FLANKING NOISE AT STACKED TOWNHOUSE ENTRANCE STAIRS

Gregory E. Clunis*[1] and Pier-Gui Lalonde†[1]
[1]Integral DX Engineering Ltd., Ottawa, Ontario, Canada

1 Background

Whereas traditional townhouses consist of horizontally adjacent units each involving all floors of the building, innovations in the Canadian housing industry have identified advantages of stacked units in lightweight wood construction. This creates a condition where part of the lower unit footprint is "cut-out" for the entrance stairs to the upper unit. The demising construction between the stacked units therefore includes the boundaries of the entrance stairwell (in addition to the main floor-ceiling separation).

Entrance stairs were identified as a possible acoustic weakness by the first stacked townhouse developer we worked with in 2003. That first project involved mock-up testing and allowed us to try several different approaches. This paper summarizes that early experience, and additional design improvements we have implemented over time.

1.1 Code Requirements and Compliance

The Ontario Building Code (OBC) requires that the separations between adjacent units in multi-unit residential construction must be designed to at least STC 50 or ASTC 47 [1]. There are no required IIC ratings, but at least IIC 55 is recommended in Appendix A of the OBC [2].

The performance of entrance stair constructions cannot directly be assessed against OBC requirements and recommendations. The small dimensions of stairwells preclude measurements to determine ASTC ratings [3]. There are no standards to measure the impact noise insulation performance of stairs.

1.2 Description of Typical Constructions

In wood-framed townhouse construction, the primary demising walls between units are typically double-stud walls. Stairwell-enclosing walls are often framed with staggered studs. For the vertical separation below entrance stairs, a common design is to frame a sloping surface below the staircase, with insulation filling the void created. Two or three layers of drywall are then installed to the framing, sometimes supported on resilient channels. While we are not aware of STC tests of this construction, Building Permit reviewers in Ottawa have accepted this design.

2 Objective

Entrance stairs are a critical location where significant airborne and impact sounds are generated. The adjacent space in the lower unit is typically an open living-dining area. The need for high-performance airborne and impact sound attenuation between these spaces is clear.

The objective is to identify ways to minimize sound transmission via entrance stair constructions, without compromising other OBC requirements (structural, fire resistance, etc.).

3 Early Experience

3.1 Initial Design Considerations

Mechanical de-coupling of the entrance stairs to the structure is expected to increase impact and airborne noise isolation performance. To that end, we have always specified that stairs should only be affixed to heavy/solid structural components at the top and bottom of the stairs. This allows a small gap to be maintained between the stair stringers and drywall, which is filled with insulation and acoustic caulk.

Our approach has also been to ensure that the framing of the sloped ceiling below the entrance stairs is fully supported by the stairwell walls only, with no connections to the stairs.

We have always specified carpeted entrance stairs with a thick underpad as the most straightforward method to meaningfully control impact noise.

3.2 Early Mock-up Testing and Results

Our earliest ASTM E336 [3] airborne noise isolation testing of entrance stairs involved a staggered-stud stairwell wall design. The construction implemented the initial design considerations above. With the sound source in the lower unit and the receiving space limited to the stairwell above, NIC 45 was achieved. While NIC cannot be directly compared to STC or ASTC ratings, this was a disappointing result, given the performance that is possible with staggered-stud walls (~STC 55) [4].

Based on subjective observations, noise radiation was predominantly via the side walls, and not directly through the stairs. It is acknowledged that we have no specific data to substantiate this observation.

4 Design Improvements

4.1 Solid Wood Sound Blocking

Following the mock-up testing, we implemented design improvements the address the sound flanking paths involving the stairwell walls above the stairs, the vertical cavity within the walls next to the stair stringers, and the lower portions of the stairwell walls within the lower unit (see Figure 1).

Our approach to mitigate vertical sound flanking was to add physical barriers within the side wall framing cavities, to separate the portions of the walls above and below the stairs. This was implemented as carefully cut pieces of wood

* greg@integraldxengineering.ca
† pier-gui@integraldxengineering.ca

installed between the studs, at an angle and height matching the locations of stair stringers. We have implemented this in staggered stud and double stud walls. Figure 1 shows an implementation in a staggered stud wall.

An obvious limitation of the sound blocking in staggered stud walls is that it confounds the mechanical separation across the wall cavity, with unavoidable degradation of direct sound attenuation through the partition. We've avoided this in double-stud walls by using insulation between the rows of studs and applying a pourable caulk above.

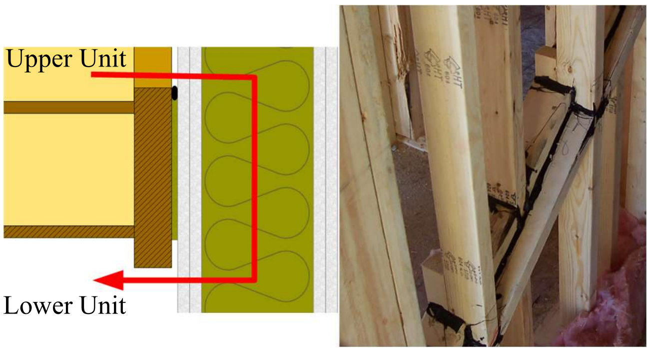

Figure 1: Left, section view (elevation) of entrance stairs and wall. The sound flanking path is shown in red. Right, view of the solid wood sound blocking pieces in a staggered stud wall, along the future location of the stair stringer.

4.2 Further Refinements

In addition to sound blocking, our design recommendations for entrance stairs have included each of the following improvements for noise.

1. Using two or more layers of regular weight 16 mm Type X drywall on both sides of stairwell walls.
2. Upgrade to higher-density insulation.
3. Caulking applied to all wood/wood and wood/drywall contact points along the plane of sound blocking.

4.3 Test Results, Improved Design

The design improvements identified following the initial mock-up testing have been implemented on all of our stacked townhouse projects, and we regularly perform NIC tests in conditions similar to the initial mock-up. These typically achieve up to NIC 49. It is acknowledged that we do not have data to quantify the relative impact of the various design changes intended to improve noise isolation.

4.4 Practical Considerations

In Ontario, it is required that stairs be provided early in construction, to allow Building Inspectors to access the upper levels. However, to properly detail the entrance stair sidewalls (sound blocking, insulation, caulk, and two layers of drywall both compounded and taped), the building must be at least partially weather-tight. The best solution we've identified is the use of temporary stairs at the earliest construction stages, narrower than the final stairs, allowing access for prep work to stairwell walls on both sides. All developers we've worked with came to agree with this approach, which has some benefits: temporary stairs can be re-used on other projects, the possibility of damage to final stairs during construction is largely avoided, and stairs can be built to the precise final dimensions of the stairwell.

The coordination and sequencing of multiple trades poses a further challenge. For example, a common problem is that the prep work does not extend far enough beyond the stair stringers, precluding access to tape all drywall joints. For success, these issues must be managed closely, with clear direction during early construction, and site inspections as the work progresses.

Some designs incorporate interior doors to close off the top of entrance stairs and/or to create a storage area below the stairs in the lower unit. While these interventions will not work for all floor plans and require owner/occupant buy-in, additional interior doors achieve an improvement for a modest additional cost.

5 Conclusions

Entrance stairs for wood-framed stacked townhouses are critical locations for airborne and impact noise isolation. It is unfortunate that no field measurement procedure currently exists which would allow for direct comparisons to the ASTC requirement per the OBC.

We have identified design improvements which increase noise isolation performance via entrance stairwells, to a level that we feel is consistent with the intent of the OBC. Even so, noise isolation via entrance stairs will typically be much less than the performance of demising partitions in lightweight wood construction. As a result, occupants are likely to notice higher noise transmission near the entrance stairs to adjacent units.

6 Future Work

It is our opinion that the necessary resources to achieve significant improvements to this condition are beyond those which are in reach of individual developers and their architects and acoustical engineers. A detailed evaluation of the condition in a laboratory environment, such as the NRC facilities in Ottawa [5], would be most helpful on multiple fronts:

1. to quantify individual sound transmission paths;
2. to establish or refine repeatable measurement procedures (laboratory and in-situ, airborne and impact noise); and
3. to investigate design improvements.

References

[1] Ontario Building Code articles 5.8.1.1. and 9.11.1.1.

[2] Ontario Building Code A-9.11., Impact Noise

[3] current version: ASTM E336-23, Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings, 2023

[4] National Building Code of Canada Fire and Sound Resistance Tables, Table 9.10.3.1.-A

[5] Estabrooks, T. et. al., NRC-IRC Flanking Sound Transmission Facility, Acoustics Week in Canada 2009 [Proceedings], 2009