LABORATORY MEASUREMENT OF THE SOUND REDUCTION IMPROVEMENT INDEX BY ACOUSTICAL LININGS DUE ONLY TO RESONANT TRANSMISSION

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ABSTRACT
Prediction of sound insulation between dwellings using Statistical Energy Analysis (SEA) or SEA-based models (e.g. EN 12354) often require only the resonant component of the sound reduction improvement index for wall linings. This is particularly relevant for wall linings used on low surface density concrete/masonry flanking walls. In this paper a measurement method to determine the resonant sound reduction improvement index in a transmission suite using structural excitation with an MLS signal is proposed. Measured data are presented using this method and ISO 140-3.

INTRODUCTION

In new buildings, conversions and refurbishment, wall linings are often used on concrete/masonry walls to achieve the required thermal insulation. However, as an undesirable side effect, wall linings can reduce the low frequency sound insulation due to mass-spring resonance phenomena. This is particularly relevant to wall linings consisting of laminate plasterboards with foamed plastics where the dynamic stiffness of the foamed plastics is relatively high. As a consequence, the mass-spring resonance frequency often occurs above 100Hz and adversely affects the ISO 717-1[1] single-number quantities used to rate the airborne sound insulation.

Data on the acoustic performance of wall linings are needed for use in prediction models. However, accurate vibro-acoustic models of proprietary wall lining laminates are not always feasible due to the complexity of the fixing, or lack of information on the material properties and dynamic properties of the wall lining components. For this reason, it is important to acquire measured data on the performance of wall linings and use these data in Statistical Energy Analysis (SEA) or SEA-based prediction models (e.g. EN 12354[2]). Typically, wall linings are assessed in the laboratory by measuring the sound reduction index of a base wall without a lining and then measuring the same wall with the lining according to ISO 140-3[3]. The "sound reduction improvement index", ΔR, due to the wall lining is then calculated as shown in Equation 1.

Equation 1

$$\Delta R = R_{with\_lining} - R_{without\_lining}$$

However, ΔR data include sound transmission due to both resonant and non-resonant transmission paths. Therefore in SEA or SEA-based models, ΔR data are only strictly relevant when the wall lining is applied to one surface of a wall when that wall faces into two different rooms, i.e. on a separating wall between dwellings. When wall linings are applied to concrete/masonry *flanking* walls, ΔR data are no longer strictly "correct" below the critical frequency when there is only resonant transmission via the concrete/masonry flanking walls.

In order to measure ΔR values in the laboratory that are relevant to flanking walls in prediction models, it is necessary to measure ΔR in a different way such that *only* resonant transmission takes place. This new parameter will be called the "resonant sound reduction improvement index", ΔR_{res}.

MEASUREMENT OF THE RESONANT SOUND REDUCTION IMPROVEMENT INDEX, ΔR_{res}

The resonant sound reduction improvement index, ΔR_{res} can be measured by exciting the wall such that only resonant transmission takes place. The method will be referred to here as the "MLS vibration method". This approach uses structural excitation from an electrodynamic shaker rather than a loudspeaker as used in ISO 140-3 measurements. The procedure requires measurement of the vibration level on the base wall and the resulting sound pressure level in the receive room. The excitation is applied to the side of the wall without the wall lining with the vibration measurements also taken on the side of the wall without the lining as shown in Figure 1.

To avoid problems in the measurement of low sound pressure levels in the receiving room, it is convenient to use an MLS signal for the structural excitation. A dual channel MLS analyser (Norsonic 840) was used to measure vibration in one channel and sound pressure level in the other channel. Red-white noise was used as the MLS signal with MLS signal-to-noise ratios $\geq$15dB as the acceptance criterion.

Figure 1 : MLS vibration method. Charge amplifier, accelerometer and electrodynamic shaker in the transmission suite.

Three excitation positions were used with four different accelerometer positions for each excitation position. Stationary microphone positions were required due to the use of MLS signal. Two different microphone positions were used to measure the sound pressure level for each accelerometer position.

The criteria in the CEN/TC126/WG6 frame document^{4} for vibration level difference measurements were used to select excitation and measurement positions. Accelerometer positions were >0.25m from any boundary of the wall, >1m from the excitation position and >0.5m away from each other.

For the wall with and without lining, the wall vibration and radiated sound pressure were measured and the standardized pressure-vibration level, $L_{\mathrm{pv},T}$, was calculated as shown in Equation 2.

The shaker was pushed up against the base wall, hence it could not be ensured that the shaker would impart the same power to the wall at each excitation position. This was overcome by taking the arithmetic average of the three excitation positions in order to calculate $L_{\mathrm{pv},T}$.

Equation 2

$$L_{pv,T} = \left[\frac{1}{3}\sum_{i=1}^{3}\left(\left(10\lg\left(\frac{1}{8}\sum_{j=1}^{8}10^{L_{p,j}/10}\right)\right)_i - \left(10\lg\left(\frac{1}{4}\sum_{k=1}^{4}10^{L_{v,k}/10}\right)\right)_i\right)\right] - 10\lg\frac{T}{T_o}$$

where

$L_{\mathrm{p,j}}$ is the sound pressure level at microphone position j in dB re 2.10^{-5}Pa

$L_{v,\mathrm{k}}$ is the base wall velocity level at accelerometer position k in dB re $2.10^{-5}\mathrm{ms}^{-1}$

T is the receive room reverberation time in seconds

T_{o} is the reference reverberation time, 0.5s

The resonant sound reduction improvement index, ΔR_{res} was calculated from the standardized pressure-vibration levels for the wall with and without the wall lining as shown in Equation 3.

Equation 3

$$\Delta R_{res} = L_{pv,T\,(without\_lining)} - L_{pv,T\,(with\_lining)}$$

TEST CONSTRUCTIONS

The base wall was built from 100mm thick aircrete blocks (AAC), with a surface density of 51kg/m^{2} and a critical frequency in the 315Hz third octave band.

Three different wall linings were applied to one side of the base wall:

1. Plasterboard laminate with extruded polystyrene attached using a metal frame.
2. Plasterboard laminate with expanded polystyrene attached using multipurpose adhesive direct bond.
3. Plasterboard attached using a metal frame with mineral fibre in cavity.

RESULTS

The sound reduction improvement index data for the three different wall linings are shown on Figure 2 to Figure 4.

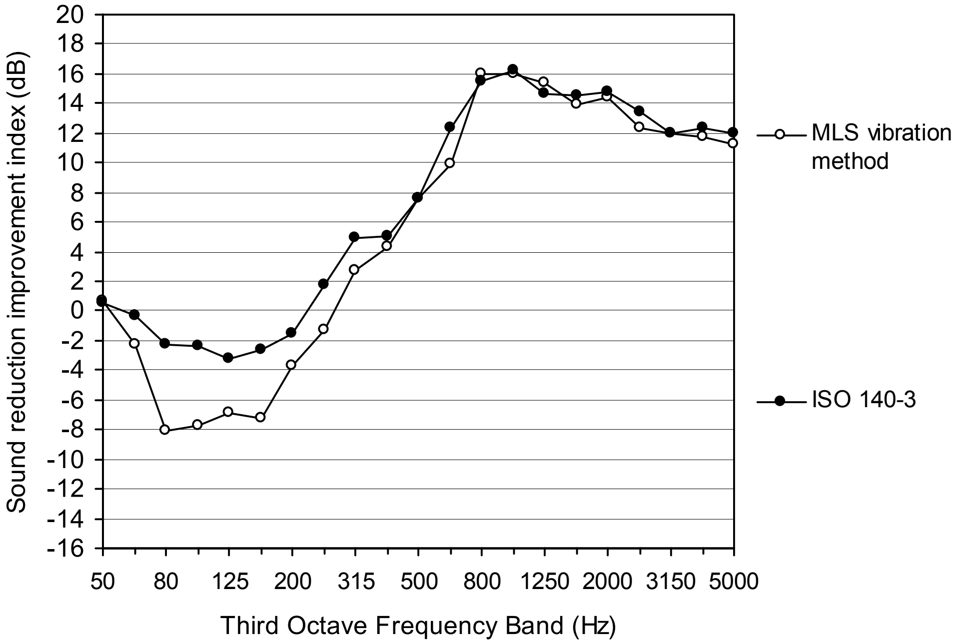

Figure 2 Sound reduction improvement index. Lining No. 1. Plasterboard laminate with extruded polystyrene attached using a metal frame.

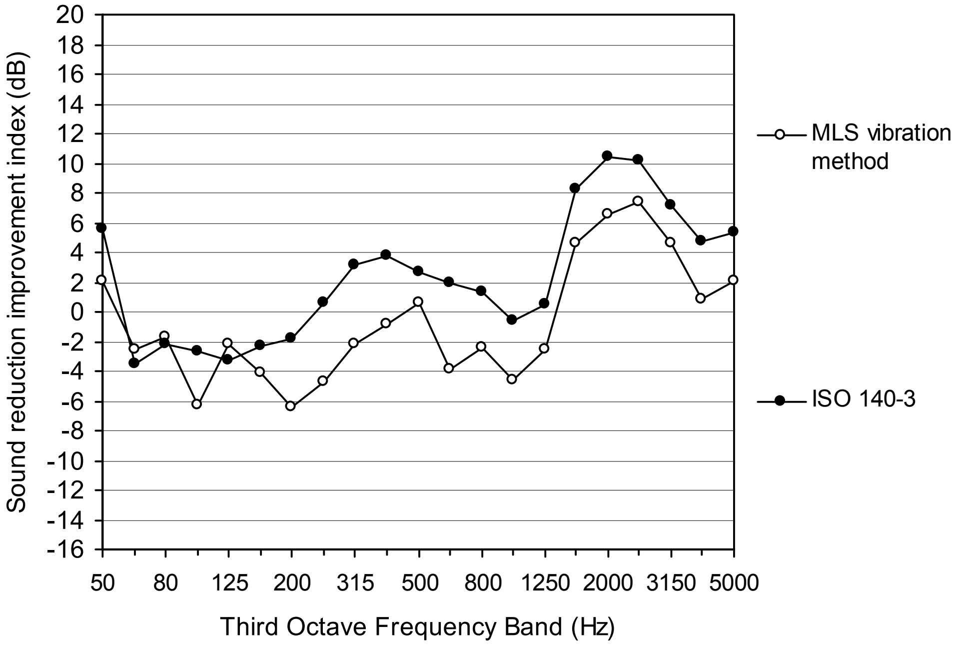

Figure 3 Sound reduction improvement index. Lining No. 2. Plasterboard laminate with expanded polystyrene attached using multipurpose adhesive direct bond.

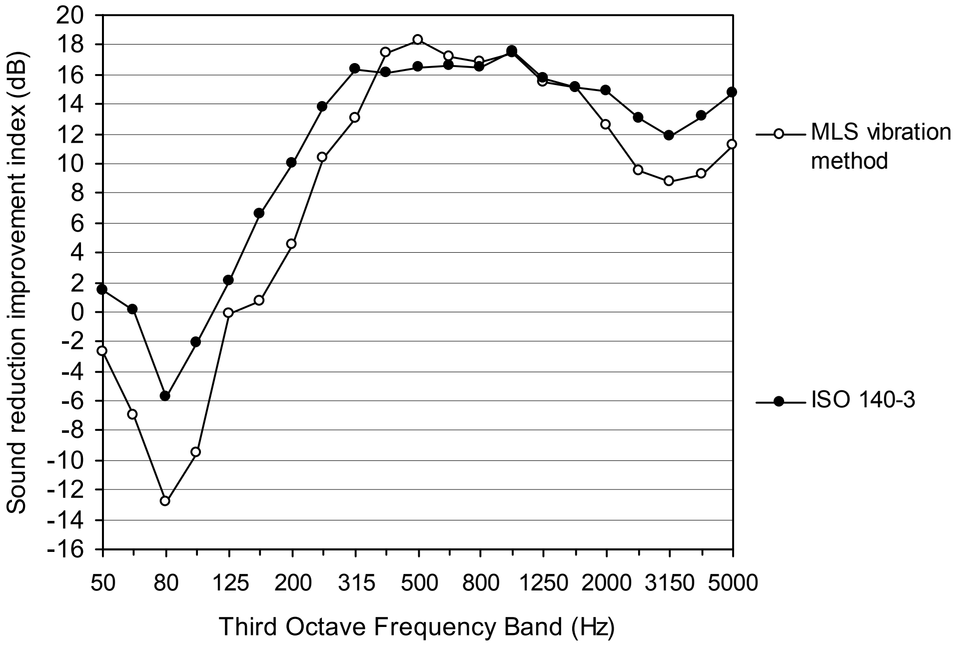

Figure 4 Sound reduction improvement index. Lining No. 3. Plasterboard attached using a metal frame with mineral fibre in cavity.

Lining No. 1: Plasterboard laminate with extruded polystyrene attached using a metal frame

The mass-spring resonance frequency of the plasterboard laminate on the air gap is calculated to be in the 125Hz third octave band, which corresponds to the frequency range where there are negative values of the sound reduction improvement index. The mass-spring resonance frequencies of the plasterboard on the extruded polystyrene and the plasterboard laminate on the metal frame are not known. Below the critical frequency of the base wall (315Hz third octave band) in the region of the mass-spring resonance frequency of the plasterboard laminate on the air gap, the MLS vibration method gave significantly lower values for the sound reduction improvement index than the ISO 140-3 method.

Lining No. 2: Plasterboard laminate with expanded polystyrene attached using multipurpose adhesive direct bond

The mass-spring resonance frequency of the plasterboard laminate on the air gap is calculated to be in the 250Hz third octave band. The mass-spring resonance frequency of the plasterboard on the polystyrene is estimated (from previous measurements of the dynamic stiffness with similar polystyrene specimens) to be in the 630Hz third octave band. The MLS vibration method gave 0.5dB to 6dB lower values for the sound reduction improvement index than the ISO 140-3 method over the majority of the frequency range.

Lining No. 3: Plasterboard attached using a metal frame with mineral fibre in cavity

The mass-spring resonance frequency of the plasterboard on the air gap is calculated to be in the 100Hz third octave band. However, from the dip in the sound reduction improvement index it appears that the presence of the mineral fibre in the cavity has reduced the resonance frequency to the 80Hz third octave band. At 80Hz the MLS vibration method gave significantly lower values than the ISO 140-3 method.

CONCLUSION

The results all indicate that ΔR_{res} tends to be lower than ΔR. In particular, ΔR_{res} is significantly lower than ΔR around the mass-spring resonance frequency and at frequencies below the critical frequency of the base wall.

In this project it has not been possible to verify whether the inclusion of ΔR_{res} data in prediction models leads to more accurate predictions, especially around the mass-spring resonance frequency. Future work should therefore assess the accuracy of prediction models that incorporate these ΔR_{res} data.

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REFERENCES

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[2] **EN 12354-1:2000** Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 1: Airborne sound insulation between rooms.

[3] **ISO 140-3:1995** Acoustics – Measurement of sound insulation in buildings and of building elements. Part 3: Laboratory measurement of airborne sound insulation of building elements.

[4] **CEN TC126 WG6 N284** Laboratory measurement of the flanking transmission of airborne and impact noise between adjoining rooms. Part 1: Frame document.