Impact Insulation Data for Solid-Joist Floor-Ceiling Construction

Wilson Byrick, Pliteq Inc., Toronto, Ontario, Canada

Reducing impact sound in wood-joist construction is a common challenge in building acoustics, especially in multifamily construction. One of the primary areas of failure is ceiling installation. Through laboratory testing, two different questions were examined: What is the effect of short-circuiting the deluxe resilient channel on one-third-octave-band impact insulation data according to ASTM E492? And what is the effect of a retrofit ceiling applied over the short-circuited gypsum board with minimal impact to the unit owner? Sound isolation clips were used in the retrofit ceilings with insulation to limit mass-air-mass resonance in the cavity created. By drilling holes in the existing ceiling 48-inches on center, the air pressure was relieved and resonance reduced.

Impact insulation class (IIC) is used to quantify a floor-ceiling assembly's ability to attenuate impact sound from a standardized tapping machine source. The laboratory test method is ASTM E492. An IIC 50 rating is required for floor-ceiling assemblies in multifamily construction when separating dwelling units from public or adjacent dwellings. IIC 50 only became mandatory in 2006 in the International Building Code (IBC), creating a need for laboratory data and better understanding of design options.

The most common floor-ceiling designs include the use of gypsum concrete and a resilient interlayer that are intended to decouple the gypsum topping from the subfloor. The gypsum board ceiling is commonly suspended from a resilient channel, a z-shaped steel channel intended to resiliently decouple the ceiling from the structure. The resilient channel is commonly short circuited as a result of screw penetration through the channel and into the structural joist. We wanted to determine the effect of such short circuiting.

In multifamily dwellings built prior to IIC code implementation or conversions of other types of space, it is helpful to determine what retrofit steps are possible to bring floor-ceiling assemblies up to "code minimum" and improve IIC performance. Often times the flooring is a less desirable renovation for the owners, and gypsum concrete is not possible to add to the structure due to loading constraints. Therefore, we are commonly asked only about a ceiling-side retrofit. In this article, we look at data from a possible retrofit solution of adding sound isolation clips and a furring channel to an existing short-circuited ceiling and present the data findings.

Methodology

At National Gypsum Company's laboratory in Buffalo, NY, a floor-ceiling system was constructed of:

- 300-mm-wide (12 in.), 8 mm thick ceramic tile
- 2-mm (3/32-in.) re-bonded recycled rubber underlayment
- 15.9 mm (5/8-in.) tongue-and-groove plywood subfloor
- 12.7-mm (1/2-in.) plywood subfloor
- 38-mm x 254-mm (nom. 2-in. x 10-in.) solid-wood joist spaced 400 mm (16 in.) OC
- 89-mm (3.5-in.) batt insulation
- 12.7-mm (1/2-in.) Clarke-Dietrich RC deluxe resilient channel spaced 24 in. OC
- 12.7-mm (1/2-in.) Type C gypsum board

For the purpose of this article, this will be known as the base assembly. All tests were conducted in accordance with ASTM E492 – laboratory measurement of sound transmission through floor-ceiling assemblies using the tapping machine. Variations on the assembly included the following:

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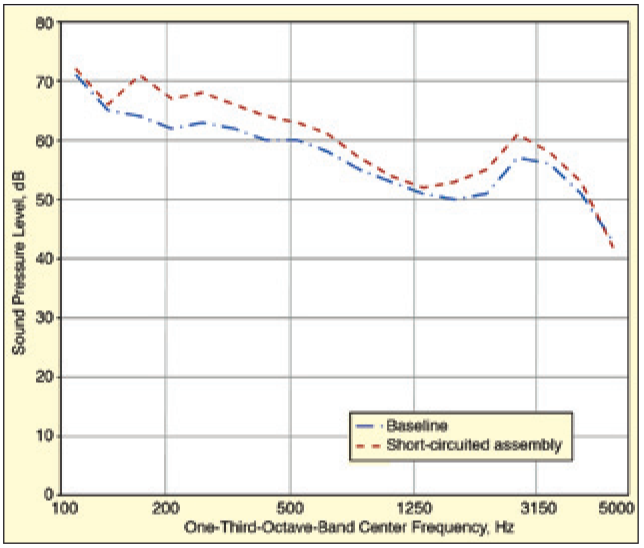

Figure 1. Sound pressure level vs. frequency – one third octave band spectrum comparing resilient channel ceiling vs. same ceiling with 12 short-circuited screws.

- Base assembly
- Adding 12 additional screws through the ceiling and resilient channel connecting to the structural joist
- Adding a sound isolation clip, furring channel and ½-in. gypsum board to create a retrofitted additional ceiling
- Removing the retrofit ceiling and drilling 3-in. diameter holes 48 in. on center and replacing the sound isolation clip ceiling
- Removing the resilient channel ceiling and installing the sound isolation clip ceiling directly to the structural joist

Experimental Results

The results of the six test assemblies can be viewed in Table 1. The one-third-octave-band data are shown in Figures 1 through 3. The initial baseline assembly was tested to an IIC 44. The addition of 12 screws creating short-circuits from the gypsum board ceiling to the structure resulted in an IIC 42. See Figure 1 for the complete one-third-octave-band comparison. Retrofitting a sound isolation clip ceiling resulted in an IIC 46. Drilling holes in the short-circuited ceiling and re-plying the retrofit sound isolation ceiling resulted in an IIC 50. After removing the ceiling and attaching sound isolation clips directly to the structure, the IIC was measured as IIC 52. See Figures 2 and 3 for further one-third-octave-band comparisons.

Discussion and Conclusions

At the end of the testing, only the sound isolation clip assembly

Table 1. Results of ASTM-E492 tests on various solid-wood joist assemblies.

Assembly	IIC Rating	SPL @ Low Frequency (Avg. of 100, 125, 169 Hz)	SPL @ 3150 Hz
Baseline	44	66.7	56
Add 12 short circuits	42	69.7	58
Add ceiling retrofit	46	65.3	28
Add 3-in. holes in cavity	50	64.3	31
Isolation clip direct to joist	52	65.0	42

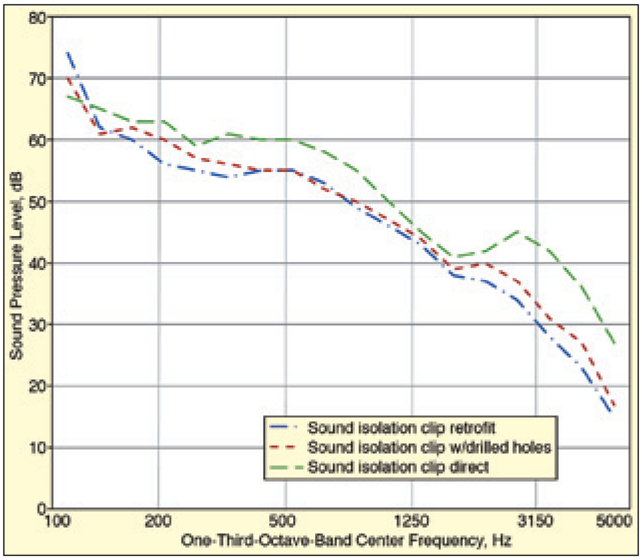

Figure 2. Sound pressure level vs. frequency – one third octave band spectrum comparing sound isolation clip retrofit ceiling and the same retrofit ceiling but with holes drilled in the baseline and a sound isolation clip ceiling directly attached.

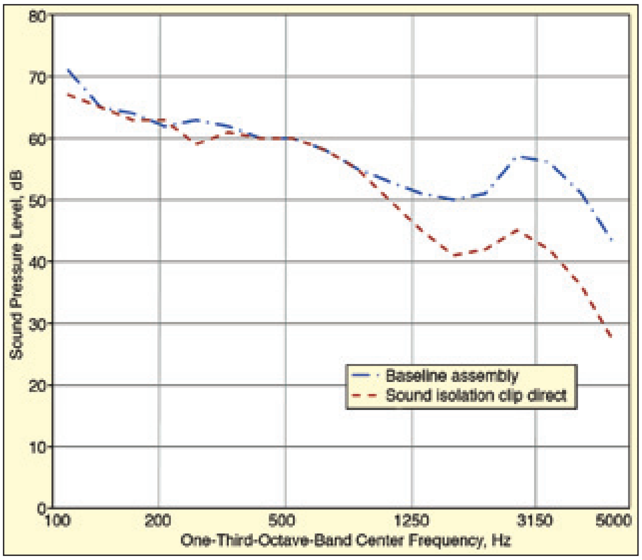

Figure 3. Sound pressure level vs. frequency – one third octave band spectrum comparing sound isolation clip directly attached to the ceiling and a deluxe resilient channel directly attached to the ceiling in a wood frame construction.

directly attached to the joist and the retrofit assembly with holes drilled met the design goal of IIC 50. The best results overall were observed when the sound isolation clip was retrofitted and holes were drilled in the existing ceiling.

Based on acoustics theory, there is mass-spring-mass resonance in a retrofit ceiling assembly due to the double-leaf effect. The air acts as a spring and causes resonance effects at low frequency. This was observed since the drilling of holes in the original ceiling caused a 4 dB improvement at 100 Hz.

While this helped increase the overall IIC that was controlled at 100 Hz by the 8-dB rule, we still see better high-frequency performance when the holes were not present. The best performance at 100 Hz was measured when the sound isolation clip was attached directly to the wood joist. This also resulted in the highest overall IIC rating. The retrofits were much better at high frequencies due to the additional drywall and double leaf.

When comparing the resilient channel baseline assembly and short-circuited assembly, negative effects of the short circuits are observed across the frequency spectrum. Large increases in sound pressure level are observed at 160, 200 and 250 Hz (7 dB, 5 dB and 5 dB, respectively). The assembly had approximately 108 drywall screws before the short circuits.

The additional 12 screws caused a significant increase in low frequency SPL. This effect is commonly observed in field installations. As with all studies, it would be advantageous to collect more iterations and data points to verify these findings. Conclusions cannot be made based on single data points, but the data can be of interest for developing future test programs and possible solutions.

Acknowledgements

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References

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The author can be reached at: wbyrick@pliteq.com.