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SOUND TRANSMISSION THROUGH DRY LINED WALLS

R. Wilson and R.J.M. Craik

Heriot-Watt University, Department of Building Engineering and Surveying, Edinburgh, EH14 4AS, UK.

1. INTRODUCTION

Dry lined walls consist of two parallel plates with a cavity between them. One of the plates is thick, dense and rigid (the core wall) and the other plate is thin, light and flexible (the dry lining). Common examples of this form of construction are independent partitions (a core wall with the dry lining fixed to an independent frame), dry lined walls (a core wall with plasterboard fixed to it on plaster dabs or battens) and concrete floors with floating timber walking surfaces. The properties of the core wall and dry lining, the width of the cavity and the nature of the coupling between the two leaves will differ for each example but the basic sound transmission paths through them will be the same.

Statistical Energy Analysis (SEA) provides a flexible framework within which complex structures, such as dry lined walls, can be modelled. It allows individual transmission paths to be studied and the effects of flanking transmission can be included. The results from measurements performed on a dry lined wall built in a transmission suite are compared with predictions from an SEA model. The behaviour of the wall with battens, wall ties and with no structural sound bridges across the cavity is examined.

2. SEA MODEL OF A DRY LINED WALL

The SEA model of a single wall which could be used to predict the performance of either the core wall or the dry lining is shown in Fig 1. It consists of two rooms, subsystems 1 and 3, separated by the wall, subsystem 2. The coupling loss factors (CLFs) necessary to predict the performance of the system are given by Crocker and Price[1]. For a simple model such as this, there are two important transmission paths. One is the resonant path through the wall, path 1-2-3 and the other is the non-resonant path, 1-[2]-3. The square brackets indicate that the transmission is non-resonant. The non-resonant (or mass law) path dominates transmission below critical frequency and the resonant path dominates above critical frequency. For the core wall, which will usually have a low critical frequency, the non-resonant path is only important over a small range of frequencies and the resonant path will dominate the overall performance. The dry lining will tend to have a high critical frequency and so its performance is dominated by the non-resonant path.

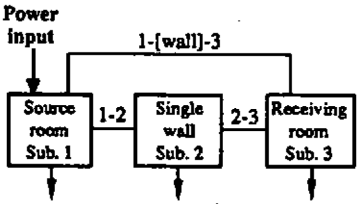

Fig 1. SEA model of a single wall

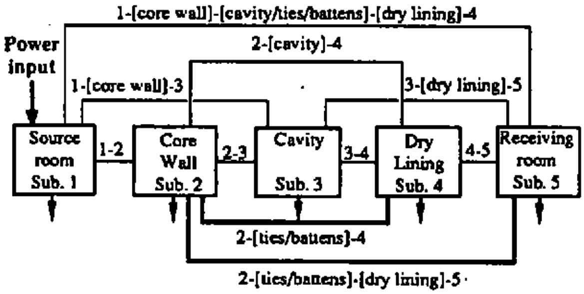

Fig.2 SEA model of a dry lined wall

Fig. 2 is an SEA model for a dry lined wall. Adding a second leaf to the core wall results in a significant increase in the complexity of the wall's behaviour. Expressions for the CLFs between the walls and the cavity are given by Price and Crocker [2]. These differ from the expressions for the coupling between walls and rooms because the cavity is narrow compared with its other two dimensions. For a wide range of frequencies, therefore, it will support modes in only two directions and so can not be modelled as a room. In addition to the coupling with the cavity modes, the air in the cavity can connect the two leaves of the wall by behaving like a spring. In this mechanism, particle motion is normal to the wall surface and the cavity behaves non-resonantly (response is not affected by cavity damping). An approximate method for modelling this is to assume that the stiffness can be concentrated at a single point and use an expression for wall tie coupling [3].

3. THE TEST WALL

A horizontal section through the dry lined wall on which the measurements were performed, is shown in Fig 3.

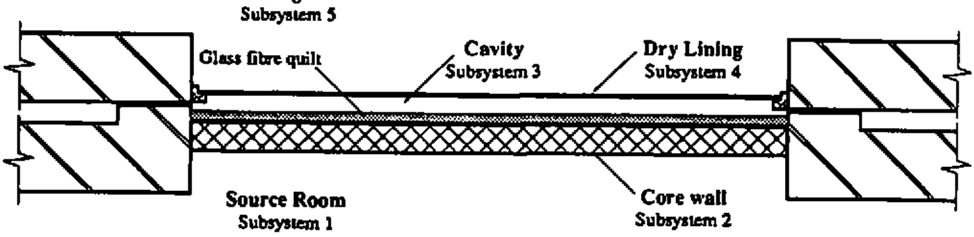

Fig. 3 Horizontal section through a dry lined wall.

It consisted of a core wall built from 100 mm thick concrete blocks (density = 2010 kg/m^3, critical frequency = 297 Hz) and a 6 mm thick plywood dry lining (density = 667 kg/m^3, critical frequency = 3507 Hz). These were 4 x 3 m in size and separated by a 100 mm wide cavity containing a 35 mm glass fibre quilt tacked to the surface of the core wall. The two leaves of the wall were structurally isolated from each other by building each leaf in a separate chamber of a transmission suite.

Measurements of the airborne level difference (standardised to T_{60} = 0.5 s) were made for the wall were the two leaves were coupled only by the air in the cavity. Measurements were repeated with steel wall ties bridging the cavity and with timber battens bridging the cavity.

4. PERFORMANCE OF A DRY LINED WALL WITH NO STRUCTURAL SOUND BRIDGES

The measured and predicted airborne level difference for the dry lined wall with no sound bridges is shown in Fig. 4 together with the results for the core wall tested on its own. The addition of the dry lining to the core wall has resulted in a significant improvement in the sound insulation at all but the lowest frequencies. At very low frequencies the air in the cavity is very stiff and the two leaves of the wall will have the same velocity[4]. In this frequency region the addition of the dry lining to the core wall would not result in any significant increase in sound insulation.

The mass-spring-mass (MSM) frequency, f_o, for a double wall where one leaf is significantly heavier than the other, is given by,

$$f_o = \frac{1900}{\sqrt{\rho_s \, d}} \tag{1}$$

where d is the cavity width in mm and ρ_s is the surface density of the dry lining. In the region of the MSM resonance, the increased response of the structure due to the resonance results in greater transmission and the performance of the dry lined wall is usually worse than that of the core wall when tested on its own. For the wall tested, the MSM resonance was predicted at 95 Hz and the figure shows that in this frequency region the performance of the dry lined wall is worse than that of the core wall. Above the MSM resonance, the two leaves become decoupled and the addition of the dry lining results in an improvement in the sound insulation, up to 30 dB for the wall tested.

The predicted results for the walls are also shown on the figure. The single wall prediction was obtained using the SEA model shown in Fig. 1 and the dry lined wall predictions using the model in Fig. 2. In addition to the subsystems shown in Figs 1 and 2, the structure of the transmission suite was also included in the model to account for flanking transmission. Measured values of absorption coefficient for the materials in the cavity were used to obtain the cavity damping.

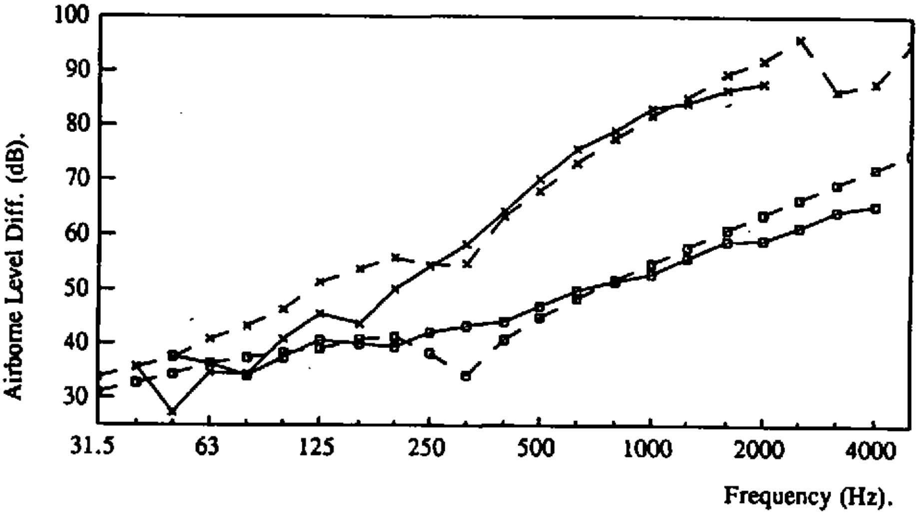

Fig. 4 Measured and predicted airborne level difference for a dry lined wall with no wall ties. —×—, Dry lined wall (measured); ---×---, dry lined wall (predicted); —□—, core wall (measured); ---□---, core wall (predicted).

In general the agreement between the measured and predicted curves is good, especially above the critical frequency of the core wall. Below 95 Hz the dry lined wall behaves like a single wall and the SEA model in Fig. 2, which models it as two subsystems, is inappropriate. As the mass of the dry lining is negligible compared with the core wall, the behaviour of the dry lined wall may be approximated by the core wall in this frequency region. There is a small region, between the MSM frequency and the critical frequency of the core wall, where the agreement is poor.

In addition to predicting the overall performance of the dry lined wall, it is also possible to predict the relative importance of the different transmission paths through wall and hence identify which are of importance. Between the MSM resonance and the critical frequency of the dry lining, the dominant path is 1-2-3-[4]-5. This involves (for the direction of transmission in which the tests were performed), resonant transmission from the source room into the cavity by the core wall. Transmission then occurs from the cavity to the receiving room via the dry lining by a non-resonant (mass law) mechanism. Above the critical frequency of the dry lining the resonant path 1-2-3-4-5 dominates the wall's performance.

5. PERFORMANCE OF A DRY LINED WALL WITH STRUCTURAL SOUND BRIDGES

In addition to testing the wall with no structural coupling across the cavity, tests were also made with point sound bridges (steel wall ties) and line sound bridges (timber battens). These create additional transmission paths between the core wall and the dry lining and are shown as bold lines in the SEA model in Fig. 2. As the bridges are relatively short, they can be modelled as stiffnesses, making their behaviour non-resonant. From a knowledge of the impedances of the leaves of the walls and the sound bridge, the CLF for transmission across the bridges can be determined[3]. There will also be nearfield radiation from the region on the dry lining around the sound bridge, path 1-2-[ties/battens]-[4]-5, which effectively couples the core wall directly to the receiving room. If it is assumed that the bridge is rigid and that the mass and stiffness of the dry lining are negligible compared with those of the core wall, the velocity on the dry lining in the region of the sound bridge will equal the velocity of the core wall. From the expressions for the power radiated by point and line sound bridges in Cremer *et al*[4], the CLF for point bridges can be given by,

$$\eta_{25} = R\,\frac{4\rho_o c_o^3}{\pi^4 f_c^2 f S_2 \rho_{s2}} \tag{2}$$

where R is the total number of connections, f_c is the critical frequency of the dry lining and S_2 and ρ_{s2} are the surface area and surface density of the core wall respectively. For line bridges the CLF is,

$$\eta_{25} = L_b\,\frac{\rho_o c_o^3}{\pi^2 f_c^2 f S_2 \rho_{s2}} \tag{3}$$

where L_b is the length of the sound bridge.

The addition of wall ties (threaded steel rods with a diameter of 7 mm) bridging the cavity of the dry lined wall had a significant effect on the wall's structural performance, the velocity level of the dry lining increasing by 3 dB each time the number of ties was doubled. The lining, however, does not radiate efficiently so that the increased response due to the ties had a negligible effect on the airborne performance as shown in Fig. 5. The predicted results for the wall with 0, and 4 ties are also plotted on the figure. The effect of the wall ties on the airborne results is negligible because the path via the cavity, path 1-2-3-[4]-5, dominates the wall's performance and this is much stronger than any of the paths involving the wall ties ie. path 1-2-[ties]-4-5 and path 1-2-[ties]-[4]-5.

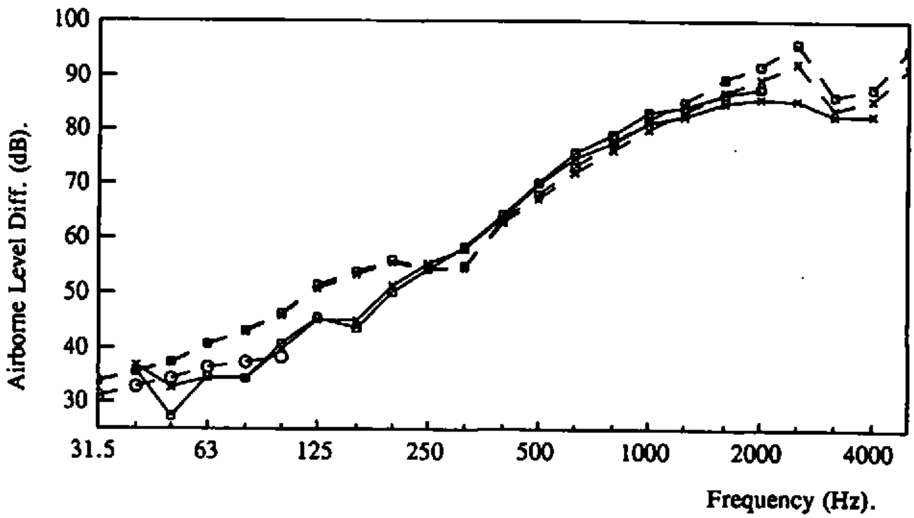

Fig. 5 Measured and predicted airborne level difference for a dry lined wall with point bridges. —×—, Dry lined wall with four wall ties (measured); ---×---, dry lined wall with four wall ties (predicted); —□—, dry lined wall with no wall ties (measured); ---□---, dry lined wall with no wall ties (predicted); ---O---, core wall (predicted).

The measured and predicted airborne performance of the wall with 4 timber battens (each of length 2 m) is shown in Fig. 6. The battens result in a significant reduction in the airborne level difference, this dropping by between 10 and 15 dB. A study of the transmission paths showed that the non-resonant path 1-[2]-3-[4]-5 dominated transmission between the MSM resonance and the critical frequency of the core wall. Between the critical frequencies of the core wall and the dry lining transmission is dominated by nearfield radiation from the dry lining, a finding in agreement with the results of Cremer *et al*[4], Above this frequency region, the resonant path 1-2-3-4-5 dominates transmission.

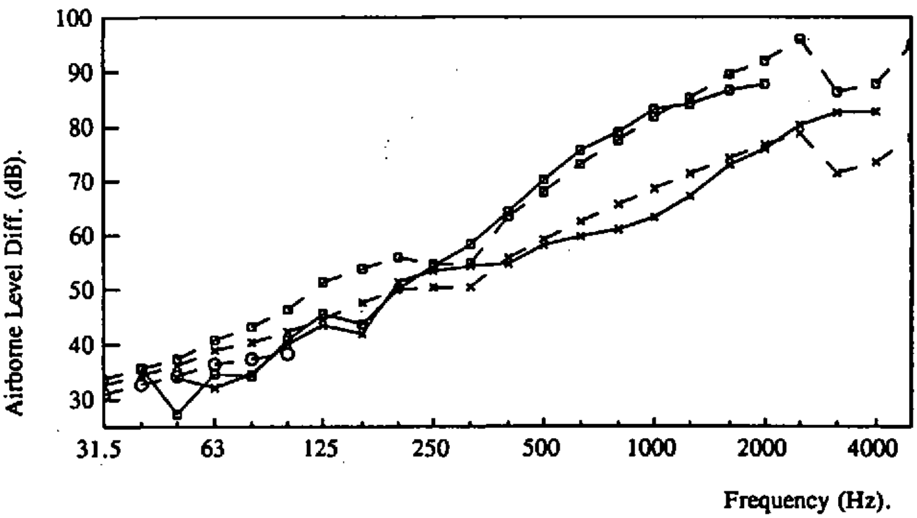

Fig. 6 Measured and predicted airborne sound transmission through a dry lined wall attached by battens. Dry lined wall with four battens (measured); —×—, dry lined wall with four battens (predicted); —□—, dry lined wall with no wall ties (measured); ---□—, dry lined wall with no wall ties (predicted); —O—, core wall (predicted).

6. DISCUSSION

The wall tested in this paper is similar to an independent partition, a double wall where the dry lining is built onto a frame which is decoupled from the surface of the core wall and where the cavity is relatively wide. The important transmission paths and the frequency ranges over which they dominate transmission will probably, therefore, be similar.

Where the dry lining is fixed to the core wall on battens or plaster dabs, the cavity will be narrow, consequently the frequency at which the MSM resonance occurs will rise for this type of construction and may fall in the building acoustics range of frequencies. Nearfield radiation from the regions around the sound bridges on the dry lining will be an important transmission path.

For a concrete floor with a timber walking surface it is common to isolate the timber battens from the concrete structural floor using a resilient quilt. The addition of the resilient layer reduces the transmission of sound through the floor by reducing the strength of the path involving nearfield radiation and reducing the structural coupling. The improvement in airborne performance that can be achieved by increasing the resilience of the layer beneath the batten is, however, limited. As the strength of the nearfield path diminishes, the path involving non-resonant (mass law) transmission through the flooring 5-[4]-3-2-1, will begin to dominate. Changes to improve the isolation between the flooring and the structural floor via the batten will, therefore, have no further effect on the airborne performance of the floor.

7. CONCLUSIONS

The wall described in this paper had two leaves with very different properties. The performance of the core wall is dominated by resonant transmission and that of the dry lining is dominated by non-resonant (mass law) transmission. This affects the way in which a dry lined wall made from these two components will behave. The dominant transmission path through the dry lined wall with no sound bridges involved resonant transmission from the source room to the cavity by the core wall and non-resonant (mass law) transmission from the cavity to the receiving room through the dry lining.

The addition of ties and battens forms structural sound bridges across the cavity and can result in significant increases in the sound transmitted between the two leaves of the wall. Only the addition of battens, however, had any significant impact on the airborne performance of the test wall. The dominant transmission path for this form of construction involved non-resonant transmission from the nearfield on the dry lining in the vicinity of the sound bridge.

The use of SEA to analyse the behaviour of complex systems allows the overall performance to be predicted whilst still allowing the performance of individual transmission paths to be studied. The use of SEA has the additional advantage that the effects of flanking transmission may be included.

8. REFERENCES

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9. ACKNOWLEDGEMENTS

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