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ON TRANSMISSION OF STRUCTURE BORNE POWER FROM WOOD STUDS TO GYPSUM BOARD MOUNTED ON RESILIENT METAL CHANNELS – PART 1: FORCE AND MOMENT TRANSMISSION

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1. INTRODUCTION

A systematic study [1], recently conducted at the NRC has verified most of the fundamental assumptions made when using the mobility approach for direct attached gypsum board. These assumptions need to be verified for the more complex and practical situation of gypsum board mounted on resilient channels (RC's). This paper, the first of two, examines assumptions relating to power flow as a function of position and number of fasteners between the gypsum board and RC's. Also considered is if the power transmitted by a rotational component of the stud is negligible compared the translational component. The second paper [2] examines further assumptions and gives estimates of the change in radiation efficiency and acoustic power due to adding RC's.

2. SPECIMEN AND EVALUATING TRANSMISSION

Figure 1 shows the wall evaluated consists of a single sheet of 16 mm Type X gypsum board attached to one, or more, rows of resilient metal channels, RC's. These are attached to 35 x 85 mm clear western red cedar studs, spaced nominally 406 mm on centre. A single point force was applied to one of the studs.

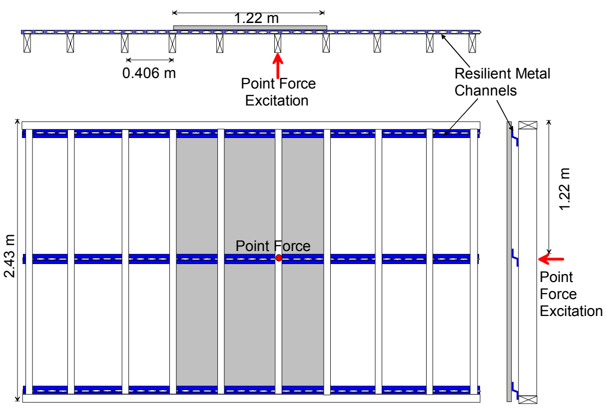

Figure 1: Sketch showing wall framing and the single sheet of gypsum board mounted on RC's.

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

$$\eta_{12} = \left(\frac{W_{12}}{E_1\omega}\right) = \left(\frac{m_2}{m_1}\eta_2\left(\frac{\langle v_1^2\rangle}{\langle v_2^2\rangle}\right)\right)^{-1} \qquad (1)$$

where subscript 1 indicates source, 2 receiver, W is transmitted power, E is energy, and ω is angular frequency, m is mass, η_2 is the total loss factor (TLF) of the gypsum board and $<V^2>$is space averaged RMS velocity. Because the mass of the stud and gypsum board are constant, the measured velocity ratio $<V_1^2>/<V_2^2>$ is proportional to the ratio of E_1/W_{12} or inversely proportional to the ratio of gypsum board TLF and the coupling loss factor (CLF), η_{12}, between the stud and gypsum board.

This paper uses a CLF to describe the power flow from the stud to the gypsum board, which will be expressed in dB and can be thought of as being the fraction of the stud energy transmitted to the gypsum board in one cycle. Measurements of the velocity ratio are obtained from differences in the space average stud level (sampled using 14 points) and the gypsum board level (sampled using 98 points).

3. TRANSLATION AND ROTATION DISPLACEMENT

In theory, a point force applied to the neutral axis of a homogenous isotropic beam will cause only pure translation (displacement in the direction of the applied force). Wood studs are not homogeneous and isotropic so there will be both translation parallel to the force and rotation about an effective centre of mass. Structure borne transmission for both types of motion are shown in Figure 2 and must be evaluated because both will transmit power.

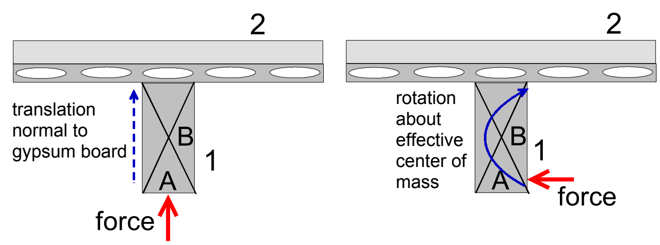

Figure 2: Locations of the point force applied to the stud to induce translation (left) and rotation (right). The stud is labelled 1 with its faces A and B. The gypsum board is labelled 2.

For each source location the velocity was measured at 14 positions on faces A and B along a line that passed through the applied force. Also, the resulting gypsum board velocity was measured. The measurements gave a set of two simultaneous equations from which the CLF for the two types of motion can be determined.

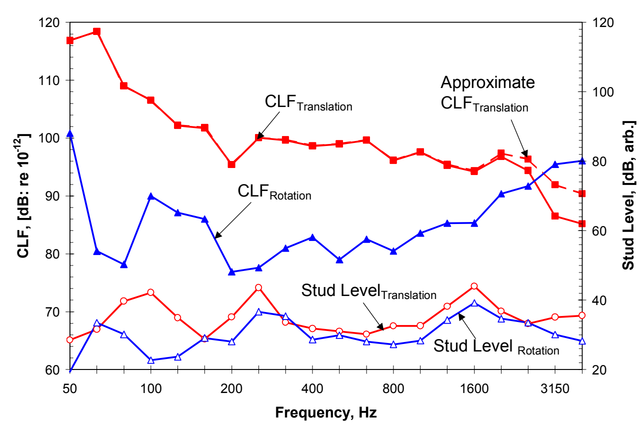

Figure 3: Measured $CLF_{Translation}$ and $CLF_{Rotation}$. Also given is the Approximate-$CLF_{Translation}$ obtained assuming rotation transmission is negligible. Stud velocity levels due to a point force applied to face A of the stud are shown on a separate axis.

Figure 3 shows that below 2500 Hz, the CLF is considerably greater (i.e., more power is transmitted) for stud translation than for rotation. Above this frequency more power is transmitted by rotation. Figure 3 also shows the average stud levels on faces A and B when a point force on face A excites the stud. Since the velocity due to rotation is less than translation it is possible to state that for frequencies less than 2500 Hz power transmission due to rotation will be less than translation when the stud of Figure 2 (left) is excited on face A by a force normal to the gypsum board. The figure also shows that the Approximate $CLF_{Translation}$ (obtained by exciting the stud on face A and collecting the resulting space average stud velocity on face A and gypsum board velocity) is an excellent approximation for frequencies below 3150 Hz. Henceforth, in this paper and in Part 2 we will use the Approximate $CLF_{Translation}$ and simply call it CLF, recognising that above 2500 Hz the value will be an overestimation for pure translation.

4. FASTENERS BETWEEN GYPSUM BOARD AND RC'S

To determine if location and number of fasteners attaching the gypsum board to the RC's are factors in determining power transmission, fasteners were systematically installed in all five columns, one column at time, as shown by the insert in Figure 4. Three resilient channels were installed.

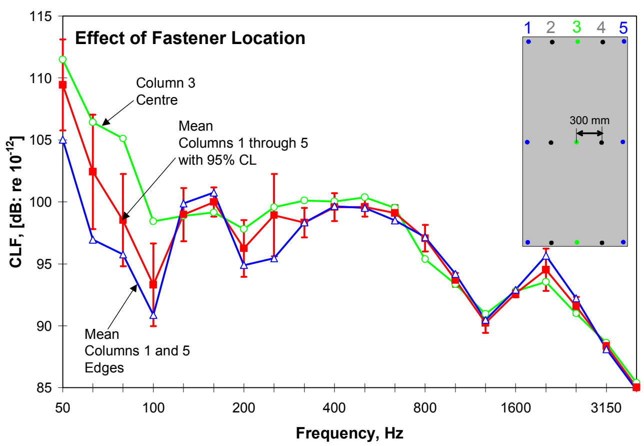

Figure 4: Sensitivity of CLF to location of fasteners attaching the gypsum board to RC's. Insert shows location of the five columns.

Comparing the CLF's it is clear that below 125 Hz the strongest transmission occurs at column 3 (near the gypsum board centre and excited stud). While, the weakest coupling is at columns 1 and 5 (near the edges of the gypsum board). Above 250 Hz there is very little effect associated with a change in fastener location. Thus, fastener location would not have to be modelled explicitly for this frequency range. However, below 250 Hz, assuming that all positions could be represented by a mean CLF could sometimes underestimate or overestimate by about 8 dB. Although, on average the estimate would be correct.

A measurement series investigated increasing the number of fasteners attaching the gypsum board to the RC's, from 1 to 5. Figure 5 shows the results for two different channel configurations. For both, the change in CLF above 315 Hz is considerably less than 7 dB (10log(5)) expected from simple theory. Below 315 Hz, simple theory based on incoherent motion at the fastener reasonably approximates the change.

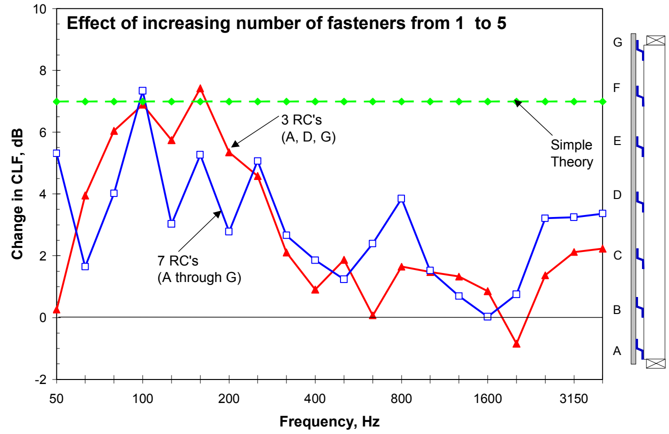

Figure 5: Change in CLF due to increasing the number of fasteners from 1 (located at column 3) to 5 in each RC with three and seven RC's installed.

5. DISCUSSION AND CONCLUSIONS

This paper has shown that typically studs will have both a rotational and translation motion, but that with RC's the translation displacement (normal to the gypsum board) couples more strongly than rotation. For practical purposes if the rotation velocity is less than or equal to the translation velocity, then structure borne transmission due to the rotation component can be ignored for frequencies below about 2500 Hz.

Results showed that above about 315 Hz there is little effect associated with either the location or the number of fasteners attaching the gypsum board to the RC's. However, below this frequency there is a rather significant effect associated with both the number and location. This is somewhat surprising as it is the opposite of what was observed for direct attached gypsum board [1]. The cause was not examined in detail because this is a preliminary study. However, it is speculated that in the high frequencies the RC's are sufficiently stiff that vibration levels are reasonably uniform with distance along the RC and that a series of ill-defined contact points exist so that adding fasteners or changing their location does not have a significant effect. But in the low and mid frequencies there is a complex modal interaction between the studs and the RC's that span the width of the wall, such that the vibration level of the RC varies significantly with distance away from the excited stud. As shown in Part 2 of this paper [2] the system becomes more complicated and the CLF is more sensitive to physical changes in the low frequencies because of a very low mode count.

A detailed examination of the sensitivity of the number and location of fasteners between the gypsum board and RC's is suggested for future work.

6. REFERENCES

1 T.R.T. Nightingale, Katrin Kohler, Jens Rohlfing (2004), "On predicting structure borne sound transmission from wood stud to direct-attached gypsum board," Proceedings of ICA 2004, Kyoto Japan, April 5-9.

2 Andreas Mayr, T.R.T. Nightingale, (2004), "On transmission of structure borne power from wood studs to gypsum board mounted on resilient metal channels – Part 2: Some simplifications for modelling", Canadian Acoustics, Vol. 32(3).