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UNIFORMITY OF SOUND FIELDS IN LARGE ROOM VOLUMES FOR THE MEASUREMENT OF FAÇADE SOUND INSULATION

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ABSTRACT

In some countries, it is necessary to measure sound insulation with large receiving rooms that are currently outside the scope of ISO 16283-3. Façade sound insulation needs to be measured in schools, universities and offices, which often have room volumes greater than 250 m^3. In this paper, grid measurements of the sound pressure level are made in a receiving room of about 470 m^3 with a non-uniform absorption distribution. This allows an assessment of the spatial variation of sound pressure level when measuring the façade sound insulation, where the façade includes windows with relatively low sound insulation. The results show high sound pressure levels near the windows. This results in standard deviations for the spatial variation in the mid and high-frequency range that are higher than would be expected due to the direct field from these windows.

Keywords: *large volumes, façade sound insulation, spatial variation*

1. INTRODUCTION

The current version of ISO 16283 all parts is intended for room volumes from 10 m^3 to 250 m^3 in the frequency range from 50 Hz to 5000 Hz. This is a change with respect to the previous version of the ISO 140 relative to the on-site measurements. In fact, the series ISO 140 did not include limits for the volumes of the receiving rooms. In the present version, therefore, it is out of the scope of the standard the measurements of room volumes exceeding 250 m^3. In particular, this can be an issue for façade sound insulation that must be measured in some countries, such as schools or open-plan offices. The main issue in small room volumes, such as in dwellings, is the large variation in the sound pressure level at low frequencies [1]. Although low-frequency issues are potentially less problematic in large rooms, an assessment is needed to check whether there are any issues for façade sound insulation when the receiving room volume exceeds 250 m^3. As a first step, this paper assesses the spatial variation of the sound field inside a large room of about 470 m^3 using grid measurements of the sound pressure level.

The spatial variation of the sound field is often assessed with the sound source inside the room [2, 3]. In the present study, which is focused on façade sound insulation, the sound source is outside the room. The diffuse field theory predicts a uniform sound field in the centre of a room. On the basis that the onset of reflected sound cannot occur prior to the arrival of the direct sound, Barron and Lee [4] developed a revised theory for large-volume concert halls that predicts the average behaviour of sound levels more accurately.

This paper compares the measured standard deviation from the grid of microphone positions with different theories. For a diffuse sound field where the direct field is negligible, Schroeder's theory [5] is used along with the Lubman-Craik approach [6, 7, 8] for low-frequencies where there is a modal sound field. The Gaussian Orthogonal Ensemble GOE approach from Langley and Cotoni [9] is combined with Lubman's theory [6] for the direct field in a source room, as described by Davy [10].

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2. MEASUREMENT SET-UP

The measurements were performed in a historical university lecture room of about 470 m^3 volume. The room has 15 rows (see Fig. 1) of continuous school desks and folding chairs with a Class D absorptive ceiling. The floor surface of the room is approx. 141 m^2, and the dimensions are approximately 17 m in length, 8.3 m in depth and 3.5 m high. The two facades of the room are made of 0.7 m plastered double walls with 0.4 m full bricks, an internal air gap, and 0,14 m hollow bricks. Include two wood frame single pane windows 2 m long and 2.7 m high that were not sealed and, therefore, not airtight.
Sound pressure level measurements were made in a three-dimensional grid when the outside sound source pointed towards the windows on the longest façade. The grid points are indicated in Fig. 2. For each point of the grid, four different heights were measured to give a total of 648 grid points.

Figure 1. View from the front of the lecture room with the longest façade wall on the right-hand side.

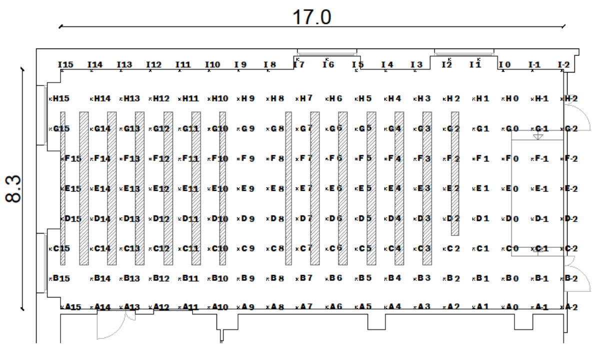

Figure 2. Sketch of the lecture room with grid points.

3. RESULTS

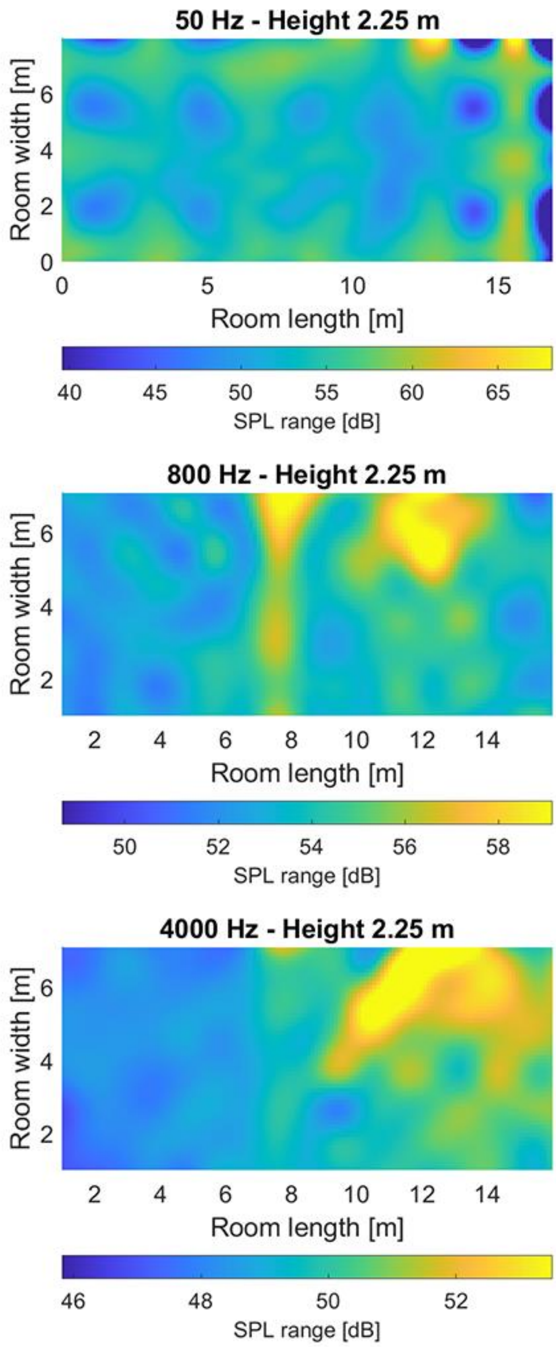

Figure 3. Contour plots of the sound pressure level at a height of 2.25 m. The SPL range shown at the bottom of each plot is a function of the frequency of the surface plot range.

Figure 3 shows contour plots of the sound pressure level at a height of 2.25 m at 50 Hz, 800 Hz and 4 kHz, with the exception of points located on the room's edges. At 50 Hz, there is evidence of modal behaviour. At 800 Hz, there is evidence of strong sound radiation from both windows, with sound transmitted across the room that is reflected across the desks. At 4 kHz there is strong radiation from the right-side window that is expected to be caused by the absence of seals around the window frame and a closing mechanism that causes a gap near the top of the window.

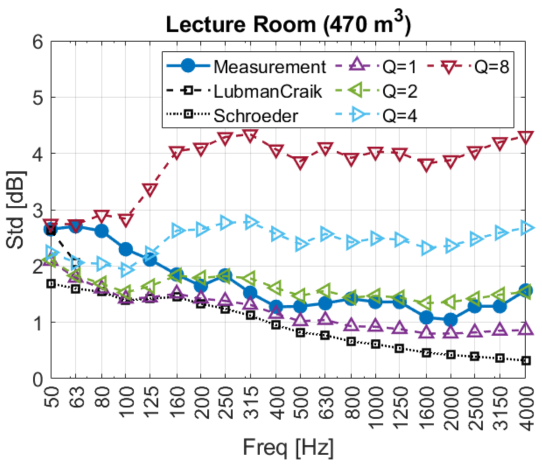

Figure 4. Standard deviations from measurements and theory.

Figure 4 shows the measured standard deviation of the sound pressure levels from the grid, excluding grid points next to the walls, floor and ceiling. At 50 Hz, where there are approximately seven modes, the theory from Lubman-Craik shows the closest agreement with measurements as this theory accounts for low modal density. The Schroeder theory underestimates the standard deviation across the entire frequency range because no account of the direct field from the high levels of transmitted sound from the windows is taken. Ideally, the directivity, Q, needs to be related to a physically meaningfully description for the source. For Q=1 the source would be omnidirectional; hence this would not be appropriate. For Q=2 the source would be sited on a plane and this is a reasonable approximation, but Q=4 might represent a source situated along an edge to represent a leak from the top edge of the window. However, the actual situation is more complex because there is a deep niche of approx. 0.4 m and there could be a two-dimensional reverberant field within the niche above 1 kHz. Comparison of the measured standard deviation with Q=1, 2, 4 and 8 indicates that Q=2 is a reasonable value that the deep niche might justify.

4. CONCLUSIONS

Extending ISO 16283-3 to larger room volumes requires an assessment of the standard deviation for the spatial variation of sound pressure levels. Schroeder theory (or other theories) that only considers the reverberant field underestimate the standard deviation across the entire frequency range because no account is taken of the direct field. The large room considered in this paper had windows with relatively low airborne sound insulation, which led to significant levels of mid- and high-frequency sound radiating from the windows across the room. Therefore, it was necessary to consider the direct field when calculating the standard deviation.

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