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THE PREDICTION OF TRANSMISSION LOSS OF COMPOSITE WALL, USING MODELLING TECHNIQUE.

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Introduction

Knowing the Transmission Loss, T.L., of two or more single walls of different materials, the T.L. of a composite wall made up of any of those materials can be predicted using Eq. (1).

$$T.L._{com} = 10 \log \left(\frac{1}{\tau_{com}}\right) = 10 \log \frac{S_1 + S_2 + \cdots S_n}{\tau_1 S_1 + \tau_2 S_2 + \cdots \tau_3 S_3} \qquad (1)$$

where τ_1, τ_2 ··· τ_n are transmission coefficients of the separate materials 1, 2, ··· n, and S_1, S_2, ··· S_n are their corresponding areas in the composite wall. It can be shown that the equation merely adds up the T.L. of individual single wall normalised for area. Although Ver[1] has remarked that interaction between elements is not accounted for in classical theory, the applicability of Eq. (1) in practice has not yet been investigated.

Theory

In the ideal situation of an isolated test wall between source and receiving rooms, the transmission of sound takes place via resonant and non-resonant paths. This is true for all frequencies.

The non-resonant T.L. of the wall can be predicted using Eq. (2)[2], given the limiting angle of incidence of source room, θ.

$$T.L._{\theta} = 10 \log \frac{K^2 (1 - \cos^2\theta)}{\ln(1+K^2) - \ln(1+K^2\cos^2\theta)} \qquad (2)$$

where $K = \frac{\omega \rho s}{2\rho c}$

ρs = surface density (kg/m²)

ω = angular frequency

ρc = characteristic impedance of air.

Surface density is the only variable in Eq. (2) for a given situation. Given a constant ρs, non-resonant transmission properties of a material should not change with area. It can, therefore, be normalized for area without causing any error, theoretically.

Resonant Transmission Loss, $T.L._R$, can be predicted using SEA method (Eq. 3),[1] assuming that reciprocity operates.

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$$T.L._R = 20 \log \left(\frac{\rho_s \omega}{2\rho c}\right) + 10 \log \frac{f}{f_c} \times \frac{2}{\pi} \times \frac{\eta}{\sigma^2} \qquad (3)$$

where f_c = critical frequency (Hz)

η = total loss factor

σ = radiation ratio

The radiation ratio varies with the plate's area and perimeter in a non-linear relationship along the frequency axis for frequencies up to coincidence. The total loss factor is a function of elastic stiffness, coupling and edge damping. Given that the first two variables are constant and have the same edge condition, 'η' should increase as area decreases. This is due to the fact that the perimeter to area ratio increases as area decreases. In considering the effect of 'η' in isolation the normalisation to take account of area will underestimate the $T.L._R$ since the area increases in terms of square function whereas perimeter to area ratio increases linearly.

Theoretically, Eq. (1) is valid for non-resonant transmission but not for resonant transmission. However, 'η' is approximately independent of frequency. Error due to area normalization of 'η' can be corrected.

Structural interaction is evaluated using Statistical Energy Analysis, SEA.

Measurement

To investigate on the practical application of Eq. (1), T.L. measurement was carried out for eleven composite walls with varying window size and pane thickness (Table 1).

Table 1

Window size (mm)	Pane thickness (mm)
300 x 600 (60 x 120)	12, 6, 3 (2.03, 1.24, 0.56)
450 x 900 (90 x 180)	6
600 x 1200 (120 x 240)	12, 6*, 3
900 x 1800 (180 x 360)	6
1200 x 2400 (240 x 480)	12, 6*, 3

( ) dimension of 1/5 scale model. *SEA study carried out.

T.L. Measurement was made in accordance to BS 2750 but in the scale frequency range 500 - 16000 Hz. The investigation was carried out at 1/5 scale. The windows used were of dead-light design set in 225 mm thick lightweight concrete block wall which was plastered both sides. For the model scale, simulation on aluminium plate was used in place of glass.

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The T.L. of single walls of block work and aluminium plates were measured for the prediction of $T.L._{com}$ using Equ. (1).

Due to the lack of modes for the smaller window plates, SEA investigation was carried out for two composite walls only. SEA parameters were measured except for modal density which was predicted by mode count.

Results

The agreement between the measured and predicted (Eq. 1) T.L. was good for the three walls with larger window. The generally poor agreement at frequencies at or below 1250 Hz was attributed to the lack of diffusion within the scaled reverberation chambers. For walls with the same window size, it was found that the agreement improves as the pane thickness decreases. This is due to the fact that the plate's fundamental frequency increases and its coincidence frequency reduces as the plate thickness increases. This increases the amount of resonant transmission for which Eq. (1) is unsuitable within the frequency region investigated. This phenomenon is especially marked in the case of the composite wall with the smallest window (Fig. 1a, 1b, 1c). For the thickest plate (Fig. 1c), the critical frequency is at 5953 Hz, and the natural frequency is at 1408 Hz. It is almost completely resonant controlled in the frequency range of interest.

Above critical frequency, the measured T.L. is generally higher than the predicted T.L. (Eq. 1). This is due to the difference in total loss factor between the single window and that in a composite wall. This is in agreement with the theory.

As for structural interaction, the noise reduction along all possible paths of transmission between the source and receiving rooms were calculated using SEA Figure 3a & 3b show that path 1-2-4, 1-3-4 and 1-4 dominate the transmission. The paths which include structural interaction, 1-2-3-4 and 1-3-2-4 are insignificant. Therefore, it is shown in this case that structural interaction is not an attribute to the error caused by Eq. (1) or at least in the context of timber frame windows.

Conclusions

The measured results agree generally with theory, i.e. Equ. (1) operates in the non-resonant transmission situation. However, it is not strictly valid for resonant transmission. Nevertheless, the error caused by the difference in total loss factor at frequencies above coincidence can be easily corrected. Structural interaction is not important in the case of timber frame windows.

References

(1) VER, I.L. and HOLMER, C.I., 1971, Noise and Vibration Control, Chapter 11, edited by L.L. Beranek, McGraw-Hill,

(2) BAZLEY, E.N., 1966, The Airborne Sound Insulation of Partitions, NPL, HMSO, London.

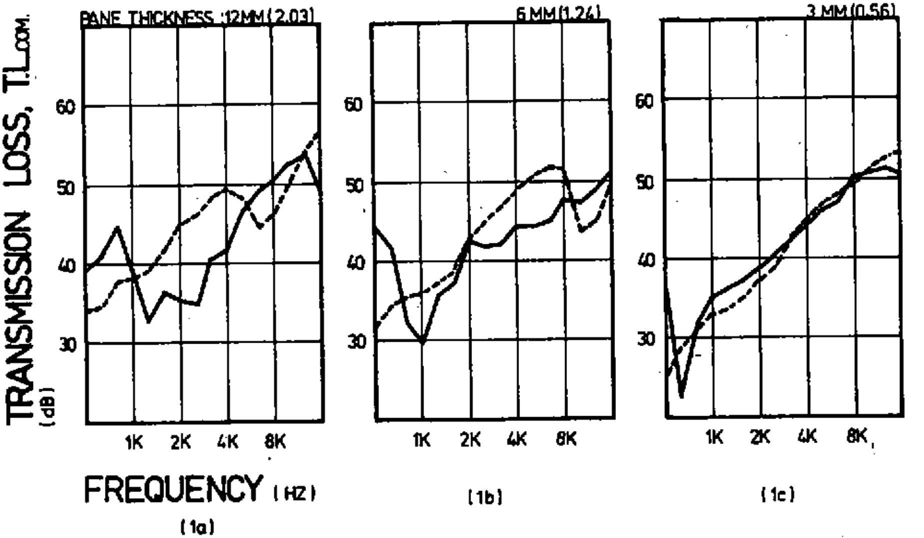

FIGURE 1: SIZE OF WINDOW = 300×600 MM (60 × 120); ——— MEASURED VALUES; - - - - PREDICTED VALUES (EQ.1)

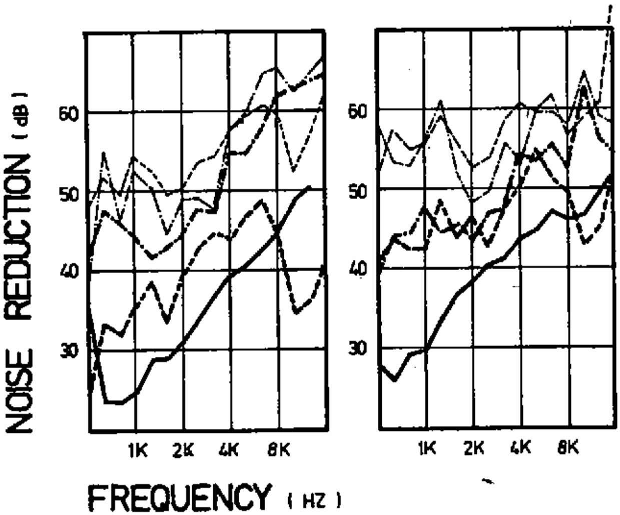

FIGURE 2:

NOISE REDUCTION OF VARIOUS PATHS :

—·—·— 1→2→3→4

- - - - - 1→3→2→4

-·-·-·- 1→2→4

-- -- -- 1→3→4

——— 1→4

WHERE

1 = SOURCE ROOM

2 = WALL

3 = WINDOW

4 = RECEIVING ROOM

WINDOW SIZE : 1200×2400 MM (240×480)	600×1200 MM (120×240)
PANE THICKNESS : 6MM	6MM (1.24)
(2a)	(2b)