Case Studies: Effect Of Fasteners Bridging Resilient Channels On AIIC Performance In Wood-Framed Condominiums

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1 Introduction

This paper presents two case studies of wood-framed condominium projects where complaints were raised by occupants/owners within the first year of occupancy. The complaints were consistent with low insulation of impact sounds across floor-ceilings – footfalls from the units above were said to be intrusive within the units below.

Apparent Impact Insulation Class (AIIC) measurements, as well as inspection of the floor-ceiling construction with ceiling drywall removed, were completed within several units. It was confirmed that many drywall fasteners penetrated floor joists, thus bridging resilient channels and negating their proper function.

For both projects discussed in this paper, a strong correlation was found between the percentage of resilient channel / floor joist intersections with bridging fasteners, and the AIIC score.

2 Background information

Impact Insulation Class (IIC) is a single-number rating system that describes the insulation of sounds due to impacts on the top side of a floor-ceiling assembly within the space below. A greater IIC value indicates better insulation of impact sounds. The Ontario Building Code recommends a minimum design rating of IIC 55 between stacked residential spaces [1], which can be a challenging value to meet in non-carpeted, wood-framed construction without a concrete topping [2]. IIC ratings are determined by carefully controlled laboratory measurements. In the field, Apparent IIC (AIIC) measurements are used, per the measurement procedure defined in ASTM standard E1007 [3]. A floor-ceiling assembly which performs well in terms of airborne noise isolation (as determined by its Sound Transmission Class – STC – rating), may not necessarily perform well in terms of IIC.

In multi-unit wood-framed residential construction, floor-ceiling assemblies are typically constructed of insulated “I” floor joists. The construction between the floor joists and the finished floor will typically include one or more layers of wood sheeting, as well as an impact insulation layer made of a compressible material (e.g. high density glass fibre, foam, rubber). The finished flooring essentially “floats” above the impact insulation layer, which reduces the efficiency of vibration transmission to the structure. Below the floor joists, the ceiling construction typically consists of two layers of gypsum boards, either 13 mm or 16 mm thick. Airborne and impact noise isolation performance is improved by mounting the ceiling gypsum boards to resilient channels, which in turn are mounted to the floor joists in the perpendicular direction. When properly installed, resilient channels de-couple the ceiling gypsum boards from the floor joists. This results in significantly reduced transmission of vibrations, and therefore of structure-borne sounds due to impacts, compared to otherwise similar constructions with gypsum boards rigidly affixed to floor joists.

Ceiling constructions that include resilient channels must be carefully built to ensure that the resilient connection between gypsum boards and floor joists is maintained. One challenge in achieving this is that fasteners affixing gypsum boards to the channels are typically long enough to penetrate the bottom chords of floor joists, essentially defeating the resilient connection across the web of the resilient channel. Therefore, the ceiling installers must take steps to ensure that the location of floor joists are known, and avoid installing gypsum board fasteners for either layer of gypsum boards which are directly below the floor joists. Errant fasteners are a common construction deficiency for assemblies that include resilient channels, which significantly reduces AIIC performance.

3 Case studies

3.1 Project A

The project is a three-storey condominium building, totaling 37 residential units. Complaints were raised by occupants/owners at the time of the one year performance audit required by the Tarion Warranty Program in Ontario Canada. The floor-ceiling assembly construction is described below:

- Finished hardwood flooring, 19 mm thick
- 19 mm oriented strand board
- Foam impact insulation layer, 6mm thick
- 19 mm oriented strand board sub-floor
- Engineered wood “I” joists, spaced 406 mm O.C.
- 90 mm fiberglass insulation between floor joists
- 13 mm resilient channels
- 2 layers of 13 mm gypsum board, type “C”

Properly installed, this floor-ceiling construction was expected to test to AIIC 50 or more. Initial testing completed in a sample of four stacked residential unit pairs yielded scores below expectations, which suggested a construction deficiency.

Next, it was required to identify the remaining floor-ceiling assemblies between residential units that were

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performing below expectations for impact noise insulation. To expedite measurement collection, "mini" impact tests were completed between stacked unit pairs throughout the building. The "mini" tests consisted of using only two of the four tapping machine positions specified in ASTM E1007. Rather than performing background sound level and reverberation time measurements in each lower unit as required by ASTM E1007, these measurements were completed only for a small portion of the tests, and applied at other areas. Adjustments were made to the calculations based on a visual estimate of the amount of sound absorption in the lower unit, as compared to the spaces where reverberation times were measured. Low background sound levels were ensured by switching off any significant background noise sources (e.g. unit ventilation systems). The resulting AIIC scores were used on a pass/fail basis only, to identify floor-ceiling assemblies likely to have construction defects. The simplified testing allowed all unit pairs to be tested within far less time than would be required for full AIIC measurements.

Following "mini" impact testing, inspections of the lower unit ceilings were completed within several units, spanning the range of measured AIIC scores. The inspection procedure involved removing a portion of the ceiling drywall while leaving the resilient channels in place, in a central area of the room. Then, the number of intersecting resilient channels and floor joists which contained one or more drywall fastener that penetrated the floor joist (thus precluding the resilient connection between these materials) was counted, along with the total number of visible resilient channel / floor joist intersections. This allowed the rate of improperly installed fasteners at resilient channel / floor joist intersections throughout the ceiling to be estimated, and compared to the AIIC result, as shown in Figure 1.

3.2 Project B

The project includes three buildings of stacked residential units. Each building includes two lower units (ground floor and basement), and two upper units. Occupants and owners of lower units complained of unacceptable levels of intrusive noise from the footsteps of upper unit occupants. The floor-ceiling construction is described below:

- Finished hardwood flooring, 19 mm thick
- 2 layers of 9.5 mm oriented strand board
- Glass fibre impact insulation layer, 6 mm thick
- 30 mm oriented strand board sub-floor
- Engineered wood "I" joists, spaced 406 mm O.C.
- 305 mm glass fibre insulation between floor joists
- 13 mm resilient channels
- 2 layers of 16 mm gypsum board, type "X"

The expected minimum impact insulation performance for the floor-ceiling design was AIIC 52. AIIC tests were completed within bedrooms and the main living-dining areas for a total of six unit pairs throughout the three buildings – a total of 18 AIIC tests. All but two of the tested floor-ceiling assemblies failed to meet the minimum performance expectation, which strongly suggested a construction deficiency.

Inspections were completed within nine of the 18 tested assemblies. For each inspection, both layers of ceiling gypsum boards were removed in each of the lower unit rooms, for the complete ceiling area between bulkheads and demising walls. The resilient channels remained in place. The total number of visible resilient channel / floor joist intersections was counted, along with the number of these in which errant fasteners had been installed which bridged ceiling gypsum boards to floor joists. This allowed the percentage of resilient channel / floor joist intersections with errant fasteners to be compared with the AIIC score, as shown in Figure 1.

4 Results

Figure 1 below shows the relationship between the rate of bridged resilient channel / floor joist intersections and the AIIC score for both Project A and Project B. Figure 1 also includes best-fit lines and correlation coefficients (r) for each project. The data show that AIIC performance drops significantly as the occurrence of bridging fasteners increases. In Project A, a rate of 16% reduced AIIC performance by four points, and a rate of 48% reduced AIIC performance by nine points, relative to one test scoring AIIC 52 in which no errant fasteners were found. In Project B, AIIC performance was reduced by two points for a rate of 8%, and eight points for rates of 58% and 62%, relative to the minimum performance expectation of AIIC 52.

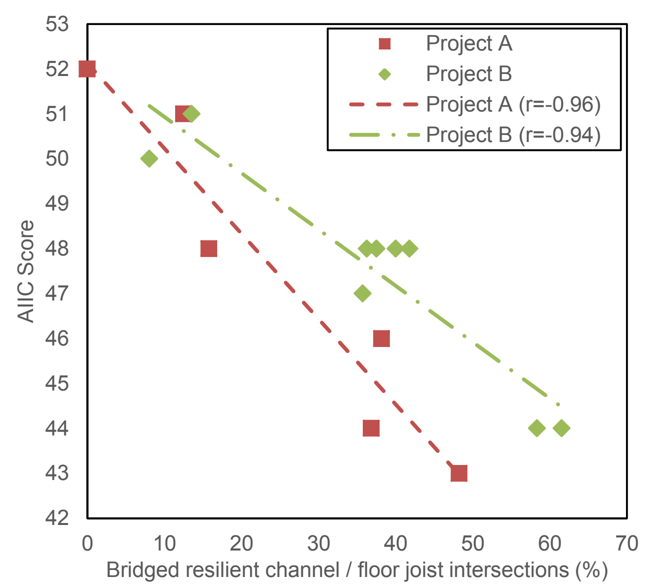

Figure 1: Relationship between AIIC scores and the percentage of bridged resilient channel / floor joist intersections

References

[1] Ontario Building Code 2012, Div.B, A-9.11.1.1.(1)

[2] A.C.C. Warnock. Controlling the Transmission of Impact Sound through Floors. *National Research Council of Canada, Construction Technology Update 35*, 1999

[3] ASTM E1007-16, Standard Test Method for Field Measurement of Tapping Machine Impact Sound Transmission Through Floor-Ceiling Assemblies and Associated Support Structures, 2016