On Structureborne Power Flow from Wood Studs to Direct-Attached Gypsum Board

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1. INTRODUCTION

This paper, the second of two [1], examines the effect of screw location and number on the power flow from a wood stud to directly attached gypsum board. It is necessary to evaluate how an offset distance between the point of an applied force and the fastening point affects the power transmitted from the stud to the gypsum board because if the wall has resilient channels drive points and fastening points will not be aligned. Earlier studies had always considered that the points would be aligned [2].

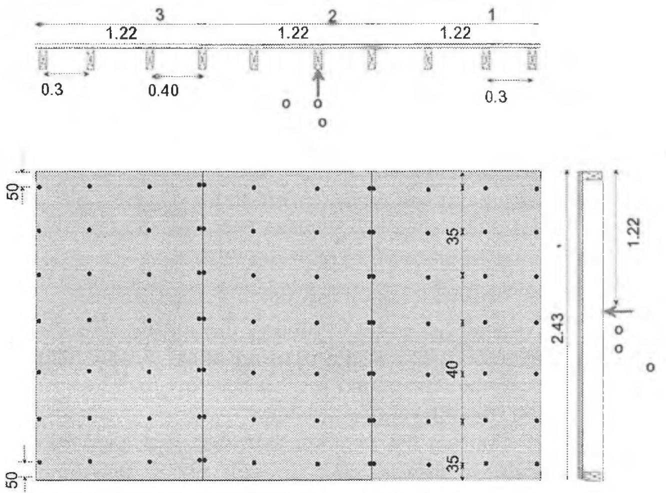

Figure 1: Sketch of the construction under investigation.

Figure 1 shows that the wall evaluated in this paper consists of a single layer of 16 mm Type X gypsum board attached to 35 x 85 mm clear western red cedar studs, spaced 406 mm on centre. A single point force was applied to one of the studs. The number and the location of the screws securing the gypsum board to the excited stud were systematically changed and the transmitted power evaluated.

2. E ALUATION METHOD

It is not practical to measure the power transmitted by a junction directly – indirect evaluation is necessary. Statistical energy analysis (SEA) may be used if both of the connected elements satisfy the conditions of a subsystem – modes are spaced equally in the frequency band and create a uniform energy density proportional to the damping. This allows one to write,

$$\mathrm{VLD}_{12,\mathrm{SEA}} = 10\,log\left(\frac{m_2}{m_1}\frac{\eta_2}{W_{12}}\frac{E_1}{\omega}\right) \tag{1}$$

where subscript 1 indicates source, 2 receiver, and m is mass, W is transmitted power, E is energy, and ω is angular frequency. The equation shows the measured VLD is inversely proportional to the transmitted power, W_{12}, and proportional to the energy contained in the source subsystem, E_1. This approach will be used in this paper. Mobility models are used to obtain an expression for the transmitted power, W_{12}.

To accurately evaluate the power flow it is necessary to determine what elements of the wall form the source and receive subsystems. The source subsystem is the excited stud. The receiving subsystem is more complicated because it may be one or all three sheets of gypsum board. To define the receiving subsystem the vibration level of the gypsum board was measured using a scanning laser vibrometer

Figure 2 shows that at 315 Hz the energy level of plate 2 is significantly greater than that of plates 1 and 3, which are not directly attached to the excited stud. The same trend is exhibited for frequencies above 250 Hz. Below this frequency the vibration levels are significantly more uniform and at about 80 Hz modal patterns are clearly evident. Thus, for 250 Hz and above the receiving subsystem is effectively that of gypsum board plate 2, while below this frequency it would be best to treat the receiving subsystem as being all three gypsum board sheets plus all studs except for the excited one.

The VLD between the excited stud and plate 2 of the gypsum board is used to gage the power flow through the screws.

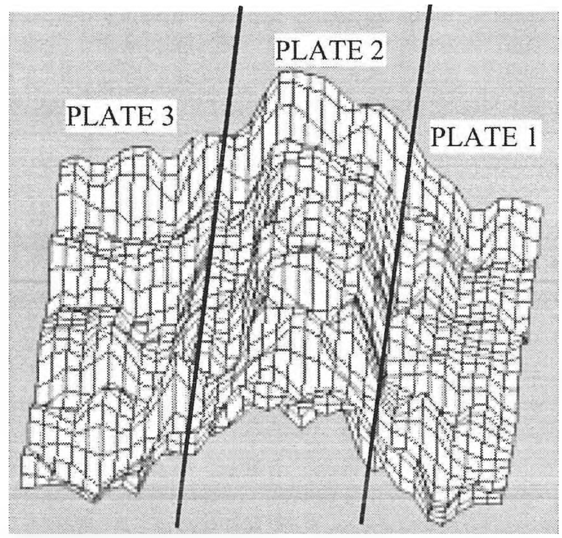

Figure 2: Surface velocity map of the gypsum board at 315 Hz when excited by the single stud shown in Figure 1. Plate 2, which is excited by the stud, is clearly identifiable by the higher levels.

3. EFFECT OF SCREW LOCATION AND NUMBER

It is has been assumed that the transmitted power is proportional to the number of screws [2]. This implies two things. First, the VLD for a single screw will be independent of screw location. Second, when there are two or more screws, the motion of each is incoherent. Figure 3 clearly shows that with the screw at location "D" (immediately opposite from the source) there is significantly lower VLD (hence significantly more transmitted power) than any other position. VLD ranking indicates less power is transmitted as the fastening point is moved away from the source.

To explain this it is necessary to examine equation 1 and vibration level of the stud in more detail. If the stud were an ideal subsystem, the energy, E_1, would be spatially uniform, but highly damped systems, or ones with low mode counts, can give rise to localized energy and the space average result may not be meaningful when there are one or a few point connections.

Figure 4 shows the measured VLD for screw locations B, C, D and E when the energy of the stud near the screw is normalized to a common level. There is considerably better agreement between the sets of data indicating that at points B, C, D and E the ratio of energy, E_1, to transmitted power, W_{12}, is resasonably invariant.

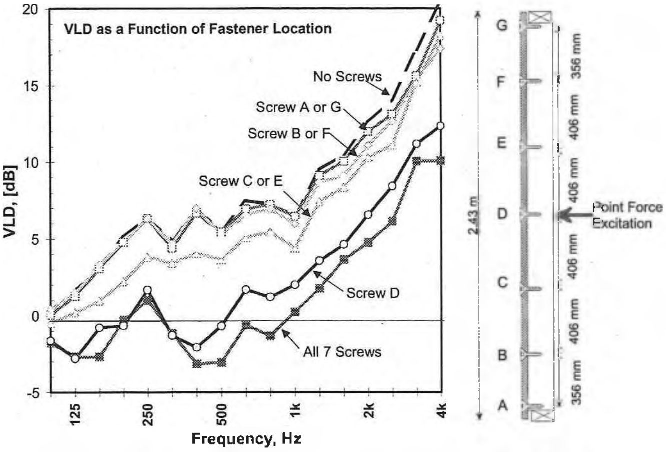

Figure 3: VLD as a function of the location of a single screw attaching the gypsum board to the excited stud Also shown are the cases with all 7 screws installed and the case with no screws.

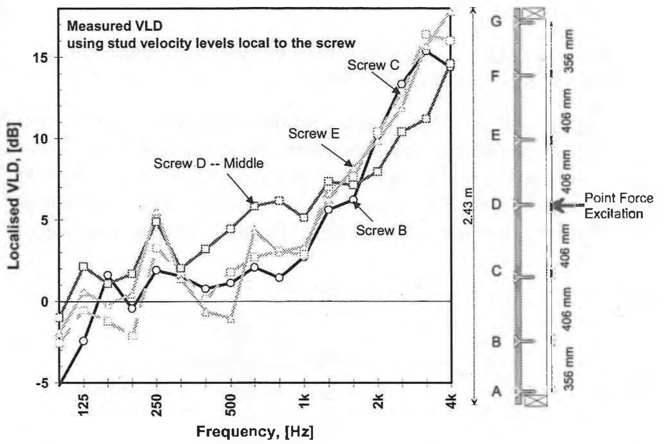

Figure 4: VLD as a function of the location of a single screw. VLD's computed using stud velocity levels local to points of fastening rather than the space-averaged results used in Figure 3.

It is important to note that the VLD (of Figure 3) does not become very large when there are no screws even though the head and sole plates of the wall are cut on either side of the excited stud. This suggests that although there are no screws there may still be points where the stud and gypsum board touch and transmit power although less effectively than if there were a screw. This prevents evaluation of points A, F, and G. However, the mobilities at all seven of the screw locations were similar which would suggest that for these points the ratio of energy to transmitted power should be invariant, too.

Having demonstrated that if the energy of the stud is spatially uniform then the transmitted power is reasonably independent of location the next step is to evaluate the assumption that the total power transmitted is proportional to the number of screws. This has been previously observed [2] for all frequencies for which the bending wavelength in the gypsum board (the least stiff element) is less than twice the screw spacing.

Figure 5 shows the measured change in VLD due to removing four (F, E, D and B) of the seven screws. Assuming the stud energy is uniform, the VLD should increase by 10log(7/3) or 3.7 dB. Inspection of Figure 3 and Figure 4 as well as inspection of the stud velocity levels indicates that of the three points A, D and G, only D contributes significantly. Similarly, only E, D, and C contribute significantly when all seven screws are installed. Thus, the predicted change in VLD will be approximately 10log(3/1) or 5.1 dB. Figure 5 shows there is good agreement for frequencies above about 160 Hz. Below 160 Hz one should not expect good agreement because the stud and gypsum board will be effectively line-connected because the bending wavelength in the gypsum board is more than twice the screw spacing (406 mm).

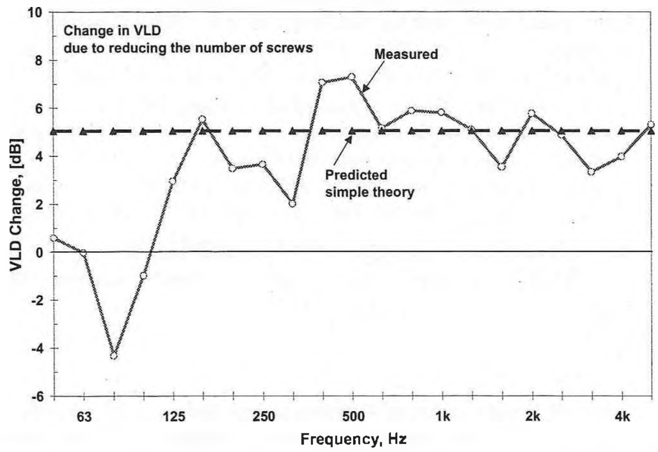

Figure 5: Change in VLD due to reducing the effective number of screws from 3 to 1.

4. DISCUSSION AND CONCLUSIONS

This paper has shown that a wall consisting of a single layer of gypsum board attached to a single row of wood studs acts as one or more subsystems depending on frequency. Above about 250 Hz, there are three subsystems. The ratio of transmitted power to source (stud) energy is reasonably independent of screw location, which is to be expected as the measured mobilities do not change appreciably if the distance from the edge was greater than 50 mm.

Because the stud is highly damped and has low modal density (i.e., poor subsystem approximation) the energy will not be uniform and the power flow will not be the same at all points. Having only one drive point (point source) represents an extreme case but illustrates the need to recognise that there will be less power transmitted by screws far from the source. Consequently, it may be necessary to include the effect of near field vibration levels in the models.

5. REFERENCES

1 T.R.T. Nightingale, Katrin Kohler, (2003), Canadian Acoustics, Vol. 31(3).

2 R.J.M. Craik, R.S. Smith, (2000) "Sound transmission through lightweight parallel plates," Applied Acoustics, Vol. 61, pp. 247-269.