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# Evaluating the measurement of the velocity level difference for building constructions which combine Type A and Type B elements

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## ABSTRACT

*As part of an ongoing research project in the new four-room flanking facility at the National Research Council Canada, the velocity level differences between cross-laminated timber floors/ceilings and lightweight timber framed walls have been measured according to the standard, ISO 10848-1. The apparent sound reduction indices between the pairs of rooms have also been measured according to ISO 10848-1. The measured apparent sound reduction indices are compared to those predicted according to the standard, ISO 12354-1 based on the measured velocity level differences, the resonant transmission losses and the dimensions of the elements of the flanking paths between the room pairs.*

## 1. INTRODUCTION

The estimation of the Apparent Sound Transmission Class (ASTC) Rating in the National Building Code of Canada (NBC) [1] is based on the method described in the standard, ISO 12354-1 [2], but implemented using ASTM metrics as described in Research Report RR-331 [3]. The calculation of the ASTC rating requires the knowledge of the structure-borne sound transmitted through the junctions between building elements in the form of the vibration reduction index ( $K_{ij}$ ) for Type A elements such as concrete walls or floors or the normalized direction-average vibration level difference ( $\overline{D_{v,ij,n}}$ ) for Type B elements such as timber or steel framed walls or floors. The calculation of the  $K_{ij}$  and the  $\overline{D_{v,ij,n}}$  from measurements made in a dedicated laboratory facility or in the field is described in the standard, ISO 10848-1 [4].

The situation invariant,  $K_{ij}$  is calculated from the velocity level difference ( $D_{v,ij}$ ) averaged for each transmission direction, the length of the junction between the elements ( $l_{ij}$ ), the surface areas of the elements and the structural reverberation time of the elements. The  $\overline{D_{v,ij,n}}$  is similarly calculated, with the exception that the structural reverberation times of the elements are not used in the calculation. For flanking transmission through flanking paths that include junctions between Type A elements and Type B elements, Section 4.3.2 of ISO 10848-1 states that  $K_{ij}$  is to be calculated, but the Type B element is to be normalized using the surface area instead of the structural reverberation time. However, following this guidance reveals that the resulting units of the equation are not correct. Furthermore, an end user may see a  $K_{ij}$  value in a report and assume that the structural reverberation times via the equivalent absorption lengths are to be used to calculate the in-situ direction-averaged velocity level difference  $\overline{D_{v,ij,situ}}$  according to Equation 10 of ISO 12354-1. The  $K_{ij}$  values for combinations of Type A and Type B values require the use of the equivalent absorption length for the Type A element but only the surface area for the Type B element. This is noted in Equation 13 of ISO 12354-1, but as part of the calculations using  $\overline{D_{v,ij,n}}$ , not  $K_{ij}$  where it should have been located. It is therefore easy to miss this guidance. It would be less confusing, especially to new

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users of the standards if a new term was introduced in both ISO 10848-1 and ISO 12354-1 to be used instead of  $K_{ij}$  when one element in the flanking path is Type A and the other is Type B.

To this end, a new situation invariant descriptor is proposed to replace the  $K_{ij}$  term described in Section 4.3.2 of ISO 10848-1 for combinations of Type A and Type B elements. This new descriptor is named the Standardized Direction-average Vibration Level Difference ( $\overline{D_{v,ij,s}}$ ) to distinguish it from the invariant descriptors  $K_{ij}$  for Type A elements and the  $\overline{D_{v,ij,n}}$  for Type B elements. The descriptor is calculated as:

$$\overline{D_{v,ij,s}} = \overline{D_{v,ij}} + 10 \log \left( \frac{l_{ij} \sqrt{l_o}}{\sqrt{a_i S_j}} \right) \quad (1)$$

where  $\overline{D_{v,ij}}$  is the direction averaged velocity level difference,  $l_o$  is a reference length of 1 m,  $a_i$  is the equivalent absorption length of the Type A element  $i$  and  $S_j$  is the surface area of the Type B element  $j$ . As with the  $K_{ij}$  and the  $\overline{D_{v,ij,n}}$ , the  $\overline{D_{v,ij,s}}$  would be used to calculate  $\overline{D_{v,ij,situ}}$ :

$$\overline{D_{v,ij,situ}} = \overline{D_{v,ij,s}} - 10 \log \left( \frac{l_{ij,situ} \sqrt{l_o}}{\sqrt{a_{i,situ} S_{j,situ}}} \right) \quad (2)$$

The  $\overline{D_{v,ij,situ}}$  is then used to calculate the flanking sound reduction index ( $R_{ij}$ ) according to Equation 15 of ISO 12354-1.

For this research project which is being conducted in the new four-room flanking facility at the National Research Council Canada (NRC), the velocity level difference for first and second order flanking paths were measured for different combinations of junctions between CLT floors and lightweight timber framed walls. In addition, the normalized flanking level difference  $D_{n,f}$  is measured for each different combination of floors and walls, according to ISO 10848-1 using loudspeakers in each room and six microphones in each room. The relationship between  $D_{n,f}$  and  $K_{ij}$  is given by Equation 1 of ISO 10848-1, the relationship between  $D_{n,f}$  and  $\overline{D_{v,ij,n}}$  is given by Equation 2 of ISO 10848-1, the relationship between  $D_{n,f}$  and  $\overline{D_{v,ij,s}}$  is given by:

$$D_{n,f} = \frac{R_i + R_j}{2} + \Delta R_i + \overline{D_{v,ij,s}} + 10 \log \left( \frac{A_o}{l_{ij} \sqrt{l_o}} \frac{\sqrt{a_i}}{\sqrt{S_i}} \right) \quad (3)$$

where element  $i$  is a Type A element, element  $j$  is a Type B element,  $R$  is the resonant sound reduction index of an element,  $\Delta R_i$  is the change in the sound reduction index due to the application of a lining on element  $i$  and  $A_o$  is a reference area of 10 m<sup>2</sup>. Note that since element  $j$  is a Type B element, the application of a change in the sound reduction index due a lining is not possible and therefore  $\Delta R_j$  is omitted from Equation 3.

## 2. MEASUREMENTS

A cross-section of the measurement facility is shown in Figure 1.

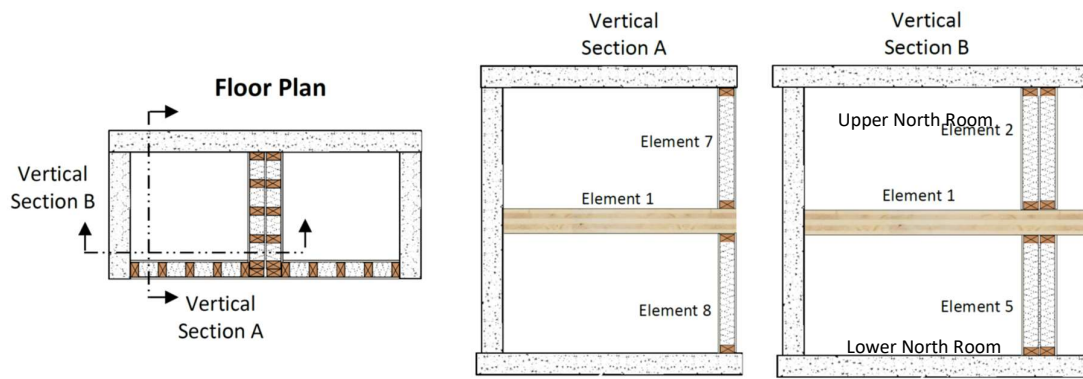


Figure 1: Cross-sections of the construction in the four-room flanking facility. Note that the facility walls are made of concrete.

The floors to be built in the four-room flanking facility will include both a 5-ply, 140 mm thick CLT (CLT140(5)) and a 3-ply, 105 mm thick CLT (CLT105(3)). The CLT140(5) ceiling and lightweight walls are shown for one of the lower rooms in Figure 2.



Figure 2: Walls and CLT ceiling in one of the lower rooms of the flanking facility

The lightweight walls include double-stud demising walls with either one or two layers of 15.8 mm thick Type X fire rated gypsum board on each side and single stud walls with one layer of 15.8 mm thick Type X fire rated gypsum board on each side as shown in in Figure 3

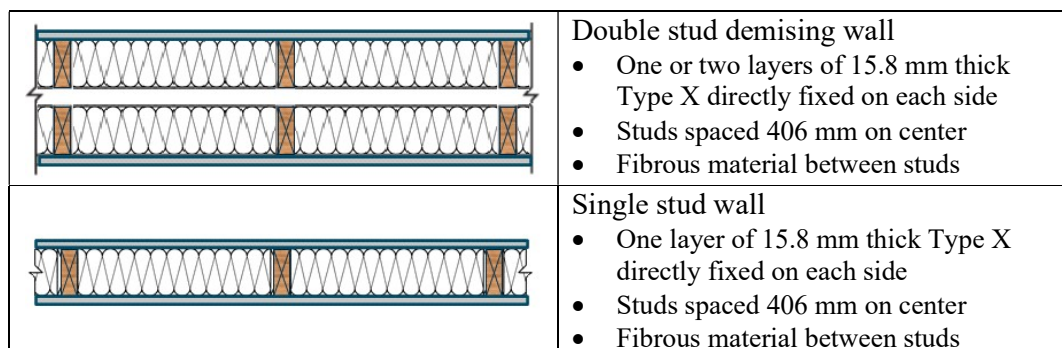


Figure 3: Timber framed walls included in the construction

The measurement of the  $D_{v,ij}$  for each flanking path were made in full accordance with ISO 10848-1. Up to six excitation positions were used for each element in accordance with the standard. An electromagnetic shaker was used for the excitation as shown in Figure 4.



Figure 4: Shaker attached to one of the timber framed walls via an impedance head.

Twenty-two measurement positions were included on each element. All measurement positions were included in the measurements, but any measurement positions within 1 m of the excitation position or greater than 3.5 m from the junction under consideration were excluded from the calculation of the  $D_{v,ij}$ . The  $D_{v,ij}$  and the  $D_{v,ji}$  values are calculated to allow for direction averaging for each flanking path.

Note that twenty-two measurement positions are well in excess of the three positions required according to the standard since it is the opinion of the author based on the collected measurement data that three positions are too few for lightweight timber framed walls due to the variation in the surface velocity caused by the studs. The data from the measurements will be used to evaluate the ideal number of excitation and measurement positions for these types of elements by excluding each excitation and measurement position to determine when the reduction begins to affect the calculated  $D_{v,ij}$  values.

### 3. EVALUATION

The flanking sound reduction index for each flanking path between each of the rooms in the flanking facility will be calculated from the  $\overline{D_{v,ij}}$  according to ISO 12354-1. The apparent sound reduction index  $R'$  between each room will be calculated from the sum of the contribution of the flanking paths and the direct path, if applicable. The  $R'$  will also be calculated from the  $D_{n,f}$  measured for each room combination to be used to evaluate the apparent flanking sound reduction index calculated from the  $\overline{D_{v,ij}}$ .

For example, a preliminary calculation of the flanking sound reduction index of each flanking path between the upper north room and the lower north room is show in Figure 5.

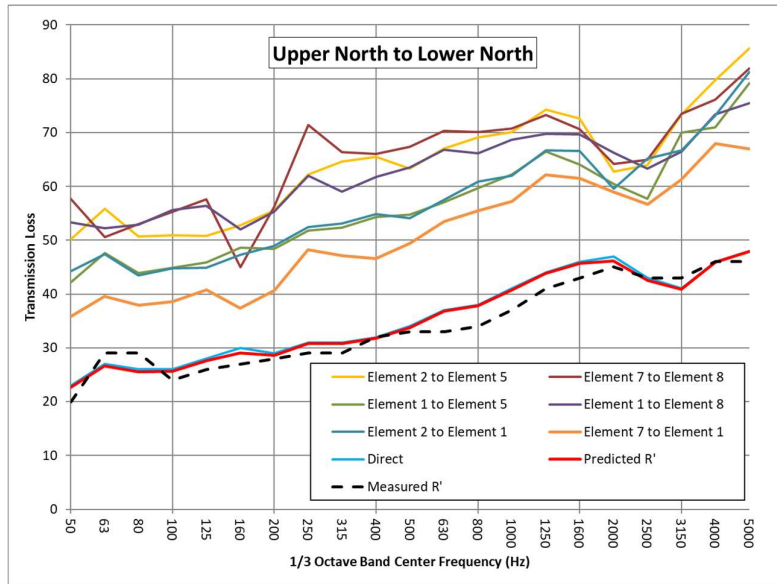


Figure 5: The estimated flanking sound reduction index for each path based on the measured vibration level differences between the room pairs in the flanking facility. The estimated and the measured apparent sound reduction indices are also shown in the figure. The direct path through the CLT floor dominates the transmission. The elements numbers are shown in Figure 1.

Once all of the measurements and the analysis has been completed, the data will be made available in the third edition of the research report RR-335: Apparent Sound Insulation in Mass Timber Buildings.

#### 4. DISCUSSION AND CONCLUSIONS

The Standardized Direction-average Vibration Level Difference ( $\overline{D_{v,ij,s}}$ ) has been introduced as a situation invariant term for flanking paths that include both Type A and Type B elements. The relationship between the  $\overline{D_{v,ij,s}}$  and the normalized level difference  $D_{n,f}$  has been shown.

The measurements of the velocity level difference  $D_{v,ij}$  and the normalized level difference  $D_{n,f}$  will allow for the evaluation of the prediction of the apparent sound reduction index  $R'$  between the different room pairs. The data will also allow for the evaluation of the number of excitation and measurement positions required for the measurement of the velocity level difference.

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