A new approach to building acoustics regulation in Canada

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ABSTRACT

A new approach to the control of sound transmission is among the proposed changes in the 2015 edition of the National Building Code of Canada. The design objective is changing from a minimum STC for the wall or floor/ceiling assembly separating adjacent units to a requirement for the Apparent Sound Transmission Class (ASTC) including flanking. The approach to design is based on combining the ASTM data from conventional laboratory measurement of direct transmission through wall or floor/ceiling assemblies with measurements of flanking transmission conforming to ISO 10848 and predictions using ISO 15712-1. To support the design and regulatory approval process, the National Research Council is preparing a series of reports detailing the design procedure for a broad range of heavy monolithic and lightweight framed constructions, and providing the supporting generic data in form of web-based tools and tables from two decades of research studies in flanking test laboratories.

Keywords: Sound, Insulation, Transmission, Flanking I-INCE Classification of Subjects: 51.3, 51.4, 51.5

1. INTRODUCTION

For over 50 years, the National Building Code of Canada (NBCC) has specified only the required minimum STC of the assembly separating adjacent units in residential buildings. Since 1990, this requirement has been for separating assemblies with STC of 50 or greater, established by laboratory testing according to ASTM E90 (1) or by field testing according to ASTM E336 (2).

Implicit in this approach is the simplistic assumption that sound is transmitted only through the obvious separating assembly—the separating wall between side-by-side rooms, or the separating floor/ceiling between rooms that are one-above-the-other. If the sound insulation is inadequate, this is ascribed to errors in either the design of the separating assembly or the workmanship of those who built it, and remediation focusses on that assembly.

In reality, the technical issue is more complex. There is direct transmission of sound through the separating assembly, but that is only part of the transmitted sound power. The airborne sound field excites all the surfaces of the source space, and all of these surfaces vibrate in response. Some of this vibrational energy is transmitted as structure-borne sound across the surfaces abutting the separating assembly, through the junctions where these surfaces join the separating assembly, and into surfaces of the adjoining space, where part is radiated as sound. This is called flanking transmission. It follows that the sound insulation between adjacent rooms is always worse than the sound insulation provided by the obvious separating assembly.

Occupants of the adjacent room actually hear the combination of sound due to direct transmission through the separating assembly and any leaks, plus the sound due to structure-borne flanking transmission involving all the other elements connected at the edges of the separating assembly.

Although the desirability of altering the building code to correctly address occupants' actual noise problem is obvious, there have been significant technical and commercial barriers inhibiting such change

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1.1 Barriers to changing the Building Code

Such a transition requires a supporting set of technical standards for measuring direct and flanking sound transmission for typical assemblies and junctions, plus a credible standardized procedure for calculating system performance from these inputs.

Although using ASTM E336 to measure ASTC between rooms in a building is routine for Canadian consultants, predicting the ASTC due to the set of transmission paths in a building is much more complex, and ASTM has not developed standards for measuring transmission of structure-borne flanking sound (in laboratory or field settings), nor for calculating ASTC from such data.

By contrast, ISO has developed a standardized framework ISO 15712-1 (4) for calculating overall sound transmission. ISO 15712-1 (aka EN-12354-1) has been used for over 20 years to support performance-based European code systems. It uses inputs from laboratory tests to characterize sub-assemblies (the ISO counter-parts of ASTM E90 and E336) and in due course will be revised to include use of the laboratory flanking measurements of ISO 10848 (5).

But there are significant impediments to applying ISO 15712-1 procedures in the context of North American construction practice:

- ISO standards for building acoustics differ appreciably from the corresponding ASTM standards used by the construction industry in North America – both in their terminology and in the specific technical requirements for measurements and ratings. Switching from ASTM to ISO ratings would be a major and costly disruption for regulators and for producers of construction products.
- ISO 15712-1 provides reliable estimates for heavy homogeneous constructions such as concrete floors and masonry walls, but not for the lightweight steel- or wood-framed construction widely used for low-rise and mid-rise buildings in North America.

The following section presents the new approach for the National Building Code of Canada to deal with these issues, both delineating how to use a combination of ASTM and ISO test data and procedures, and adapting the design procedures to base the calculation on the most suitable data for common types of construction.

2. PROPOSED OBJECTIVE AND COMPLIANCE PATHS FOR THE CODE

Following are a brief statement of the minimum requirement for sound insulation between dwellings, and an overview of the 3 ways in which compliance may be demonstrated.

2.1 The Minimum Requirement

The minimum requirement changes from STC 50 for the separating assembly to ASTC 47 for sound transmission (including flanking transmission) between adjoining dwelling units. This limit was chosen to avoid a significant increase in the average cost of construction, while discouraging the use of construction details that seriously degrade system performance.

This should be recognized as a regulatory minimum, which many occupants would <u>not</u> consider to be satisfactory sound insulation.

Many builders seek to provide much better noise control. The supporting publications and calculation tools described in Section 3 of this paper provide resources to achieve this.

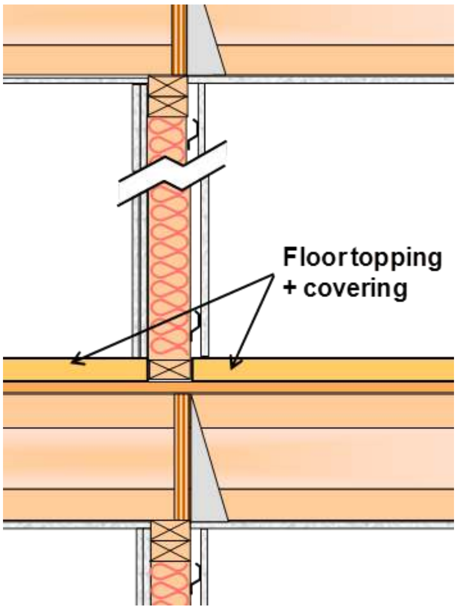
There are three paths to establish compliance with the new requirement. Rather than reproduce the requirements in Code language, the design approach is explained here in technical terms. For a more detailed explanation see NRC report RR-331 (6) which is referenced in the appendix of the NBCC.

2.2 Using Field Measurements to show compliance

A design is deemed acceptable if its details replicate a system (separating assembly, flanking constructions, and junctions) that has been shown to provide ASTC 47 or better in field testing according to ASTM E336.

2.3 Using the Prescriptive Method to show compliance

The section of the NBCC dealing with houses and small buildings provides a set of prescriptive details that are deemed to satisfy the ASTC requirement. For a limited set of separating constructions whose STC and fire resistance ratings are listed in tables in the NBCC, specific prescriptive requirements are provided for common generic flanking assemblies connected to the separating assembly at its edges. An example for a generic wood-stud separating wall combined with wood-framed floor, ceiling, and side wall flanking assemblies is presented with simplified phrasing in Fig. 1 to indicate the nature of the prescriptive requirements.



- Separating wall with single row of 38 mm x 89 mm wood studs, with resilient metal channels on one side
- Gypsum board, absorptive material between studs, and spacing of studs and resilient metal channels of separating wall as required for walls of types W5, W6, W10, or W12 in Table B.1 with STC 50 or greater
- Gypsum board on the wood-framed side walls and ceiling ends or is interrupted where it meets the framing of the separating wall,
- Wood-I joists of connected floor not continuous across floor/wall junction, joists spaced 400 mm o. c. or more, with a subfloor of OSB or plywood at least 15.5 mm thick,
- Floor topping and floor covering over the subfloor, with combined mass per unit area of 8 kg/m^2 or greater, on both sides of the junction,
  (e.g.- 16 mm hardwood strip flooring or added layer of 16 mm OSB or plywood with any flooring on top)

Figure 1: Prescriptive details required to meet design objective (ASTC=47 or greater) between side-by-side spaces, for a specific type of separating wall and attached flanking assemblies.

The prescriptive requirements were determined from calculations based on sets of single path data tested according to ISO 10848 (5) for many combinations of closely-comparable connected assemblies. Construction details such as fastening gypsum board to the framing of flanking surfaces were assumed to be the worst-case variant consistent with approved practice, and a minimum improvement was identified for the most significant flanking path – providing a heavier floor surface in this case.

An appendix notes some variants which could improve performance (such as choosing surfaces for the separating wall to increase Direct STC, or mounting the gypsum board ceiling on resilient metal channels) in order of their usefulness, but this prescriptive process gives no indication of the resulting ASTC.

2.4 Using the Design Method to establish compliance

Code requirements and ISO 15712-1 both approach the problem from the same basic concept – combining the sound power transmitted directly through the separating assembly with the flanking transmission via first-order flanking paths at each edge of the separating assembly. To discuss this, it is useful to introduce the convention used in ISO 15712-1 for labelling the transmission paths, as illustrated in Figure 2.

Consider transmission from a source room at the left to the receiving room beside it. Each 1st-order transmission path across one junction involves one surface in the source room (denoted by a capital letter) and one in the receive room (denoted by a lower case letter). **D**irect transmission through the separating wall is path **Dd**. For each edge of the separating assembly there are three flanking paths, each involving a surface in the source room and one in the receiving room, that connect at this edge: **Ff** from **f**lanking surface F to **f**lanking surface f, **Df** from **d**irect surface D to **f**lanking surface f, and **Fd** from flanking surface F to **d**irect surface d in the receiving room.

Note that the letter "F" and "f" denote **f**lanking surfaces, whereas "D" and "d" denote the surfaces for **d**irect transmission, (i.e. - surfaces of the separating assembly). Each of these labels may apply to either wall or floor/ceiling assemblies, depending on orientation of the room pair.

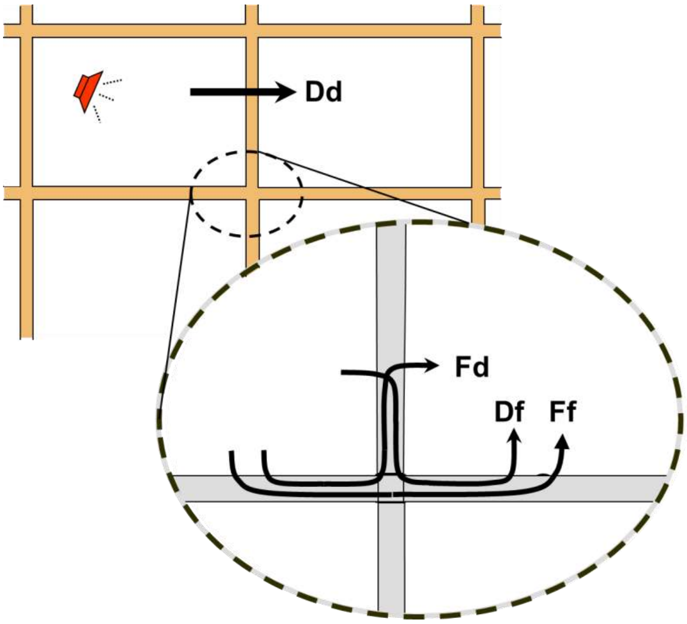


Figure 2: Labelling convention used in ISO 15712-1 for direct and flanking transmission paths

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In Canada, building elements are normally tested according to the ASTM E90 (1) or E336 (2) test protocols. The new code requirements are given in terms of Apparent Sound Transmission Class (ASTC). ASTC can be determined from the apparent sound transmission loss (ATL) for the set of frequency bands from 125 to 4000 Hz, following the procedure in ASTM E413.

Merging this ASTM context with using the ISO 15712-1 procedures, the terms "direct transmission loss" and "flanking transmission loss" have been introduced to provide consistency with ASTM terminology, but match the function of the direct and flanking sound reduction index, as applied in ISO 15712-1.

Section 4.1 of ISO 15712-1 defines a process to calculate apparent sound transmission by combining the sound power transmitted via the direct path and the twelve first-order flanking paths. Equation 14 of ISO 15712-1 is recast here with slightly different grouping of the paths, assuming rectangular room geometry and neglecting transmission due to leaks, ducts, crawlspaces, etc. which should be controlled by normal good practice. The Apparent Sound Transmission Loss (ATL) between two rooms is the decibel expression of the sum of sound power due to Direct Sound Transmission Loss TL_{Dd} through the separating wall or floor element and the sound power due to Flanking Sound Transmission Loss contributions (TL_{Ff}, TL_{Fd}, and TL_{Df}) of the three flanking paths for every junction at the edges of the separating element:

$$ATL = -10 \cdot \lg\left(10^{-0.1 \cdot TL_{Dd}} + \sum_{edge=1}^{4} \left(10^{-0.1 \cdot TL_{Ff}} + 10^{-0.1 \cdot TL_{Fd}} + 10^{-0.1 \cdot TL_{Df}}\right)\right) \qquad \text{Eq. 1.}$$

Eq. 1 is appropriate for all building systems, but the remaining challenge is to find the right expressions to calculate the path transmission for the chosen building system and situation. The design procedure proposed for the NBCC constrains these choices, depending on the type of wall and floor constructions combined to form a complete building, as follows:

1. For heavy homogenous types of construction such as concrete floors or concrete block walls, the NBCC design procedure determines the flanking sound transmission loss by either the Detailed or

Simplified calculation procedures of ISO 15712-1 (4). For input data, these calculations use sound transmission loss data (for the base wall and floor assemblies and for linings) measured according to ASTM E90.

2. For lightweight steel- or wood-framed assemblies, the NBCC design procedure substitutes experimental flanking data (treating flanking sound reduction index measured according to ISO 10848 (5) as Flanking Transmission Loss) in place of values calculated using ISO 15712-1 as above. Either a detailed calculation procedure using 1/3-octave-band data or a simplified procedure using single-number ratings is permitted.

In either case, the calculation combines the sound power due to direct and flanking transmission in the same way, specified above in Eq. 1.

3. SUPPORTING MATERIALS FOR THE DESIGN PROCESS

The brief description of the proposed design calculation procedures in the preceding section glosses over some details of the calculation process. More importantly, it ignores the issue of finding the necessary laboratory test data to use as inputs for the calculations, and the practical need for software tools to ease the calculation process for designers and regulators. These shortcomings are addressed in supporting materials published or planned by NRC, as outlined below.

3.1 Guideline to clarify the calculation process

As noted previously, the NBCC directs users to document “RR-331: Guide to Calculating Airborne Sound Transmission in Buildings” for additional advice. A first version of this guideline was published in 2013, and updated editions are expected at the end of each year as content is refined and additional sections are approved by the industry steering committee.

This Guide presents extended descriptions of the calculation process (both simplified and detailed methods) for specific types of construction, and includes numerous benchmark examples of the calculations. Users of the Guide would require a copy of ISO 15712-1 to duplicate the illustrated examples, because the Guide does not reproduce the standard’s equations or calculation inputs such as the empirical vibration reduction index values. It is intended mainly to explain extensions and adaptation of the procedures of ISO 15712-1, as a reference document for acoustical experts.

3.2 Publications with data and examples for specific types of construction

A set of documents are being prepared to present data required for the calculations and to provide guidance on spreadsheet calculations following the Simplified Method. These are being developed in collaboration with the industry associations representing specific construction materials, and are intended as guidance to a broad industry and regulatory audience.

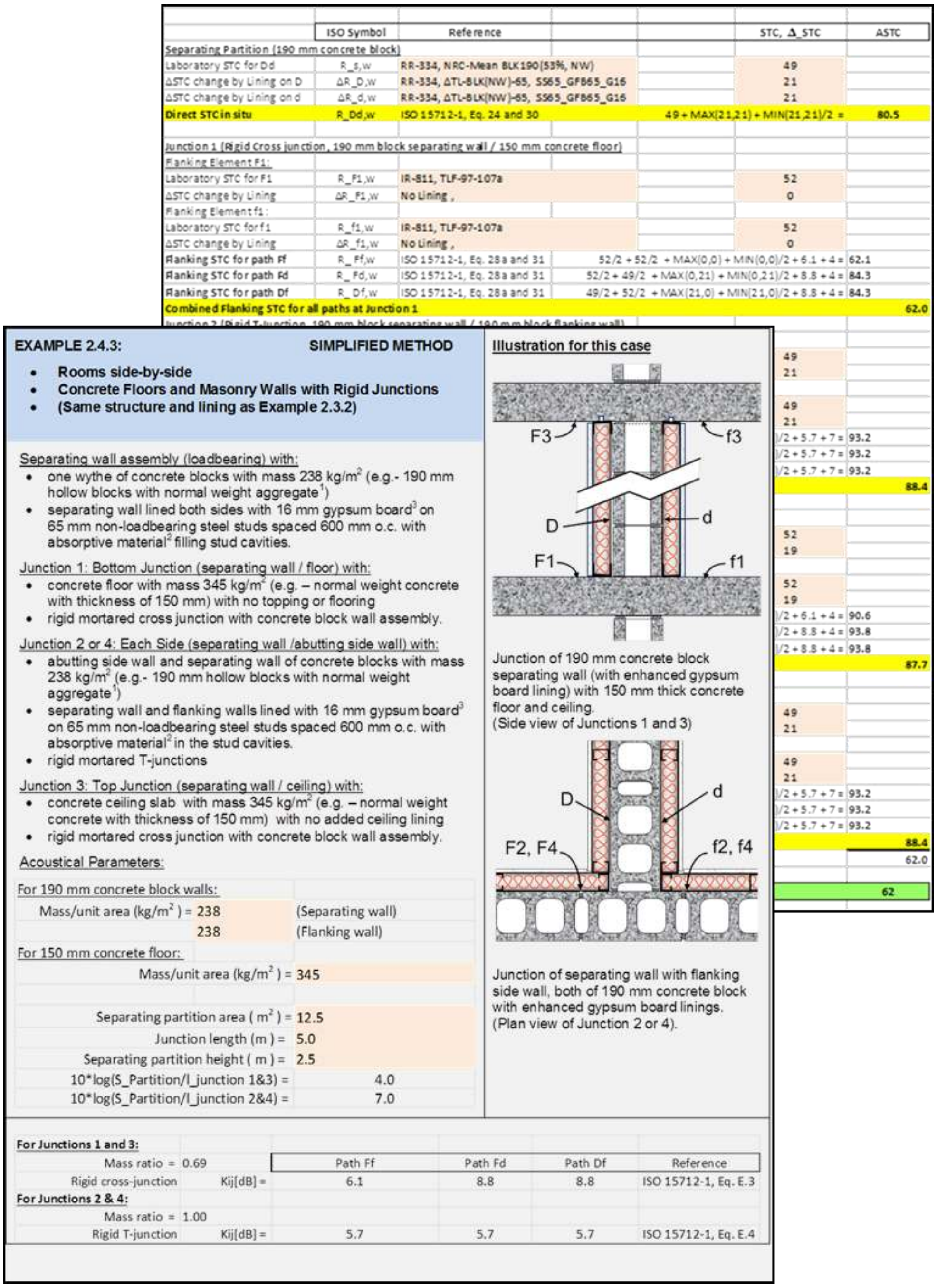
These reports are based on the results of decades of substantial experimental studies performed in the NRC flanking transmission facilities with strong support from industry partners. These studies have characterized a broad sample of the generic constructions most commonly used in North American buildings. The current plan is to publish a set of 5 documents with some overlap in content:

- RR-333, Apparent Sound Insulation in Concrete Buildings (2015)
- RR-334, Apparent Sound Insulation in Concrete Block Buildings (2014)
- RR-335, Apparent Sound Insulation in Cross Laminated Timber Buildings (2014)
- RR-336, Apparent Sound Insulation in Wood-framed Buildings (2015)
- RR-337, Apparent Sound Insulation in Steel-framed Buildings (2015)

The first of these documents (RR-334) was published in the summer of 2014 and the remainder will follow before the end of 2015. All will be reviewed and updated periodically, and can be downloaded from the NRC website at http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?lang=en.

Each of these reports presents the sound transmission data pertinent to evaluating buildings that include the construction cited in the title, plus worked spreadsheet examples combining that construction with other constructions with which it is commonly paired. The worked examples follow the Simplified Method using single-number ratings, as illustrated in Figure 3.

Each 2-page example begins with drawings and text description of the separating and flanking assemblies and their junctions. This is followed by spreadsheet images showing all steps of the calculation with clear identification of the corresponding elements and calculation steps in ISO 15712-1 or in Guideline RR-331. Examples include a detailed breakdown of the arithmetic involved and input data are clearly identified, so the user can connect them to the data provided in the reports. Each set of examples is followed by a brief description of the key factors dominating the sound transmission for this set of constructions.



	ISO Symbol	Reference		STC, Δ_STC	ASTC
Separating Partition (190 mm concrete block)					
Laboratory STC for Dd	R_s,w	RR-334, NRC-Mean BLK190(53%, NW)		49	
ΔSTC change by Lining on D	ΔR_D,w	RR-334, ΔTL-BLK(NW)-65, SS65_GFB65_G16		21	
ΔSTC change by Lining on d	ΔR_d,w	RR-334, ΔTL-BLK(NW)-65, SS65_GFB65_G16		21	
Direct STC in situ	R_Dd,w	ISO 15712-1, Eq. 24 and 30	49 + MAX(21,21) + MIN(21,21)/2 =		80.5
Junction 1 (Rigid Cross junction, 190 mm block separating wall / 150 mm concrete floor)					
Flanking Element F1:					
Laboratory STC for F1	R_F1,w	IR-811, TLF-97-107a		52	
ΔSTC change by Lining	ΔR_F1,w	No Lining ,		0	
Flanking Element f1:					
Laboratory STC for f1	R_f1,w	IR-811, TLF-97-107a		52	
ΔSTC change by Lining	ΔR_f1,w	No Lining ,		0	
Flanking STC for path Ff	R_Ff,w	ISO 15712-1, Eq. 28a and 31	52/2 + 52/2 + MAX(0,0) + MIN(0,0)/2 + 6.1 + 4 =	62.1	
Flanking STC for path Fd	R_Fd,w	ISO 15712-1, Eq. 28a and 31	52/2 + 49/2 + MAX(0,21) + MIN(0,21)/2 + 8.8 + 4 =	84.3	
Flanking STC for path Df	R_Df,w	ISO 15712-1, Eq. 28a and 31	49/2 + 52/2 + MAX(21,0) + MIN(21,0)/2 + 8.8 + 4 =	84.3	
Combined Flanking STC for all paths at Junction 1					62.0

EXAMPLE 2.4.3: SIMPLIFIED METHOD

- Rooms side-by-side
- Concrete Floors and Masonry Walls with Rigid Junctions
- (Same structure and lining as Example 2.3.2)

Separating wall assembly (loadbearing) with:
- one wythe of concrete blocks with mass 238 kg/m² (e.g.- 190 mm hollow blocks with normal weight aggregate¹)
- separating wall lined both sides with 16 mm gypsum board³ on 65 mm non-loadbearing steel studs spaced 600 mm o.c. with absorptive material² filling stud cavities.

Junction 1: Bottom Junction (separating wall / floor) with:
- concrete floor with mass 345 kg/m² (e.g. – normal weight concrete with thickness of 150 mm) with no topping or flooring
- rigid mortared cross junction with concrete block wall assembly.

Junction 2 or 4: Each Side (separating wall /abutting side wall) with:
- abutting side wall and separating wall of concrete blocks with mass 238 kg/m² (e.g.- 190 mm hollow blocks with normal weight aggregate¹)
- separating wall and flanking walls lined with 16 mm gypsum board³ on 65 mm non-loadbearing steel studs spaced 600 mm o.c. with absorptive material² in the stud cavities.
- rigid mortared T-junctions

Junction 3: Top Junction (separating wall / ceiling) with:
- concrete ceiling slab with mass 345 kg/m² (e.g. – normal weight concrete with thickness of 150 mm) with no added ceiling lining
- rigid mortared cross junction with concrete block wall assembly.

Acoustical Parameters:

For 190 mm concrete block walls:
Mass/unit area (kg/m²) = 238 (Separating wall)
238 (Flanking wall)

For 150 mm concrete floor:
Mass/unit area (kg/m²) = 345

Separating partition area (m²) = 12.5
Junction length (m) = 5.0
Separating partition height (m) = 2.5
10*log(S_Partition/l_junction 1&3) = 4.0
10*log(S_Partition/l_junction 2&4) = 7.0

Illustration for this case

Junction of 190 mm concrete block separating wall (with enhanced gypsum board lining) with 150 mm thick concrete floor and ceiling. (Side view of Junctions 1 and 3)

Junction of separating wall with flanking side wall, both of 190 mm concrete block with enhanced gypsum board linings. (Plan view of Junction 2 or 4).

			Path Ff	Path Fd	Path Df	Reference
For Junctions 1 and 3:						
Mass ratio =	0.69					
Rigid cross-junction		Kij[dB] =	6.1	8.8	8.8	ISO 15712-1, Eq. E.3
For Junctions 2 & 4:						
Mass ratio =	1.00					
Rigid T-junction		Kij[dB] =	5.7	5.7	5.7	ISO 15712-1, Eq. E.4

Figure 3: Worked example from RR-331, using Simplified Method for a pair of side-by-side rooms.

The data presentation in the reports uses summary pages giving single-number ratings in the body of the report (as illustrated in Figure 4) to support users of the Simplified Model. The corresponding 1/3-octave-band data (needed for the Detailed Method) are presented in tables in the appendices.

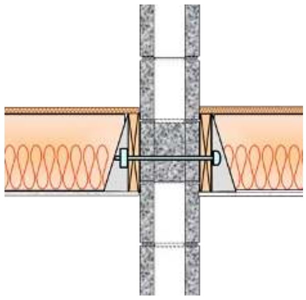
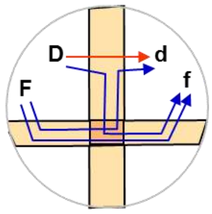
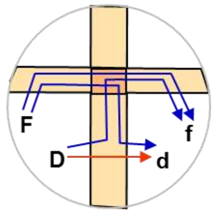
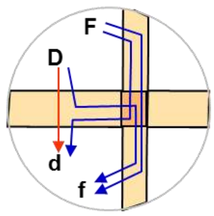
<table>
<tr><td rowspan="6">Table 3.1.01: Transmission Paths

<u>Wall assembly with:</u>
• one wythe of 190 mm hollow concrete blocks of normal weight aggregate with grout-filled cavities at 1200 mm o.c.to give stiffness and weight like reinforced block wall (mass 238 kg/m^2)
<u>Junction of wall with floor/ceiling assembly:</u>
• Course of concrete blocks at junction filled with grout.
• 2x10 (38 mm x 235 mm) wood ledger plate on each side, fastened through with 16 mm diameter bolts spaced 406 mm o.c.
<u>Floor/Ceiling assembly:</u>
• floor deck of 16 mm oriented strand board (OSB) with no floor finish or floor topping.
• floor framed with 38 mm x 235 mm wood joists spaced 406 mm o.c., with joists oriented perpendicular to separating wall and supported from ledger plate on joist hangers, with 150 mm thick absorptive material in the inter-joist cavities
• ceiling with 1 layer of 13 mm gypsum board fastened directly to bottom of floor framing on each side</td>
<td rowspan="2">BLK190-WF-LB-01
Wall-Floor Junction

</td>
<td>Path</td><td>Path STC</td></tr>
<tr><td>Dd
Ff
Fd
Df
Junction (Ff+Fd+DF)</td><td>49
59
59
59
54</td></tr>
<tr><td rowspan="2">BLK190-WC-LB-01
Wall-Ceiling Junction

</td>
<td>Path</td><td>Path STC</td></tr>
<tr><td>Dd
Ff
Fd
Df
Junction (Ff+Fd+D F)</td><td>49
65
65
65
60</td></tr>
<tr><td rowspan="2">WJ235-FW-LB-01
Floor Wall Junction

</td>
<td>Path</td><td>Path STC</td></tr>
<tr><td>Dd
Ff
Fd
Df
Junction (Ff+Fd+D F)</td><td>34
59
69
67
58</td></tr>
</table>

Figure 4: Example of data presentation for a set of flanking transmission paths in tables in report RR-334

3.3 Software to provide convenient calculation and data access

An online software tool called ***soundPATHS*** has been developed, and is currently being expanded. The ***soundPATHS*** application provides a user-friendly interface with drop-down menus to select the desired construction details, combined with a secure database that provides flanking transmission data for each junction and direct transmission data for the separating assembly. The current version of the software deals only with wood-framed constructions, but a version dealing with many types of wall and floor assemblies (plus a much-expanded supporting database) is under development. An image of the user interface (after the elements have been selected for a chosen wall/floor junction) is shown in Figure 5. The current version of ***soundPATHS*** can be accessed at
http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/soundpaths/index.html

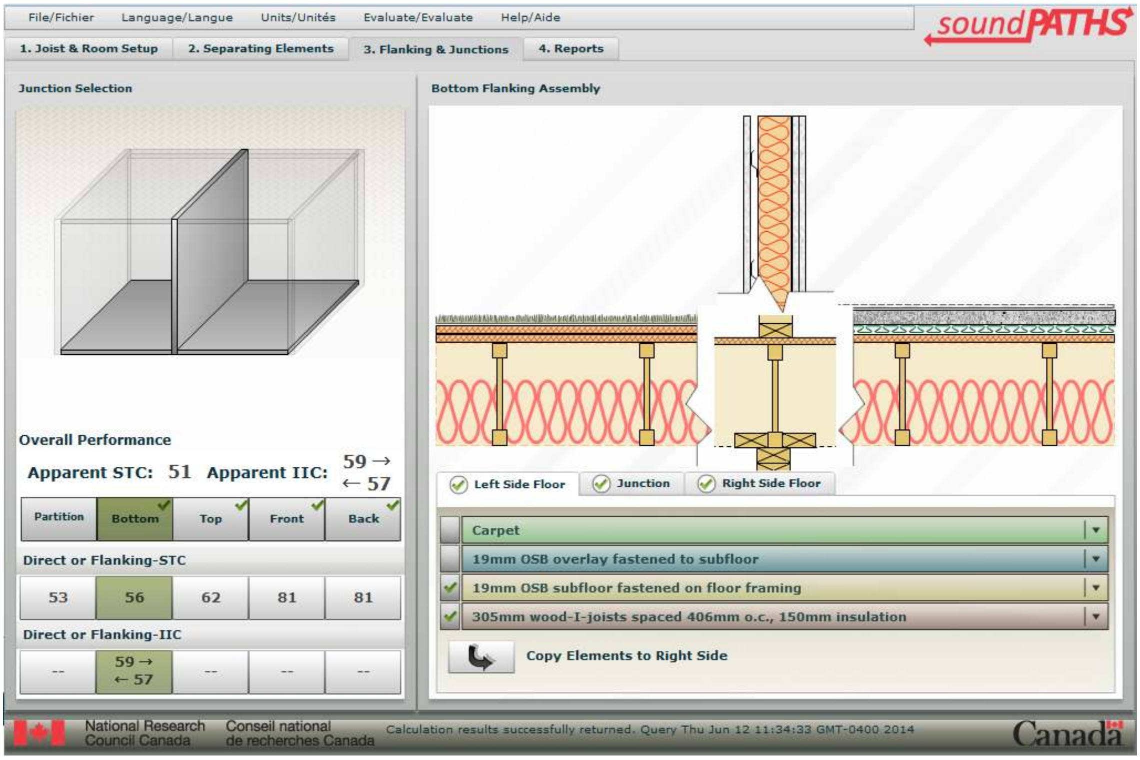


Figure 5: Image of user interface for ***soundPATHS*** online calculation of ASTC for a pair of side-by-side rooms with wood-framed wall and floor assemblies.

4. CONCLUSIONS

While the work on supporting publications and calculation tools is not yet complete, and the proposed change to the building code has not passed all stages of the approval process, the new approach offers great potential for improving acoustical design of Canadian multi-family residential buildings.

ACKNOWLEDGEMENTS

This work was sponsored by Canadian Concrete Masonry Producers Association, Canadian Sheet Steel Building Institute, Canadian Wood Council, Cement Association of Canada, Gypsum Association, Owens Corning Canada LP, Roxul Inc., and the National Research Council Canada.

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