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FORWARD AND REVERSE TRANSMISSION LOSS MEASUREMENTS

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1. INTRODUCTION

The two main standard methods for measuring sound transmission loss using the two-room method – ASTM E90¹ and ISO 140-3² – only require that measurements be made in one direction. One of the rooms is designated as the source room, the other automatically is the receiving room. Neither standard gives any guidance on how to select the role for each room in most cases. Users may choose to test in two directions but it is not mandatory.

At low frequencies the room modal response influences the measured transmission loss values, and so is a factor in determining the reproducibility of the two-room test methods. Measurements made in both directions³ at the National Research Council showed differences in transmission loss at low frequencies that were large enough to give different STC⁴, or R_w ⁵ ratings. This observation caused us to routinely measure transmission loss in both directions in our test facilities. This paper presents the findings from the data collected.

2. TEST ROOMS

In the wall test suite originally built at NRC around 1955, one room had a volume of 65 m³ and the other a volume of 250 m³. Both rooms were essentially box-shaped and the smaller was used as the source room for many years. In 1998 the smaller room was replaced⁶ with one having a volume of 145 m³. This new room has a pentagonal floor plan. The NRC floor test suite³ was commissioned in 1992 and has room volumes that are approximately equal at 175 m³. Since 1997 enough data have been collected in all three test suites to allow a closer examination of differences in transmission loss when the direction of the test is changed.

3. EXAMPLE OF DIFFERENCES.

When transmission loss plots for the two measurement directions are compared on a single chart, it is not always obvious that there are significant differences. Occasionally, however, differences are enough to cause the STC or R_w ratings to be different. Figure 1 shows one such result measured in the floor facility. In this case, “forward” and “reverse” mean the upper room and the lower room respectively act as the source room.

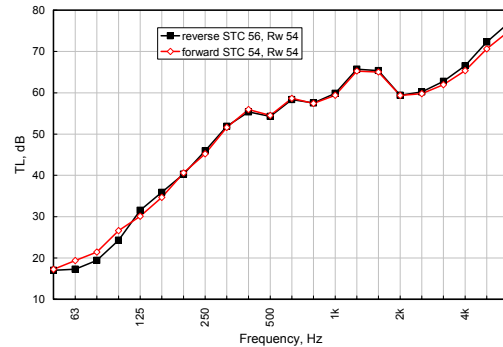


Figure 1: Sound transmission loss measured in two directions in the floor facility.

The graph shows differences in transmission loss at low frequencies as might be expected but there are also differences at high frequencies. The STC rating differs by two points for this floor while, in this case, the R_w rating is the same. When only differences are plotted, as in Figure 2, it is clear that the differences are much greater than the repeatability limits for the facility. These differences in transmission loss due to direction are not random. Once a specimen has been installed, the differences do not change significantly when the measurements are repeated.

4. MEAN DIFFERENCES

Inspection of many of these difference plots suggests that the average difference for the frequency range 200 to 800 Hz is zero. In a few cases there were small but obvious biases that were attributed to the uncertainty associated with calibration. To minimize such effects, each difference spectra was normalized so the mean difference in the frequency range 200 to 800 Hz was zero.

The normalized differences for the floor test suite are shown in Figure 3. The graph shows the mean difference, the minimum and maximum differences observed and the standard deviation of the differences. It is disturbing that the average difference is not zero at all frequencies. It is even more disturbing that the maximum and minimum differences observed are so different from zero. Such differences can be expected to lead to differences in single number ratings such as STC. While the details differ, each test suite shows the same kind of general behavior.

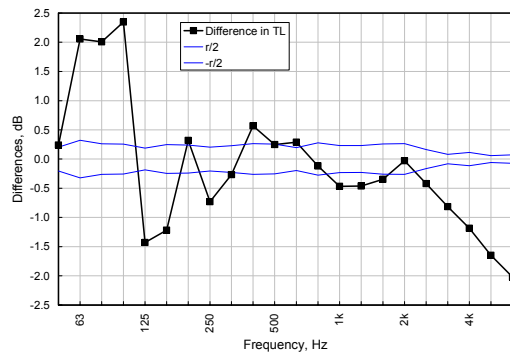


Figure 2: Difference in transmission loss for two measurement directions compared with repeatability limits for the floor facility.

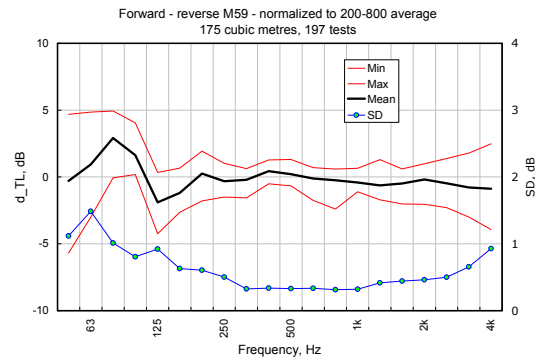


Figure 3: Normalized forward-reverse differences for the NRC floor test facility and the standard deviation of the differences.

The conclusion that derives from these graphs is not really new. The expression used to calculate transmission loss, $TL = L(\text{source}) - L(\text{receive}) + 10 \log S/A$, is only an approximation to the reality of reverberation room test suites. Dependence on test direction is evident throughout the frequency range. It is commonly assumed that when the measurement frequency is high enough – above the Schroeder frequency for example – that the rooms provide a good approximation to the ideal diffuse field. If this were so, transmission loss would not depend on measurement direction, but it does.

5. VARIATIONS IN RATINGS

These differences cause differences in the summary ratings generated by the test methods. The table below shows the distribution of STC and OITC⁷ differences for 507 tests run in the three NRC facilities. Simply by reversing the test direction, ratings can be obtained for a specimen that are different enough to make the difference between meeting or not meeting building code requirements in North America.

For many lightweight stud walls and joist floors, the STC rating is determined by application of the 8 dB rule to the transmission loss values below 250 Hz; quite often the STC is determined by the transmission loss in one band. Because of the 8 dB rule, the STC rating is very sensitive to changes

in transmission loss caused by changing test direction. The 8 dB rule is sometimes applied at high frequencies. In one measurement, the STC changed by 3 points when the test direction was changed because of the application of the 8 dB rule at 2500 Hz.

Table 1: Distribution of forward-reverse differences for one ISO and two ASTM ratings.

Difference	STC	OITC	R _w
-4	1	0	0
-3	12	0	0
-2	38	6	1
-1	186	103	48
0	222	202	433
1	46	141	22
2	2	45	1
3	0	9	1
% different	56%	57%	14%

6. SUMMARY

Changing the direction of a transmission loss test can change the STC or other ratings generated. A laboratory operator who chooses to run a standard test in both directions has no way to decide which of the two sets of results obtained is correct. It would be preferable for standard test methods^{1,2} to require measurements in both directions as a means of improving reproducibility for these test methods. The number of microphone positions required for a test in one direction could be reduced somewhat to avoid doubling the time for testing if this is thought necessary. With automated systems, however, the measurement time is negligible compared to time spent on construction, administration and report preparation.

REFERENCES

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- ⁶ R.E. Halliwell. Renovations of the IRC/NRC Acoustical Transmission Loss Facility for Walls, and their Effects, Internal Report 826, Institute for Research in Construction, National Research Council Canada, 2001
- ⁷ ASTM E1332. Standard Classification for Determination of Outdoor-Indoor Transmission Class.