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ACOUSTIC INTENSITY AS A TOOL FOR ASSESSING SOUND ISOLATION AND FLANKING TRANSMISSION IN LIGHTWEIGHT BUILDING CONSTRUCTIONS

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INTRODUCTION

The technique of acoustic intensity is used to investigate the sound isolation of lightweight wood frame constructions having various degrees of flanking transmission. The ability of the intensity technique, using a P-P probe, to correctly resolve the radiated sound power of a building element is examined subject to various levels of extraneous noise from adjacent flanking surfaces. The effect on the estimate of sound power is shown to be related to the relative importance of the extraneous noise enclosed in the measurement volume. Masking adjacent surfaces is necessary to achieve a reasonable estimate.

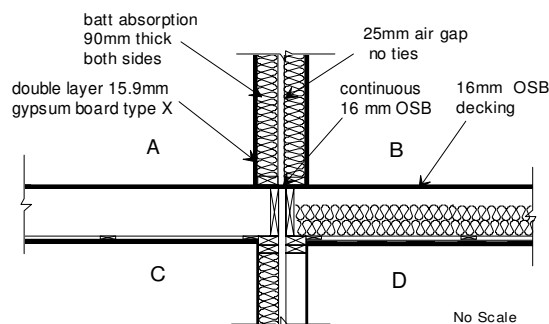


Figure 1: Sketch of the construction used to evaluate the intensity technique.

Figure 1 shows a sketch of the flanking facility and the construction. This paper will restrict itself to the examination of the sound isolation between the upper two rooms (labeled A and B in the figure). In all the cases considered in this paper the floor decking was continuous under the party wall which introduced a strong flanking path involving the receive room floor.

ROBOTIC MEASUREMENT SYSTEM

The Institute for Research in Construction of the National Research Council of Canada has just recently completed installing computer controlled robots for positioning microphone probes in each one of the four rooms of the flanking transmission test facility. Stepping motors with incremental encoders are used to provide absolute position error checking through feedback. Two of the four robots have four degrees of freedom and are used for positioning an intensity probe at up to 900 discrete measurement points on a planar

measurement surface. The system removes uncertainty in probe placement associated with human error and enables tests to run unattended.

The robots, constructed in-house, were based on the X-Y principle used in many chart plotters. A track and a runner are resiliently mounted to the ceiling of the facility and become the guide for a gantry which traverses the X direction. Mounted on the gantry by the use of v-grooved bearings is a small platform that traverses the length of the gantry; the Y direction. Rectangular metal stock forms the guide of a small carriage that traverses the Z direction. This carriage serves to hold a stepping motor that rotates an off-set aluminum pole. A probe is mounted on the end of the whisker pole such that the pick-up axis is normal to the measurement surface. To minimize costs and construction time, commonly available materials were used. For example, ladders formed the guide and gantry while small stepping motors drive cable chains via a gear reduction box. The resulting system is light weight with an absolute accuracy of 0.01 m. The largest cause of uncertainty in absolute position was due to the backlash in the bearing systems that provided the guides for the gantry.

MEASUREMENT DESCRIPTION AND REPEATABILITY

For all measurements the receive room has treated with sound absorbing material to reduce the amount of reverberant sound energy. Typically, at least 25 m² of 50 mm thick sound absorbing material was evenly distributed on all non-measurement surfaces reducing the reverberation time to less than 0.5 seconds for 200 Hz and above. Sound absorbing material was placed at least 0.5 m from the measurement volume.

In all the measurements presented a P-P probe was used with the acoustic centres of the microphones separated by 12 mm. The probe was placed between 13 and 15 cm from the measurement surface. The sound intensity at each measurement point was sampled for 40 seconds.

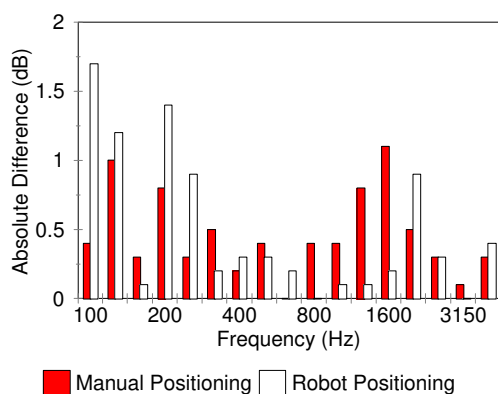


Figure 2: Measured repeatability of the intensity technique using robotic positioning and manual positioning.

levels of reverberant energy since the absorbing material is very much less effective at the low frequencies. Increasing both the integration time and the amount of absorption would tend to improve the results. However, for practical

The total sound power of the party wall (2.4x4.5 m) shown in Figure 1 was measured using 11x12 grid points with the microphone positioned manually and with the robot system. Figure 2 shows that in both cases the repeatability is very good with the mean difference for the manual method being 0.46 dB and 0.49 dB for the robot positioning system. Both have significant uncertainty in the low frequencies which may not be due to position accuracy but rather due to greater

measurements, it would appear that either manual positioning or robot positioning will provide adequate repeatability.

EXTRANEOUS NOISE FROM ADJACENT RADIATING SURFACES

The measurement surface, a flanking surface or even the nominally separating element, is often connected to an adjacent radiating surface. If the adjacent radiating surface is connected at right angles to the measurement surface then a portion of the adjacent surface becomes an extraneous noise source contained in the measurement volume defined by the area of measurement surface and the probe distance from the measurement surface. For example, if measuring the party wall of Room B of Figure 1, the floor decking becomes an adjacent radiating surface with the strip of the floor (defined by the probe distance and the length of the wall) as an extraneous noise source contained in the measurement volume.

An extraneous noise source contained in the measurement volume will affect the estimate of the sound power of the measurement surface. It can artificially increase the sound pressure level at the microphones which will aggravate any phase mismatch resulting in a larger value of the ISO 9614 F_2 indicator (where F_2 is defined as the mean sound pressure less the mean of the unsigned intensity vector). It will also increase any errors associated with insufficient integration time and/ or spatial sampling¹.

Measurements of the sound power radiated by a party wall shown in Figure 1 were made with and without masking of the adjacent flanking surface; the floor. Two cases are considered. In the first case the sound power radiated by the adjacent surface is very weak when compared to the measurement surface. While, the second case has significantly more energy radiated by the adjacent surface than the measurement surface.

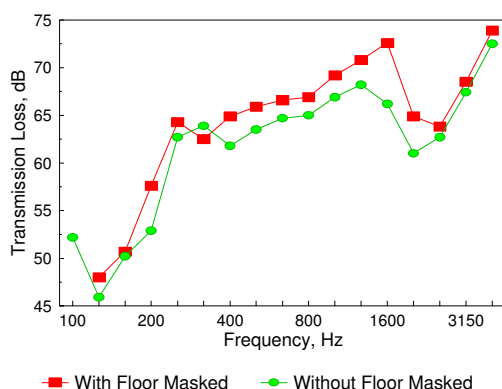


Figure 3: Measured party wall transmission loss with and without the floor masked.

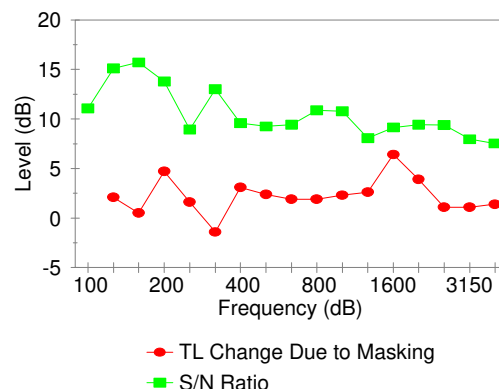


Figure 4: Measured signal to noise ratio and the change in transmission loss as a result of masking the floor.

Figure 3 shows that the measured transmission loss estimate is lower when the floor surface is exposed and a small portion is included in the measurement volume. The area of floor surface included in the measurement volume will depend on the probe distance from the wall. Figure 4 shows the

change in transmission loss and the signal to noise ratio (defined as the ratio of total measurement surface sound power to the sound power radiated by the portion of the adjacent surface contained in the measurement volume). The signal to noise ratio was typically between 7 and 15 dB and the change in the measured transmission loss estimate was typically between 0 and 5 dB.

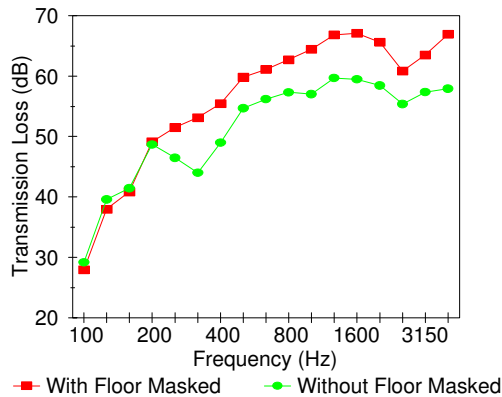


Figure 5: Measured party wall transmission loss with and without the floor masked.

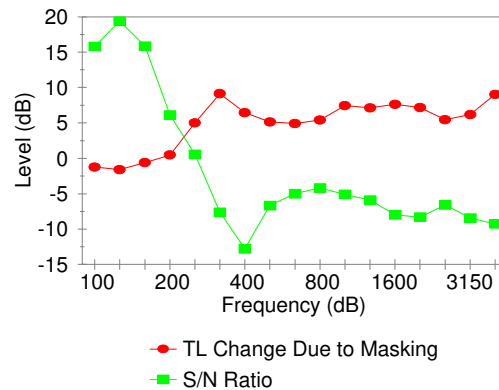


Figure 6: Measured signal to noise ratio and the change in transmission loss as a result of masking the floor.

The floor was masked using steel plates and 16 mm thick gypsum board. The gypsum board was placed over 50 mm thick open-cell foam material which covered the complete floor area except for a 600 mm wide section parallel to the wall/ floor joint. Special shields (a layer of 4.5 mm thick mass-loaded material sandwiched between two sheets of 1.5 mm thick sheet steel) were placed such that one edge butted into the wall/ floor joint while the opposite edge was placed on top of the gypsum board and foam. This technique minimized the area of the measurement surface shrouded by the masking (nominally 7.5 mm x 4.5 m). Joints in the masking panels were sealed with caulking and adhesive tape.

In the second case, the construction was changed to achieve a signal to noise ratio that exhibits a change from large positive values to large negative values. The 16 mm gypsum board of the party wall was replaced by 13 mm material. In the floor the joists were re-oriented (now parallel to the party wall) and the decking was changed to 16 mm plywood. Figure 5 shows that there is a very significant difference in the estimate of the transmission loss of the party wall with and without the masking. Without the adjacent surface masked the transmission loss estimate is between 5 and 10 dB lower for all frequencies greater than 200 Hz. This was reflected by a corresponding change in the single number rating by 5 STC points and by 4 R_w points. Figure 6, shows that the construction change resulted in there being very much more energy radiated by the floor than the measurement surface for all frequencies greater than 200 Hz. The figure also shows that the signal to noise is very highly correlated with the change in the transmission loss. When the S/ N ratio is between -7 and -12 dB the transmission loss of the measurement surface is consistently underestimated by 5-8 dB.

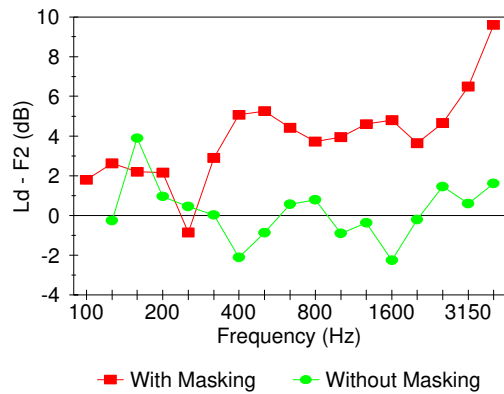


Figure 7: Quality indicator for party wall the measurements with and without the floor masked. ISO Criterion 1 is satisfied for all positive values.

extraneous noise problem because of the degradation to the F_2 indicator.

GRADIENTS IN THE RADIATED SOUND POWER

The discrete point method of measuring the radiated sound power can be very useful in characterizing the sound radiation of the surface. Figure 8A shows the fraction of the total sound power radiated as a function of the fraction of the sampled floor area (floor joist perpendicular to the party wall and a single layer of 16 mm OSB decking). The sampled area begins nearest the party wall and is increased by continually sampling more of the floor away from the party wall. If the floor radiated with equal intensity throughout its entirety then the data would form straight lines of unity slope. The figure indicates that only the initial portion of the data curves are straight lines and that the slope is not unity. For all frequencies, the figure would suggest that close to the wall/ floor joint, more energy is radiated than would be expected if the floor energy density were uniform. Each data curve exhibits a change in, or changing, slope such that with increasing areas (or distance from the driving edge) there is a small change in sound power for a large change in the area of the floor sampled. The practical implication is that if the room were made only half as deep (2.05 m from 4.10 m) then the total radiated sound power would only drop by 1 dB. Thus, the radiated sound power by the floor as a flanking surface is largely independent of the depth of the room.

The experiment was repeated with a layer of 16 mm OSB fastened to the existing floor decking. The results shown in Figure 8B indicate that the additional layer of floor decking does not change the behaviour of the floor appreciably with the exception of the 500 Hz third octave band. The behaviour of the floor seems to be reasonably independent of the thickness of the floor decking.

Figure 9 shows the same plot for the case when the floor joists were parallel to the party wall and the floor decking was 16 mm plywood. The general trends are similar between all three cases. However, the case where the joists are parallel to the party wall and the decking is plywood exhibits much

Figure 7 shows $L_d - F_2$, (where L_d is the dynamic capability index given in ISO 9614 and the bias error taken to be 10 dB for either engineering or precision grade measurement and F_2 is defined as the mean sound pressure less the mean of the unsigned intensity). ISO criterion 1 is satisfied for all positive values of $L_d - F_2$. With masking, the measurement satisfies the criterion for all but two bands, whereas without masking the measurement fails the criterion for all frequencies above 250 Hz. Thus, Criterion 1 appears to correctly identify the

stronger radiation near the party wall than do the cases when the joists are perpendicular and the decking is OSB. This suggests that the distribution of the radiated sound power by an edge-excited flanking surface is determined by a complex function of the framing member orientation (or structural stiffeners) and the type of cladding.

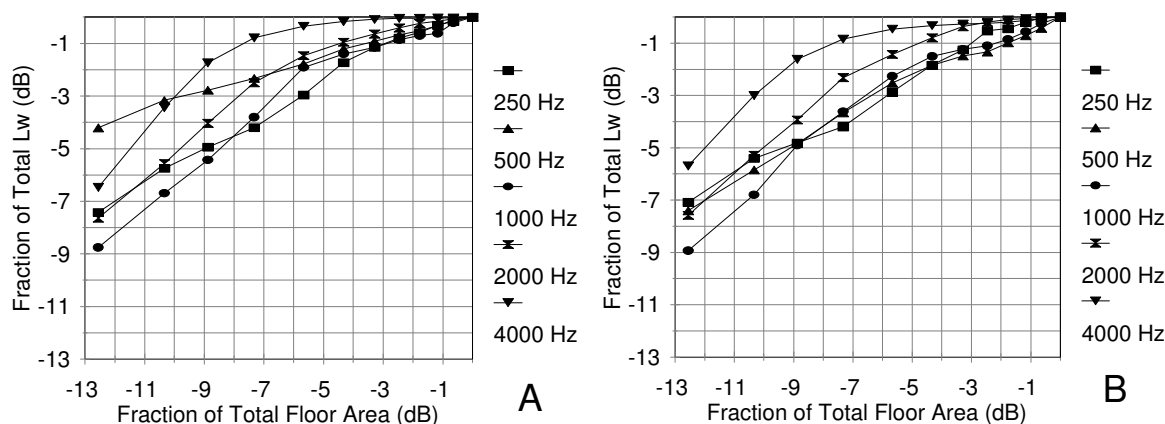


Figure 8: Measured fraction of the total sound power radiated (L_w) as a function of the fraction of the floor surface area as measured from the floor/wall joint. The joists are oriented perpendicular to the party wall. A: Single layer of 16 mm OSB decking. B: Two layers of 16 mm OSB decking fastened 100 mm on centres.

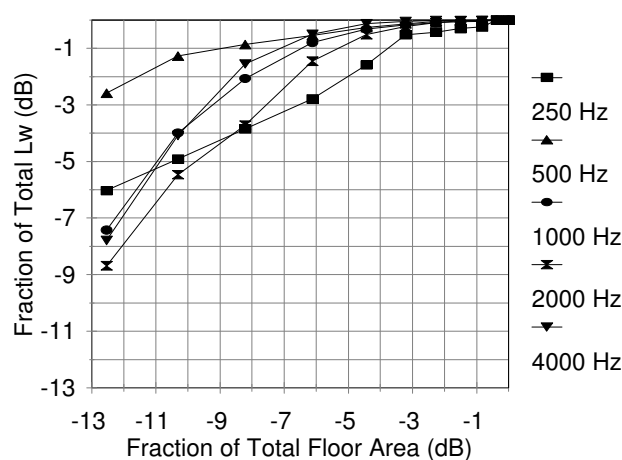


Figure 9: Measured fraction of the total sound power (L_w) radiated as a function of the fraction of the floor surface area as measured from the floor/wall joint. The joists are oriented parallel to the party wall and the floor decking is 16 mm plywood.

CONCLUSIONS

The acoustic intensity technique using the P-P probe has been shown to be a very effective tool in determining the sound power radiated by various building surfaces. The sound power was shown to be overestimated when a portion of an adjacent flanking surface was included in the measurement volume. The presence of this extraneous noise due to an adjacent flanking surface was correctly identified by the ISO F_2 indicator and the ISO Criterion 1. If a high degree of precision is required then masking of adjacent radiating surfaces is recommended.

¹ Jacobsen, F., "Sound power determination using the intensity technique in the presence of diffuse background noise," Journal of Sound and Vibration, Vol. 159 No. 2, pp. 353-371, 1992.