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IMPLEMENTING ISO 12354-2 FOR BUILDING CODES: THE CANADIAN PERSPECTIVE

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ABSTRACT

To support a potential introduction of an impact sound requirement into the National Building Code of Canada, the National Research Council of Canada has initiated several research projects. For one of these projects, an industry-sponsored consortium has been formed with the goal of providing supporting documents and online tools to help building designers incorporate impact sound requirements into their work. One of the deliverables of the synergy between the NRC and the industry group will be a guide document which will follow in the footsteps of the highly successful research report, RR-331 The Guide, soon to be released its sixth edition. The guide will provide easy to understand guidance and explanations on how to combine direct and flanking sound transmission, in this case for impact sound. The Impact Guide will use the method presented in ISO 12354-2 along with a lexicon to translate the ISO metrics into the ASTM metrics commonly used in North America. This paper provides an overview of the work to create the impact sound guide document, how the implementation of ISO 12354-2 will be achieved using ASTM standards, and what the future plans for the project are.

Keywords: *residential buildings, impact sound, ISO 12354, flanking sound transmission, Canada*

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1. INTRODUCTION

The National Research Council of Canada (NRC) has identified impact sound transmission in multi-unit residential buildings as one of its focus areas of investigation. Several long-term research projects have been initiated in this context, in part with the goal to support a potential addition of an impact sound requirement into one of the next editions of the National Building Code of Canada (NBC).

Following the successful model of research report RR-331 [1] that supports the change in the 2015 edition of the National Building Code of Canada (NBC) to incorporate flanking sound transmission for airborne sound transmission, work on a new guide document for a potential addition of a requirement for impact sound in one of the next editions of the NBC has been started. Fundamentally, the document explains the application of the approach of ISO 12354-2 [2] for impact sound transmission – including flanking impact sound transmission – for the construction types and practices typically used in Canada. This is intended to help prepare the designers and other practitioners for the potential new NBC requirement for impact sound, thus lowering the burden and ensuring successful building designs.

In this contribution, the translation of the ISO approach into the ASTM standard ecosystem is presented in Sec. 2, including the equations using the ASTM single number metrics and an approach for measuring and rating the improvement due to linings. Some calculation examples for different construction types using this framework are introduced in Sec. 3. The paper finishes with conclusions and an outlook for future work in Sec. 4.

2. TRANSLATION OF THE ISO 12354-2 APPROACH FOR THE CANADIAN CONTEXT

To apply the concept of ISO 12354-2 to the standards and construction practices used in Canada several modifications to the procedures and calculations need to be made. These modifications are described in the following sections.

2.1 Relationship between single number metrics in ISO and ASTM standards

The relevant ISO measurement and rating methods for impact sound that are used in ISO 12354-2 are similar in principle to the corresponding ASTM standards, which makes them readily applicable in an ASTM context. For example, both ISO and ASTM standards for impact sound use the normalized impact sound pressure level (NISPL), L_{n}, in one-third octave bands for the direct and flanking paths, measured using the standard tapping machine. This is why the frequency-dependent equations for the Detailed Method from ISO 12354-2 are directly applicable without change.

For the single number ratings, the frequency range considered in ISO 717-2 [3] is the same as in ASTM E989 [4] and includes the one-third octave bands between 100 Hz and 3150 Hz. However, there are two major differences between the ISO and ASTM metrics for impact sound:

- As for airborne sound, the ASTM standard E989 includes a rule for a maximum deviation of 8 dB from the reference curve (usually referred to as the ”8dB-rule”), which does not exist in the corresponding ISO standards.
- Opposed to the weighted NISPL metric in ISO 717-2, $L_{\mathrm{n,w}}$, where lower values indicate better performance, the impact insulation class (IIC) according to ASTM E989 is defined in the opposite way, where larger values are better.

With these two differences in the single number metrics – and a difference in rounding before the rating process – a direct relationship between $L_{\mathrm{n,w}}$ and IIC cannot be established. However, in cases where the 8dB-rule is not applied, an approximate relationship can be formulated for the direct and flanking paths as

$$IIC \approx 110\,\mathrm{dB} - L_{\mathrm{n,w}}\,, \tag{1}$$

and for the apparent impact insulation class (AIIC) as

$$AIIC \approx 110\,\mathrm{dB} - L'_{\mathrm{n,w}}\,. \tag{2}$$

2.2 Equations for the Simplified Method in ISO 12354-2

The relationships according to Eqn. (1) and Eqn. (2) lead to changes to the equations in ISO 12354-2 for the Simplified Method. The reverse way of definition of the IIC compared to the $L_{\mathrm{n,w}}$ rating leads to a change in the sign compared to the original ISO 12354-2 equations.

The AIIC rating is calculated in analogy to Eqn. (18) of ISO 12354-2 as

$$AIIC = -10\,\log_{10}\left(10^{-IIC_{\mathrm{Dd}}/10} + \sum_{j=1}^{n} 10^{-IIC_{\mathrm{ij}}/10}\right), \tag{3}$$

where IIC_{Dd} and IIC_{ij} are the IIC ratings for the direct path and the flanking path, respectively.

The ASTM versions of the equations for IIC_{Dd} and IIC_{ij} for Type A elements are

$$IIC_{\mathrm{Dd}} = IIC_{\mathrm{Dd,lab}} + \Delta IIC_{\mathrm{D}} + \Delta IIC_{\mathrm{d}}\,, \tag{4}$$

$$IIC_{\mathrm{ij}} = IIC_{\mathrm{i}} + \Delta IIC_{\mathrm{i}} + \frac{STC_{\mathrm{j}} - STC_{\mathrm{i}}}{2} + \Delta STC_{\mathrm{j}} + \overline{K_{\mathrm{ij}}} + 10\,\log_{10}\left(\frac{S_{\mathrm{i}}}{l_0\,l_{\mathrm{ij}}}\right), \tag{5}$$

which are the equations corresponding to Eqn. (15) and Eqn. (16) in ISO 12354-2. In Eqn. (4), ΔIIC_{D} and ΔIIC_{d} are the improvements of the IIC rating by a floor and ceiling lining, respectively. In Eqn. (5), STC is the sound transmission class according to ASTM E90 [5], which corresponds to the weighted sound reduction index, R_{w}, according to ISO 717-1 [6], and ΔSTC_{j} is the improvement of the sound transmission class by a wall lining on the receiving side. $\overline{K_{\mathrm{ij}}}$ is the single number rating of the vibration reduction index, determined according to ISO 10848-1 [7], S_{i} is the area of element *i* in m^2 and l_{ij} is the common length of the junction between elements i and j in m. l_0 is the reference length of 1 m.

For Type B elements, the direct IIC is calculated according to Eqn. (4) and the flanking IIC is calculated by one of the following equations, depending on which data is available:

- If data is available for the laboratory measurement of the flanking IIC, $IIC_{\mathrm{ij,lab}}$, the flanking

IIC is calculated according to Eqn. (6), which corresponds to Eqn. (17) of ISO 12354-2:

$$IIC_{\mathrm{ij}} = IIC_{\mathrm{ij,lab}} + 10\,\log_{10}\left(\frac{l_{\mathrm{ij,lab}}}{l_{\mathrm{ij}}}\,\frac{S_{\mathrm{i}}}{S_{\mathrm{i,lab}}}\right). \tag{6}$$

- If data is available for the single number rating of the normalized direction-averaged junction velocity level difference between elements i and j, $\overline{\overline{D_{\mathrm{v,ij,n}}}}$, the flanking IIC is calculated from the performance of the elements according to Eqn. (7), which corresponds to Eqn. (D.4) of ISO 12354-2 transferred from the laboratory situation to *in situ* values:

$$IIC_{\mathrm{ij}} = IIC_{\mathrm{i}} + \Delta IIC_{\mathrm{i}} + \frac{STC_{\mathrm{j}} - STC_{\mathrm{i}}}{2} + \Delta STC_{\mathrm{j}} + \overline{\overline{D_{\mathrm{v,ij,n}}}} + 10\,\log_{10}\left(\frac{S_{\mathrm{i}}}{l_0\,l_{\mathrm{ij}}}\right). \tag{7}$$

- If neither data for the laboratory flanking IIC nor for the junction velocity level difference is available, the flanking IIC can be estimated from the laboratory airborne flanking sound transmission class, $STC_{\mathrm{ij,lab}}$. By converting Eqn. (G.4) of ISO 12354-1 [8] to the STC rating the following expression is obtained:

$$STC_{\mathrm{ij,lab}} = \frac{STC_{\mathrm{i}} + STC_{\mathrm{j}}}{2} + \Delta STC_{\mathrm{i}} + \Delta STC_{\mathrm{j}} + \overline{\overline{D_{\mathrm{v,ij,n}}}} + 10\,\log_{10}\left(\frac{S_{\mathrm{i,lab}}}{l_0\,l_{\mathrm{ij,lab}}}\right), \tag{8}$$

which can be rearranged for $\overline{\overline{D_{\mathrm{v,ij,n}}}}$ and inserted into Eqn. (7). This yields:

$$IIC_{\mathrm{ij}} = IIC_{\mathrm{i}} + \Delta IIC_{\mathrm{i}} + STC_{\mathrm{ij,lab}} - STC_{\mathrm{i}} - \Delta STC_{\mathrm{i}} + 10\,\log_{10}\left(\frac{l_{\mathrm{ij,lab}}}{l_{\mathrm{ij}}}\,\frac{S_{\mathrm{i}}}{S_{\mathrm{i,lab}}}\right). \tag{9}$$

Eqn. (9) is especially useful for estimating the flanking IIC when only airborne flanking data, for example from RR-331, is available.

2.3 Reference curves for ΔIIC

For heavy homogeneous floor assemblies, the values of ΔIIC needed for the equations in the previous section can be obtained according to either ASTM E2179 [9] or Annex H of ISO 10140-1 [10]. However, this is not immediately possible for assemblies made of mass timber elements, such as Cross-Laminated Timber (CLT), because no values of the NISPL for corresponding reference floors are listed in ISO 10140-5 [11]. In this case the procedure in ISO 10140-1 allows the use of a custom reference curve. The determination of such a reference NISPL curve for 5-ply CLT floor assemblies with a thickness between 110-175 mm is described in this section.

To determine the NISPL values that could serve as a general reference for 5-ply CLT floor assemblies, the results of the NISPL of six standard measurements of impact sound transmission – carried out in the floor testing facility of the NRC according to ASTM E492 – were averaged for 5-ply CLT floor assemblies with thicknesses between 110 mm and 175 mm. The individual results together with the average are presented in Fig. 1.

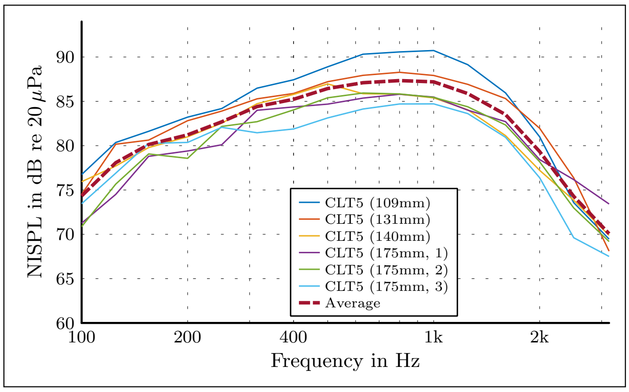

Figure 1. NISPL for six CLT assemblies of different thickness together with the average

It can be seen that the NISPL for CLT floor assemblies of different thickness does not show a significantly different behaviour with frequency and hence the data was deemed to be acceptable for averaging. It should be noted that the procedure for ΔIIC measurements only depends on the shape of the reference curve and not on the absolute value of the reference curve, which is why the differences in terms of absolute level of the results for the CLTs of different thickness did not have a negative impact on the validity of the obtained reference curve.

In Fig. 2, the average NISPL is presented for measurements on a 150 mm concrete floor assembly and for the 5-ply CLT assemblies, together with the reference curve for heavy floors from Annex C.2 of ISO 10140-5 and the reference curve determined for 5-ply CLT floor assemblies.

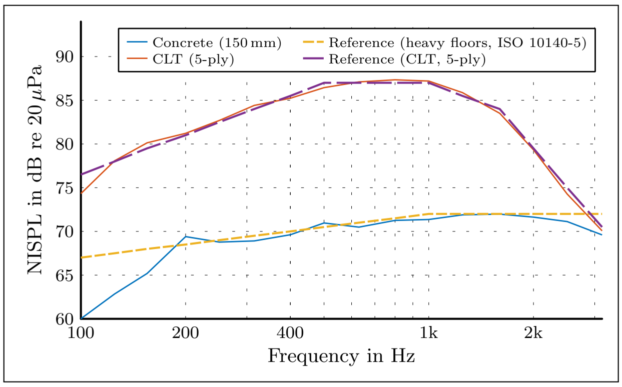

Figure 2. NISPL values for the average measurement results and idealized reference curves for the determination of ΔIIC values for heavy homogeneous floor assemblies (150 mm concrete, "heavy-weight reference floor" according to Annex C.2 of ISO 10140-5) and for 5-ply CLT floor assemblies.

The reference curve for 5-ply CLT floor assemblies was obtained from the averaged NISPL data by using four straight-line segments with the following characteristics: in the frequency range from 100 Hz to 500 Hz, the values increase by 1.5 dB per one-third octave, starting at 76.5 dB and reaching 87 dB at 500 Hz. Between 500 Hz and 1 kHz, the value remains constant at 87 dB. The values at 1.25 kHz and 1.6 kHz decrease at a rate of 1.5 dB per one-third octave and above 1.6 kHz the values decrease at a rate of 4.5 dB per one-third octave, resulting in a value of 70.5 dB at 3.15 kHz. The single number metrics for this reference curve according to ISO 717-2 and ASTM E989, respectively, are: $L_{\mathrm{n,w}}\ (C_{\mathrm{I}}) = 87\,\mathrm{dB}\ (-6)$ and $IIC = 23$.

A similar agreement between the measurement data and the idealized reference curves can be observed for both the concrete and CLT floor assemblies. The obviously different behaviour of the NISPL as a function of frequency of the CLT floor assemblies compared to concrete floor assemblies justifies the creation of a new reference curve instead of trying to use the "heavy floor" reference curve for CLT floor assemblies.

3. EXAMPLES

In this section, the procedure as described in Sec. 2 is applied to several examples for three different construction types. All of the examples are taken from the fifth edition of RR-331. Although some of the references to the examples used here point to the chapters for the Detailed Method in RR-331, the calculations presented in this paper were all carried out using the Simplified Method.

3.1 Heavy-homogeneous construction

The base assembly for the examples for heavy homogeneous construction is a 150 mm concrete floor with concrete block masonry walls. The three examples chosen for this paper had the following linings applied to the base assembly:

- Example 2.3.3: wall lining of 13 mm gypsum board on 65 mm non-loadbearing steel studs spaced 600 mm on centres with no absorptive material filling the stud cavities.
- Example 2.3.5: same as Example 2.3.3, but with a suspended ceiling with one layer of 16 mm gypsum board and a cavity depth of 150 mm fully filled with absorptive material.
- Example 2.3.6: same as Example 2.3.5, but with absorptive material in the wall lining.

An illustration of the assembly for Example 2.3.5 is shown in Fig. 3 and the results of the IIC values for the direct path, the flanking path, and for the AIIC for all three examples are presented in Tab. 1.

Table 1. Examples of impact sound calculations for heavy homogeneous construction. Referenced are examples in the fifth edition of RR-331.

Example	Direct IIC	Flanking IIC	AIIC
2.3.3	29	37	28
2.3.5	53	37	36
2.3.6	53	54	50

3.2 Cross-Laminated Timber (CLT) construction

The base assembly for the examples for CLT construction consists of a floor and walls made of 175 mm thick 5-ply CLTs. The examples chosen for this paper had the following linings applied to the base assembly:

- Example 3.1-V1: base assembly.
- Example 3.1-V2: floor lining of 38 mm concrete over 12.7 mm wood fibre board; suspended ceiling with one layer of 16 mm gypsum board and a cavity depth of 150 mm fully filled with absorptive material; wall lining of two layers of 13 mm gypsum board supported on 38 mm × 38 mm wood furring strips spaced 610 mm on centres and with absorptive material in the cavities.

An illustration of the assembly for Example 3.1-V2 is shown in Fig. 4 and the results of the IIC values for the direct path, the flanking path, and for the AIIC for both examples are presented in Tab. 2.

Table 2. Examples of impact sound calculations for CLT construction. Referenced are examples in the fifth edition of RR-331.

Example	Direct IIC	Flanking IIC	AIIC
3.1-V1	24	34	24
3.1-V2	59	48	47

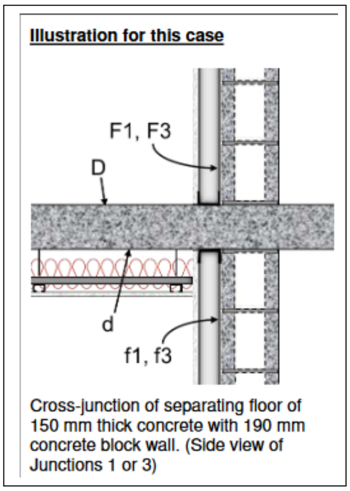

Figure 3. Illustration of the assembly used in Example 2.3.5 in the fifth edition of RR-331.

3.3 Wood-framed construction

The base assembly for the examples for wood-framed construction is a floor with 305 mm wood I-joists spaced 400 mm on centres with a subfloor of 19 mm oriented strandboard (OSB), a ceiling of two layers of 16 mm gypsum board attached to resilient channels spaced 400 mm on centres and 150 mm absorptive material in the floor cavity. The flanking walls were framed with 38 mm × 89 mm wood studs spaced 400 mm on centres with two layers of 16 mm gypsum board directly attached to the studs and absorptive material in the wall cavity. The examples chosen for this paper had the following linings applied to the base assembly:

- Example 4.2-V1: base assembly.
- Example 4.2-V3: floor topping of 38 mm gypsum-concrete on 9 mm thick resilient foam underlay. The gypsum board on the flanking walls was attached to resilient channels spaced 600 mm on centres.

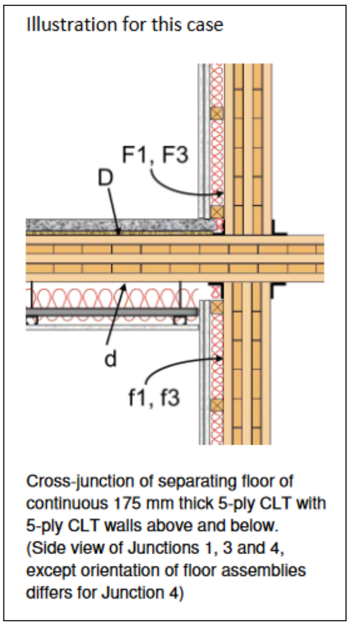

Figure 4. Illustration of the assembly used in Example 3.1-V2 in the fifth edition of RR-331.

An illustration of the assembly for Example 4.2-V3 is shown in Fig. 5 and the results of the IIC values for the direct path, the flanking path, and for the AIIC for both examples are presented in Tab. 3.

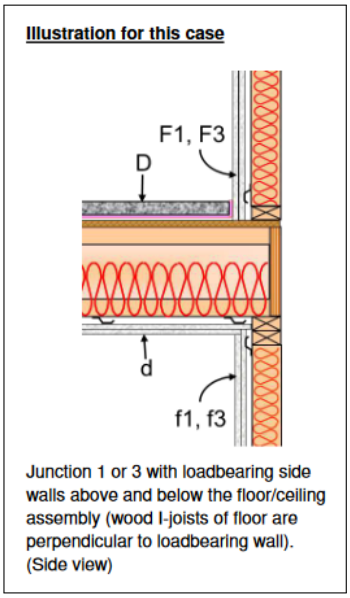

Figure 5. Illustration of the assembly used in Example 4.2-V3 in the fifth edition of RR-331.

Table 3. Examples of impact sound calculations for wood-framed construction. Referenced are examples in the fifth edition of RR-331.

Example	Direct IIC	Flanking IIC	AIIC
4.2-V1	44	45	41
4.2-V3	55	≥ 53	≥ 51

The results of the flanking IIC and the AIIC for Example 4.2-V3 are shown as a minimum estimate because the underlying airborne flanking data was not available for the individual flanking paths and hence only an estimate could be made. This is not a restriction inherent in the method but rather shows the complexity of carrying out flanking measurements. Future testing will highlight and hopefully resolve this issue.

4. CONCLUSIONS

In this paper, the calculation method for impact sound in ISO 12354-2 was translated for and applied to the context of the Canadian building code. It was discussed that the approach for the Detailed Method is directly applicable in Canada, as the metrics for impact sound are very similar to the ISO metrics. The equations for the Simplified Method were converted to the ASTM single number metrics used in North America and a new reference curve for 5-ply CLT floor assemblies was introduced that can be used for the measurement of the performance improvement with linings.

The method was then applied to various examples for three different construction types. Such calculations are useful to highlight the issues of flanking sound transmission and provide design guidance in terms of the choice of linings for different construction types.

The approach introduced in this paper will be incorporated with the examples shown here and with additional examples into a new research report. Further testing and analysis, especially regarding the use of reference floors for the measurement of the performance improvement with linings, is planned for the future. The method and data will also be incorporated into a new version of the online tool SoundPATHS, which currently only calculates airborne sound transmission.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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