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Measurement and Evaluation of Lateral Impact Noise Isolation

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ABSTRACT

Impact noise isolation measurements and evaluation are traditionally defined for vertical adjacencies, where the impact source is located in the space above the receiving room. For North American projects, ASTM standards provide no guidance for performing a lateral impact noise isolation measurement, so the authors have developed methods and practices for performing this measurement. ISO 16283-2 also describes procedures and methods for the measurements and analysis of lateral impact noise measurements. The various measurement methods are compared and evaluated. For some assembly types, there is an advantage to maintaining a constant distance from tapping machine to the separating partition. Appropriate ratings for categorization of lateral impact isolation are discussed.

Keywords: Lateral, Impact, Measurement
I-INCE Classification of Subject Number: 72

1. INTRODUCTION

Lateral (or horizontal) impact noise isolation is measured in the field (in situ) in conditions where the source and receiving spaces are adjacent and on the same level. Lateral impact isolation has had little study compared to vertical impact noise isolation. ASTM E1007[1], which defines field measurement of impact noise isolation, explicitly allows lateral impact measurements, but the procedure is clearly designed for vertical measurements. ISO 16283-2[2] does not explicitly mention lateral impact testing in the body of the standard, but provides guidance for the measurement in Annexes D and E (informative). The authors have previously developed a measurement procedure, which is a modification of the ASTM procedure.[3] In this paper, the various measurement methods are compared in several different structural types.

The authors have also developed a two-rating methodology for evaluating impact noise insulation.[4] The analysis so far has been on vertical impact transmission; here investigation of lateral impact isolation is begun.

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2. MEASUREMENT METHOD

2.1. Existing Standards

ASTM E1007[1] is commonly used in North America to measure impact noise isolation. It states in section 3.2.7.2 that "The receiving room is usually the room below the floor-ceiling assembly being excited by the tapping machine but, depending on the metric being measured, it may be on the same level, diagonally below, or, in some cases, above the source room."

However, there are no adjustments to the procedure or guidance for how to perform a lateral impact test. Specifically, the standard requires measurement of the sound level from four positions of the tapping machine, and these positions are explicitly defined and are all near the center of the floor. These positions are shown in Figure 1. Section 9.4 specifying the tapping machine position is clearly written for vertical adjacencies, with references to the spaces "above" and "below" as well as "separating floor-ceiling." Further, the ASTM standard clearly defines that tapping position 1 is in the middle of the floor (specimen) when the rooms are the same above and below, but is mute in the description of this location in horizontal measurement applications.

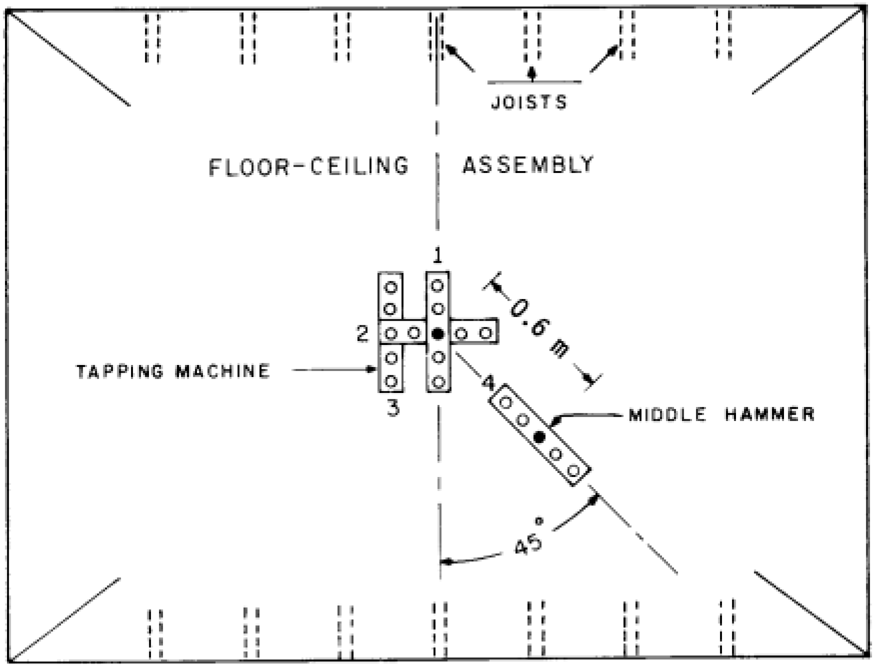

Figure 1: Tapping machine positions in ASTM E1007

The relevant ISO standard is 16283-2[2] which does not refer explicitly to lateral measurements in the body of the standard, but only generically to "source" and "receiving" spaces. The tapping machine is required to be placed in "at least four different positions randomly distributed on the floor under test."

Annex D (informative) in Ref. 2 provides guidance for horizontal measurements in section D.3, along with example diagrams in Annex E. It states that four tapping machine positions shall be used (per usual) for source rooms with a floor area less than 20 m^2. If the source room is larger than 20 m^2, then the tapping machine positions should be limited to the 20 m^2 nearest the partition with the receiving room. However, the area including the tapping machine must be the full width of the partition to the receiving space, and no less than half of the source room in the direction away from the receiving room. Therefore, in some rooms, the resulting area can be much larger than 20 m^2.

Under ISO 16283-2, therefore, the distance from the farthest tapping machine location to the partition separating the source and receiving rooms can be up to half the dimension of the source room. For large spaces, some tapping machine locations will be far from the horizontal intersection (e.g. junction between the source and receiving rooms).

2.2. ASTM Modified Method

To the authors' knowledge, the exact rationale for the tapping machine locations specified in the two standards in Section 2.1 has not been published. However, both concepts have an apparent justification in the context of vertical measurements where source and receiving rooms have similar floor plans. The ASTM method uses four positions apparently designed to average over any variation due to joist layout. These are clustered near the center of the space, where they would radiate evenly within the receiving room. The ISO method distributes the impacts across the floor, again providing an apparent uniform radiation into the receiving space.

The ASTM method would result in all four tapping machine locations at a distance from the wall distance would vary depending on the size of the source room. This seems problematic, and to the authors, it makes more sense to measure at a fixed distance from the receiving room (i.e. from the lateral junction). Some time ago (prior to the publication of the ISO standard), the authors developed a measurement protocol for impact isolation using a modified ASTM method. Three tapping machine positions were defined and used, corresponding to the first three positions described in Ref. 1, with the middle hammer of the tapping machine on a line parallel to and 1.5 m (5 feet) from the separating wall, and centered on the wall. See Figure 2. The distance between the tapping machine in Positions 1 and 3 remained as half the distance between the joists or 0.6 m for homogenous floors, the same as in the ASTM standard.

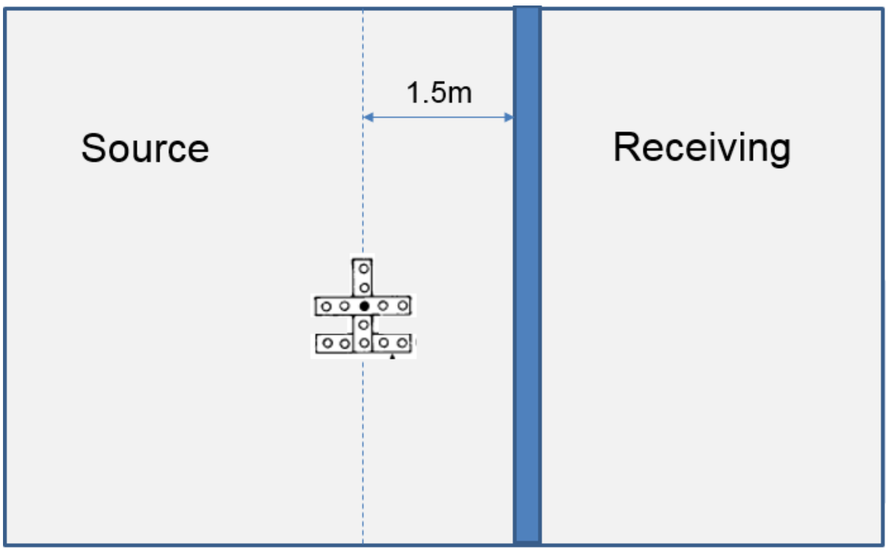

Figure 2: Modified ASTM tapping machine positions for lateral impact noise measurements

2.3. Comparison Testing

To investigate the differences between the two methods, lateral impact noise testing was performed in three different buildings. For each test, the measurement was repeated using tapping machine locations from both the ISO and the modified ASTM method. Structural types included poured concrete slab-on-grade, 200 mm (8-inch) structural concrete slab, and wood-joist structure with continuous plywood sheathing. Details were given in Ref. 3.

It was concluded that, overall, there were only minor differences between the test methods. However, there were tests where the noise level from the individual tapping machine positions varied widely, apparently corresponding to distance from the separating wall.

The ISO method allows for a large variation in distance from the tapping machine to the wall, and, for assemblies with significant damping, the vibration level from impact can vary with distance. The spectra were normalized to a distance of 1.5 m by adding a factor

$$20\log\frac{d}{1.5} \tag{1}$$

with d the distance between the tapping machine and the common wall in m. (Bands that were controlled by background noise level were not normalized for distance.) There is no particular theoretical justification for Eq. 1, except for the general principle of geometrical divergence, and a different coefficient (instead of 20) may be appropriate for other conditions. For these measurements, however, Eq. 1 appears suitable, and suggests that the ISPL for a given floor and receiving room varies only as the distance between the tapping machine and the wall. See Figure 3.

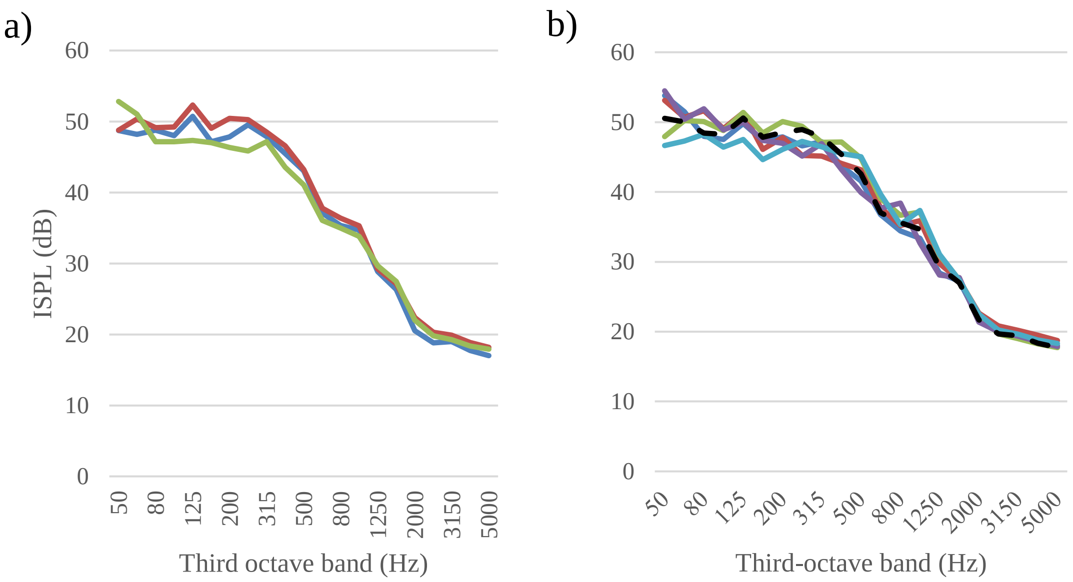

Figure 3: Lateral ISPL spectra for each tapping machine position for a) proposed modified ASTM positions and b) ISO positions normalized according to Eq. 1. The dashed line in b) is the average of the three positions in a).

A justification for the ISO positions might be that the impact source may occur at any location in the room. However, the standard already restricts the sources to the closer half of the room, apparently recognizing that distant tapping machine locations are not appropriate. Compared to the modified ASTM method, the ISO method results in either the same results (if the closer positions dominate) or slightly better results (if the average ISPL is reduced because of more distant positions). Averaging the levels in this manner does not seem to provide any additional information, but merely increases the variance in the measurement.

Therefore, the authors' opinion is that a method that maintains a constant distance to the receiving room is preferred for evaluating the lateral impact noise isolation between two spaces. The modified ASTM method as described above is used for the testing presented in the rest of this paper.

3. LATERAL VS. VERTICAL TRANSMISSION

3.1. Field Measurements

A number of vertical and lateral impact insulation measurements were performed in a high-rise condominium building. The structural system was 200 mm (8-inch) post-tensioned slab. The flooring was similar, with luxury vinyl, engineered wood, or wood laminate planks (typically 5–12 mm thick) over rubber or cork sound mat (approximately 10 mm thick). Receiving rooms were not identical but of similar size. All were furnished. Ten lateral and ten vertical tapping tests were compiled. The testing was performed per ASTM E1007, with the lateral test procedure modified as discussed in Section 2.

The results in third-octave bands are graphed in Figure 4. Solid lines are the average spectra in the vertical and lateral directions, and the dashed lines show the standard deviations. Figure 5 shows the difference between the averaged vertical and lateral spectra. Throughout the bulk of the frequency range, the difference is about 7.5 dB and approximately constant with frequency, although there is a slight positive slope of about 0.5 dB/octave. The roll off at the high frequencies is presumably due to background noise level.

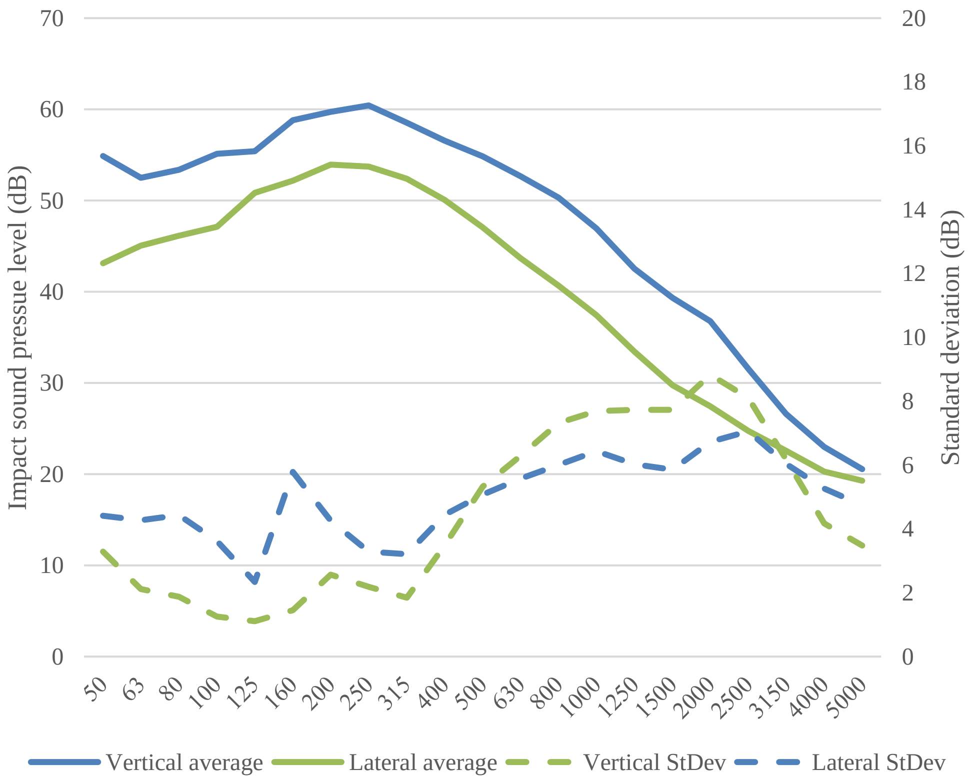

Figure 4: Average and standard deviations for vertical and lateral impact testing at the building described in the text.

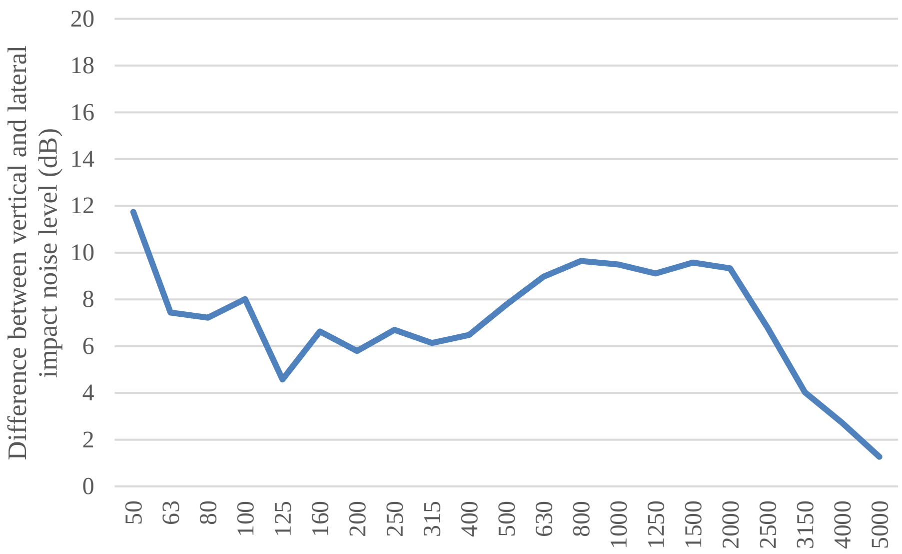

Figure 5: Difference in vertical and lateral impact spectra shown in Fig. 4.

The variation in level between tests is relatively large, as measured by the standard deviation (dashed lines in Figure 4), which is attributable to the variations in the finish flooring, room dimensions and layouts. However, this variation is similar between the vertical and lateral tests.

3.2. Theoretical calculations

Lateral impact transmission can be estimated using the methods in EN ISO 12354-2[5]. In the simple situation of common concrete slabs without linings and approximately the same room sizes, the theoretical difference between the direct (vertical) transmission and the lateral (flanking) condition is the vibration reduction across the junction (K_{ij}). (See Eq. 21a in Ref. 5.) Estimates of K_{ij} are provided in Appendix E of ISO 12354-1.[6] For transmission within the common slab with a lightweight stud-framed separating wall, the prediction has no frequency dependence (see Eq. E.7 in Ref. 6.)

As seen in Figure 5, the measured vibration reduction across the junction in this building was 7.5 dB without any frequency dependence. This is qualitatively consistent with the predictions of the standard. Precise numerical comparisons were not possible, as measurements of structural reverberation time or vibration reduction were not available.

3.3. Single Number Ratings

The single-number ratings of the above measurements are shown in Table 1. LIR (Low-frequency Impact Rating) and NHIR (Normalized High-frequency Impact Rating) are ratings that the authors have proposed to evaluate the low- and high-frequency components of impact noise independently.[4]

Table 1: Single-number ratings

	NISR	LIR	NHIR	$L'_{nT,w}$	$L'_{nT,50}$
Vertical	57	73	60	53	53
Lateral	64	91	69	46	46
Difference	7	18	9	7	7

As expected, the ASTM and ISO ratings for impact noise are similar. Because the spectrum of differences is approximately constant with frequency, the broadband ratings all reflect this 7-point difference.

The existing broadband ratings appear to adequately describe the lateral impact isolation, and it may be that separately evaluating the low and high frequency domains for lateral impact isolation is less beneficial than for vertical (direct) transmission. However, the low- and high-frequency ratings still provide additional information. In particular, the LIR rating reflects the fact that the differences between vertical and lateral transmission is higher at low frequencies, particularly at 50 Hz.

4. CONCLUSIONS

With the exception of tapping machine location, the measurement method, calculation methods, and single number ratings for vertical impact noise isolation appear to apply equally well to lateral as to vertical measurements. Based on our analysis, restricting tapping machine locations at a fixed distance from the common wall improves the repeatability of the test, and therefore the modified ASTM method is suggested for adoption into the measurement standards.

In buildings with poured concrete slabs, the lack of frequency dependence in the difference between lateral and vertical impact isolation matched the theoretical expectation. The recently introduced LIR and HIR ratings can be used to describe lateral impact transmission as well as vertical.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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