manual*, Table M16.1-2

(sheathing, insulation, etc.) can be added together to approximate the performance of the entire system. Sheathing type and thickness, insulation, furring, truss depth and spacing, and several other factors may contribute to an assembly's overall STC or IIC.

Tests have been done by a number of organizations on a number of 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. Table 3 provides a list of common building materials and the STC and IIC values associated with each. 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.

Product Description	STC	IIC
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	36	33
Cushioned vinyl or linoleum	0	2
Non-cushioned vinyl or linoleum	0	0
1/2" parquet flooring	0	1
3/4" Gypcrete® of Elastizel®	7-8	1
1-1/2" lightweight concrete	7-8	1
1/2" sound deadening board (USG)	1	5
Quiet-Cor® underlayment by Tarkett, Inc.	1	8
Enkasonic® by American Enka Company	4	13
Sempafloor® by Laminating Services, Inc.	1	11
R-19 batt insulation	2	0
R-11 batt inculation	1	0
3" mineral wool insulation	1	0
Resilient channel	10	8
Resilient channel with insulation	13	15
Extra layer of 5/8" gypsum wallboard	0-2	2-4
Carpet and padding	0	20-25

Table 3: STC and IIC Values for Typical Floor and Ceiling Components[2]

Sound Transmission through Floor Trusses

When dealing with floor systems, the IIC rate is often the most critical value to consider. In general, IIC values for flooring are similar to their STC values, so satisfying the code requirement for one will typically work for the other, if not come close. Common complaints about noise through ceilings include walking, moving furniture, and dropping objects, all of which are considered impact sounds. A floor/ceiling's ability to limit sound transmission is not highly dependent on the type of joist or truss used, but rather the types of insulation, sheathing, flooring, and subflooring. As demonstrated in Table 3, most basic floor/ceiling construction materials like gypsum board and hard surface flooring don't provide much IIC value. A carpeted floor goes a long way, but is completely dependent on the design of the space above

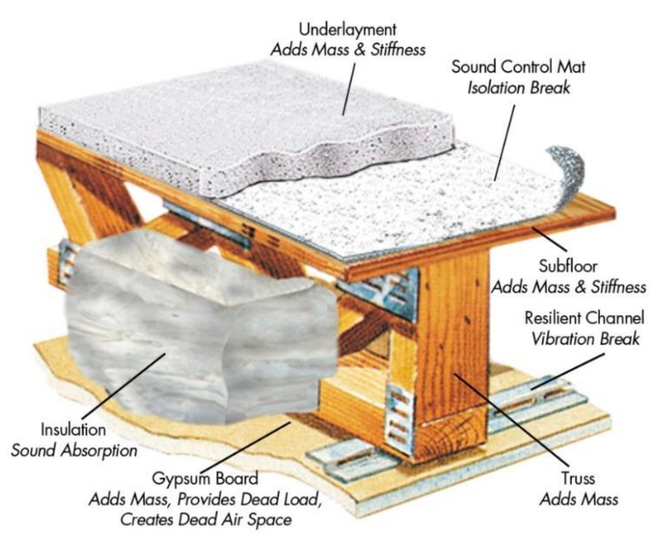

Figure 1: Floor/Ceiling System with Soundproofing Measures

[2] 2005 *ASD/LRFD Manual*, Table M16.1-9

and cannot always be included. The best way to reduce impact noise, besides substantially increasing the floor system's mass, is to use specialized acoustic products like resilient channels and special acoustic underlayments. Figure 1 shows a floor/ceiling system that is well soundproofed with several different measures in place. It's important to note that many of these measures are effective at reducing only certain types of noise and work in combination with the other measures to create a complete soundproofing system. Batt insulation for example is effective for absorbing airborne sounds, but does little or no good against structural/impact noise. On the other hand, carpeting with a fairly thick layer of padding beneath it is excellent at reducing impact noise, but is not effective against airborne noise.

Sound Transmission through Roof Trusses

Sound transmission through roof systems presents some different but still important challenges to a building designer. Unlike floor systems, the sounds being transmitted through the roof are external noises such as traffic and aircraft or environmental noises such as wind and rain. The type and degree of soundproofing needed on the exterior of a particular building is therefore dependent on its surroundings. Structures near airports or highways for example will require higher STC and IIC ratings than those that aren't, and this may require resilient channels, greater amounts of insulation, or other soundproofing products to achieve. Exterior noises vary quite a bit in frequency but certain outside noises such as aircraft may have very low frequencies, which can be very difficult to mitigate.

As with floor truss systems, the trusses themselves in a roofing system are not responsible for much sound absorption. The roof and ceiling sheathing and insulation materials do the bulk of the work. The principle of increased mass lends itself well to roof soundproofing. Roof systems with increased mass, like those with concrete decks or clay tile shingles are quite effective at reducing outside noise. Lightweight roof coverings, especially metal roofing, is seen as noisy, but can be improved greatly when it is installed over a layer of plywood and rigid foam insulation. As with floor/ceiling systems, sound transmission can be reduced in the ceiling plane. Resilient channels and proper insulation can be used here with great effect.

Methods and Design Considerations for Reducing Sound Transmission

There are several 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.

- 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.
- Viscoelastic Damping – Viscoelastic damping materials, as their name implies, exhibit both viscous and elastic behavior making it essentially part solid and part liquid. These materials have the capacity to both store sound energy and convert some of it into heat which makes them highly effective in reducing sound. Although commonly used on a small scale in electronics, viscoelastic damping compounds can also be used on a building scale in the form of adhesive compounds such as Green Glue Noiseproofing Compound. Such compounds must be installed between two rigid layers like plywood and gypsum board, but offer a substantial reduction in sound transmission, especially considering their low cost.
- Mechanical Decoupling – Decoupling refers to the act of separating different sections of a partition, thereby allowing them to vibrate independently. The use of staggered studs, separated double studs, resilient channels, and sound clips are all examples of mechanical decoupling and are all highly effective in reducing sound transmission. Of these options, the use of resilient channels is by far the most cost effective and simplest to implement and is one of the most effective methods of overall sound reduction.
- Sound Absorbing Material – Sound absorbing materials such as foam, acoustic fiberglass, and cotton batting are an inexpensive method of limiting sound transmission through absorption. Since sound absorbing materials are typically installed on the interior side of a ceiling or wall, they are not practical in many cases. Sound absorbing products are also most effective when combined with either viscoelastic or mechanical damping measures.
- Proper Seal Quality – This method should not be seen as optional and should be incorporated with or without the other soundproofing methods. Proper seal quality means that there are no gaps or cracks between ceilings and walls, and that windows, doors, and mechanical and electrical fixtures are tight fitting. Sound damping and absorption techniques will be greatly diminished if sound is allowed a direct path through a partition. Good seal quality can be achieved by accurate, tight installation of building materials and improved through the use of acoustic caulks and sealants.

- Limit Flanking Paths – Noise that is able to bypass or "flank" a specific construction can ruin its sound insulation values. It's important to identify these possible flanking paths and eliminate them wherever possible. A partition will not be able to live up to its insulation potential if sound is able to simply move around it. Typical flanking paths for sound include uninsulated mechanical ducts in partitions, back-to-back electrical outlets or plumbing penetrations, and continuous joist spaces over partitions. These flanking paths can reduce a partition's STC value by 15 to 20 points if not mitigated.

Decibel Variation with Frequency

Sound can be described both in terms of frequency and intensity, and the two are closely related. The testing method for determining STC ratings covers 16 standard frequencies ranging between 125 Hz and 4,000 Hz. The average human can detect sounds between 20 Hz and 20,000 Hz, but we are most sensitive to sounds near 4,000 Hz. For this reason, sounds at moderate frequencies (1,000 – 5,000 Hz) are perceived as louder than sounds at higher or lower frequencies even though the actual sound energy may be the same. It makes sense then that the formulation of STC and IIC values is skewed toward sounds around that range and leaves out frequencies at either extreme.

The STC testing in accordance with *ASTM E90* yields a 16-point curve showing sound transmission loss at each of the tested frequencies. These 16 points must then be converted into a single representative number; the STC value. The STC ranking of a component, therefore, is an average of that component's ability over a fairly wide range of frequencies which can be misleading. What this means is not all products or assemblies with a particular STC ranking are equal. Certain products may excel at limiting high frequency noise but lack the ability to reduce low frequency noise and vice versa. It's important therefore to evaluate the types of noise a partition is expected to be exposed to and select an assembly based on more than just the STC and/or IIC value. If available, a quick look at an assembly's test results can be very helpful.

Problems with Low Frequency Noise

As noted above, testing frequencies for determining STC and IIC values go down to 125 Hz and 100 Hz respectively. This means, according to the building code, noises below 100 Hz do not need to be accounted for. Low frequency noises such as those from home theater subwoofers or passing aircraft can be very distracting and annoying, especially if left completely unmitigated. To make matters worse, most partitions, even those with high STC or IIC values, tend to struggle at reducing low frequency noise. Reducing low frequency noise is difficult to do, much more so than mid to high 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.

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*. Per the Canadian code, the STC limit for "partywalls" or walls separating units within multifamily dwellings is 50, which is on par with the *IBC* limit. The Canadian code, however, does not have requirements for IIC ratings of assemblies.

Conclusion:

In conclusion, sound transmission as it relates to structures, and particularly limiting it, is a complicated topic that requires careful thought and planning to properly execute. Although the building code gives minimum requirements for both STC and IIC in partitions, there is often need for additional considerations depending on the structure's location and intended use. There are several methods to reduce sound transmission and a variety of products that are designed specifically to do so. 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.

This research report is subject to periodic review and revision. For the most recent version of this report, visit sbcindustry.com. For information on the current status of this report, contact SBCA.

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