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SINGLE LEAF TRANSMISSION LOSS AT LOW FREQUENCIES

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When the measured transmission losses of single panels are compared to the mass law values of transmission loss, one finds that there are sometimes differences between the two curves at low frequencies. This difference is shown to depend on some property of the rooms in which the measurements of transmission loss are made rather than on a property of the panel itself. The exact cause of the difference between mass law theory and experiment has not been found.

The size of the discrepancy implies that care should be taken when comparing low frequency results obtained in different measuring facilities.

1. INTRODUCTION

It has been known for some time [1] that the transmission loss of a single wall depends on its mass. In fact in the frequency range lying between a frequency above the basic resonance and below the coincidence frequency the transmission loss follows the mass law and depends at a particular frequency only on the mass of the wall. It is not felt that high order resonances are important in the panels which were considered.

The agreement between the measured transmission loss and mass law in this frequency range is generally good. However, it has been found in a number of cases that the measured curve lies above the mass law at the lower frequencies (100–400 Hz). London [2] attributed the cause of this discrepancy to some property of the wall and postulated a resistance term in the wall impedance. The value of this resistance term was chosen to give the best agreement between theory and experiment.

The results reported in this paper indicate that this discrepancy is not due entirely to the wall properties (if at all) but is due to some property of the transmission suite in which the measurements are made. The present results confirm those of other workers [3, 4] in showing a closer agreement between the insertion loss and the mass law at the lower frequencies than between the transmission loss and the mass law.

2. THE THEORY OF TRANSMISSION LOSS

In the frequency range lying between the basic resonant frequency of a wall and its critical frequency the transmission loss of the wall is given by the so-called "mass law"

$$TL = 10\log\left[1+\left(\frac{\omega m}{2\rho c}\right)^2\right]. \quad (1)$$

This expression may be derived if one assumes that stiffness and damping are not important and that the wall consists simply of a series of small masses. The above expression gives the transmission loss for normal incidence sound. If sound is present at all angles up to a limiting angle θ_L then the mean transmission coefficient $\bar{\tau}$ is given by

$$\bar{\tau} = \frac{\int_0^{\theta_L} \tau(\theta)\cos\theta\sin\theta\,\mathrm{d}\theta}{\int_0^{\theta_L} \cos\theta\sin\theta\,\mathrm{d}\theta}, \tag{2}$$

where

$$\tau(\theta) = 1\bigg/\left[1 + \left(\frac{\omega m\cos\theta}{2\rho c}\right)^2\right];$$

the transmission loss is then given by $10\log(1/\bar{\tau})$.

The value of θ_L is chosen so as to give the best fit between theory and experiment, a value of 82° being appropriate for the Liverpool University facility. The higher the value of the product ωm the greater is the difference between the mass law curves for different values of θ_L. The smaller the value of θ_L the greater is the predicted transmission loss. The limiting angle is not important at low frequencies except for heavy panels (heavier than are considered here).

London proposed an addition to the panel impedance so that this then became $2R\rho c/\cos\theta + i\omega m$. The transmission loss at random incidence using this expression for the impedance becomes

$$TL = 10\log a^2 - 10\log\left\{\ln\left[1 + \left(\frac{a}{1+R}\right)^2\right]\right\} \tag{3}$$

where $a = \omega m/2\rho c$.

The resistance term has the effect of increasing the transmission loss at the low frequencies. The value of R is chosen to give the best fit between theoretical and experimental results. London assumed that the value of R depended on panel parameters whereas the results of this paper indicate that the discrepancy from mass law is due to some room parameter.

3. EXPERIMENTAL RESULTS

All the transmission loss results made at Liverpool were made to B.S. 2750 [5] using white noise and five random microphone positions. It was found despite the small number of microphone positions used that results were reproducible to within 2 dB even at the lowest frequencies. This random error is much smaller than the discrepancies of up to 7 dB which were found.

A typical result obtained in the new Liverpool University facility for the transmission loss of a single panel is shown in Figure 1. The panel is of $\frac{1}{16}$ in. (16 mm) lead and the figure also shows the measured curve for a similar panel made in the old Liverpool facility. The agreement with the mass law is close (within 2 dB for both curves in the range 630–4000 Hz). However, whereas the result obtained in the old facility continues to agree closely with mass law in the range 100–630 Hz, the result obtained in the new facility lies above the mass law by as much as 5–6 dB. A similar discrepancy was also found with panels of other materials such as wood and aluminium.

Whilst the present results agree with those of London in showing a greater transmission loss than mass law at low frequencies, the discrepancy is not the same in both cases. The discrepancy found by London increased as the frequencies decreased, whereas the present results show a maximum difference from mass law in the region of 200 Hz with a return towards mass law at lower frequencies. The results of Peutz [3] show another form of discrepancy. In this case the difference from mass law occurs only in the region of 100 Hz where it is sometimes greater than 10 dB.

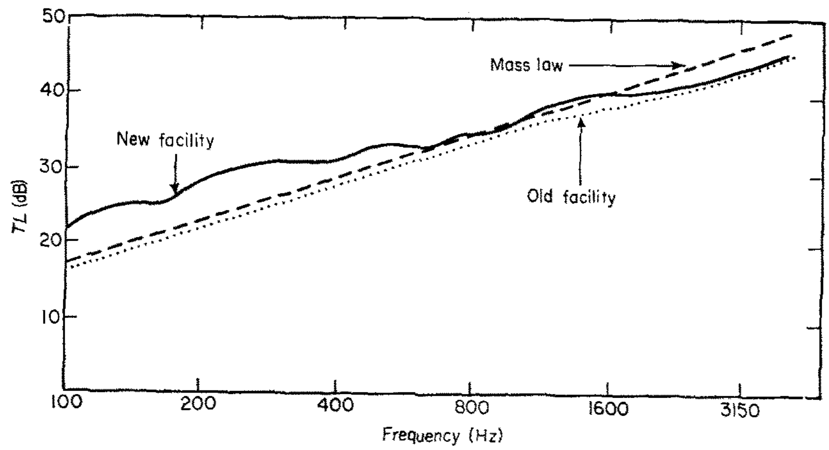

Figure 1. Lead panel.

The transmission loss of a 0·035 in. thick aluminium panel was measured in the new Liverpool facility and in the transmission loss facility at Salford University. The results are shown in Figure 2. At Salford the agreement with mass law is closer than 2 dB over most of the frequency range for a limiting angle of 82°. The result obtained at Liverpool lies above the mass law ($\theta_L = 82°$) by as much as 7 dB at 200 Hz.

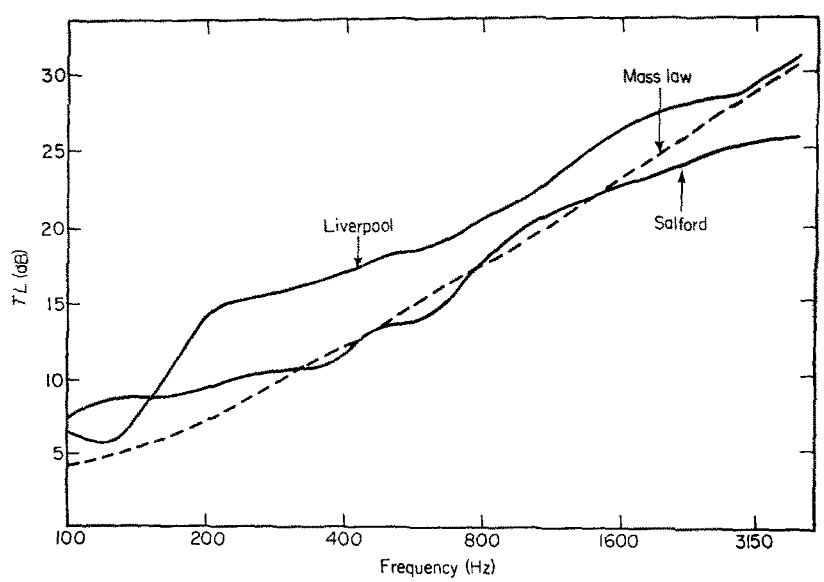

Figure 2. Transmission loss of a 0·035 in. aluminium panel.

The insertion loss of a 0·035 in. thick aluminium panel is shown in Figure 3. In contrast to the transmission loss, the insertion loss agrees closely with the mass law and lies within 2 dB of it from 100–2000 Hz. This result confirms the results of other workers [3, 4] who found that the insertion loss gave closer agreement with mass law than did the transmission loss.

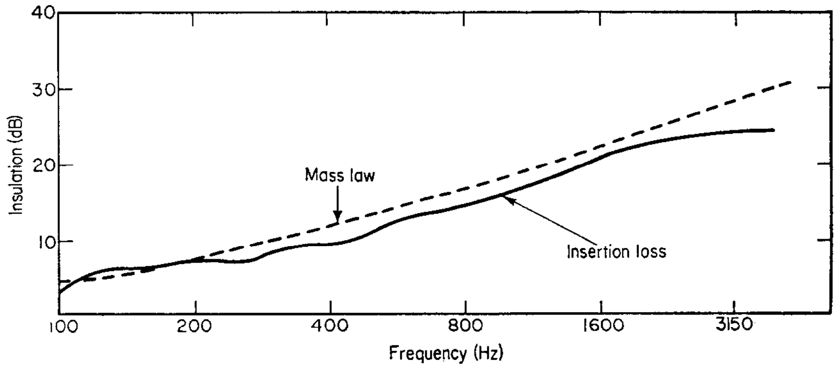

Figure 3. Insertion loss of a 0·035 in. aluminium panel.

4. DISCUSSION

From the measurements of transmission losses of single panels carried out by the author and other workers it is possible to make a number of observations about the curves at low frequencies.

(i) In some facilities the measured transmission loss is above the value predicted by the mass law at low frequencies. It is found that the form of discrepancy is largely independent of the panel material. The shape of the curve at low frequencies does however seem to be a characteristic of the measuring facility used.

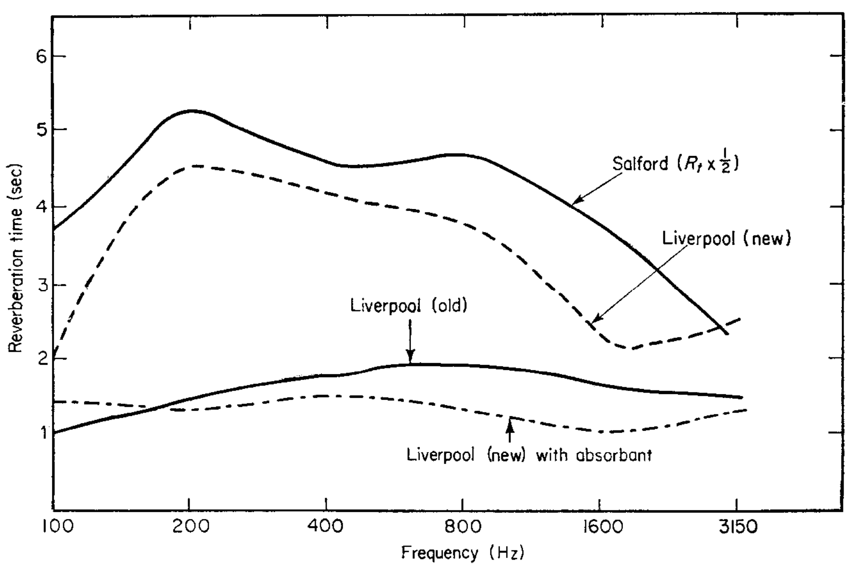

Figure 4. Reverberation times.

(ii) In other facilities good agreement with mass law has been found. Again this seems to be a characteristic of the measuring rooms. There is some evidence that the measured insertion loss gives closer agreement with mass law than does the transmission loss. This latter result might be thought to throw some doubt on the reverberant room method of transmission loss in general and the reverberation time correction in particular, but it was found when the reverberation times of the transmission rooms were changed (as shown in Figure 4) that this made no difference to the measured transmission loss. Despite the variation in times between the facilities there is no correlation between the reverberation time and the discrepancy from mass law.

(iii) The results reported above indicate that when a low frequency discrepancy occurs between the measured transmission loss and the mass law, this discrepancy arises because of some factor connected with the rooms. However, it is found that the more obvious room parameters (Table 1) do not show any correlation with the presence of a discrepancy. It is not possible to say definitely which of the measured transmission losses is the "right" one. It is felt however that the agreement found with the mass law in some facilities must be regarded as significant not only because the discrepancies from the mass law are not of the same form but also because of the close agreement found between the insertion loss and the mass law.

TABLE 1

Details of rooms

Transmission suite	Reception room volume (m^3)	Aperture (m)	Panel mounting	Reverberation time at 200 Hz (sec)	Limiting angle	Discrepancy
Old Liverpool	33	1·65 × 2·11	Eighteen clamps at edges of panel	1·3	82°	No
New Liverpool	75	1·67 × 2·13	As above	4·2	82°	Yes
Salford	224	2·44 × 3·66	Three panels nailed to a wooden frame	10	82°	No

5. CONCLUSION

It has been shown that when the transmission losses of single panels are measured in some facilities there is a difference from the mass law form which depends on the particular transmission loss facility used. It has not been possible to determine which room factor is causing this discrepancy.

Clearly the situation is far from satisfactory particularly when one wishes to compare low frequency results from several facilities. Whilst the problem remains unsolved, the situation may be improved by using more closely standardized transmission suites or by "calibrating" facilities by measuring the transmission loss of a heavy limp panel such as lead.

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