SHEAR MEMBRANES IN WOOD FRAME PARTY WALLS

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1. Introduction

On a recent project, Brown Strachan had recommended a standard party wall construction consisting of 2 x 6 wood studs @ 16" o.c., separated by a 1" air space, with fibreglass batt insulation in the stud cavities, and one layer of 5/8" gypsum wall board (gwb) on each outside face. This wall has a typical sound transmission class rating of STC 57.

Late in the design stage, however, the structural consultant added a requirement for 1/2" plywood on both inside faces of some walls. The plate spacing was increased to maintain a 1" clear space between the two inside plywood faces. A Gypsum Association test shows STC 57 with 1/2" Type X gwb on the inside face of studs @ 24" o.c. On the basis of this test, the architects concluded that the change was acceptable, as the Code required a STC 50 rating.

Geiger & Hamme had tested a similar wall consisting of 5/8" drywall on the inside of studs spaced 16" o.c., and obtained a rating of STC 45. Obviously, the bending stiffness of the inside face had a major effect on the net stiffness of the air trapped between the two inside layers, spaced 1" apart. Plywood is about eight times as stiff as gwb, and since the stiffness of the inside plate is the key factor in determining the stiffness of the air, a problem was clearly indicated.

Potential treatment options included resilient channel, extra layers of drywall, and holes in the plywood membrane which would act to vent air in the 1" airspace to the fibreglass filled stud cavity. A mathematical model was used to study the effects of the various treatment options, and field measurements were made to determine the treatment results.

2. Modelling

The frequency region of concern lies between 80 Hz and 250 Hz, well below the coincidence frequencies of the plywood and drywall surfaces. For this reason, it was felt that an analysis of the forced wave transmission loss, considering the net volume displacements of a representative stud section, should provide a useful indication of the wall motions.

Initially, the assumption was made that the studs would remain effectively motionless, relative to the drywall and plywood motion between the studs. Although stud motion had been included to allow coupling, the effect of the stud motion coupling to the other motions via the stiffness of the air space had not been considered. This led to poor agreement between predictions and measurements, to be discussed below.

Eventually, ten degrees-of-freedom were defined: four describing the motion of each of the four plates at a point centred between the studs, four describing the plate motion at the studs, and two describing the motion of air in holes drilled in the inner shear membranes. The plate motion was considered to be the sum of a sine term, with zero motion at the studs and maximum motion at the plate centre, plus a cosine term, with maximum motion at the studs and zero motion at mid-plate.

An evanescent term could have been introduced to match a clamped-clamped edge condition, but a simply supported mode shape was assumed. Appropriate adjustments to the plate bending stiffness were made in consideration of a clamped-clamped condition. For forced radiation, the effective volume displacements may be out by about 20%, or less than two decibels.

If a high plate stiffness is assumed, the model degenerates to mass law transmission, and we obtain standard mass law transmission loss below the mass-air-mass resonance. There is a five decibel reduction in reverberant transmission loss, relative to normal incidence transmission loss. For simplicity, this has been approximated by the transmission loss at 60°, with a six decibel reduction relative to normal incidence. As the model operates well below coincidence, this is considered a reasonable approximation.

To summarize, the model has a diagonal mass matrix and a fairly full stiffness matrix. This stiffness matrix includes both bending stiffnesses and air stiffnesses, expressed as equivalent volume stiffnesses per square meter. Damping terms are included as complex stiffness moduli.

At low frequencies, as discussed earlier, only a forced wave was considered, with radiation proportional to the square of the volume displacement. Thus, we have the condition that sine squared plus cosine squared equals one, and we have uniform radiation for a homogeneous plate.

3. Recommendations and Results

Early discussions regarding potential wall modifications to meet the STC 50 Code requirement focused primarily on venting the air in the 1" airspace by means of drilling holes in one of the two shear membranes. To reduce the stiffness of the airspace in the critical 80 Hz to 250 Hz region, a hole with a Helmholtz resonance of approximately 300 Hz was recommended. This corresponded to 4" holes @ 16" o.c. This should have allowed air to vent into the stud cavity and thus provide an improvement of about 10 decibels at 125 Hz, as the stiffness would have been reduced to one third of its original value. Figure 1 shows transmission loss results predicted using the mathematical model. Notably, transmission loss at 160 Hz increases with 4" holes drilled in one shear membrane.

The predicted improvement in transmission loss was not observed in field measurements. Figure 2 shows field measurement results for the tests described. As indicated in Figure 2, this wall construction received a STC 39 rating, limited in the 125 Hz and 160 Hz third octave bands. It was found that the flow resistance of the fibreglass at the hole was significant, relative to the inertia of the air in the hole. Once this was recognized, the model was modified to consider fibreglass resistance.

To reduce flow resistance at the hole, still larger diameter holes were recommended. As 8" diameter holes were unacceptable to the structural consultant, a wall with 4" holes in one shear membrane and 6" holes in the second membrane was tested. This test obtained a STC 50 rating, but indicated that a substantial open area would be required. As the costs associated with such an extensive amount of drilling proved prohibitive, alternate treatments were studied.

Evaluation of a wall system with no coupling between the studs and drywall indicated that significant improvement should be obtained by using very flexible resilient channel. It was therefore recommended that a wall using the most flexible resilient channel available be tested. A wall with resilient channel on one side and one layer of drywall on each side obtained a STC 48 rating.

A subsequent test of a wall with two layers of gwb on resilient channel received a STC 50 rating. The use of two layers of gwb was thought to raise the "beam" resonant frequency of the drywall on a 14.4" "span", to the extent that the drywall and stud motions remain in phase, thus adding to the effective net inertia at the stud. This effect would lower the low frequency mass-air-mass resonant frequency, a resonance which was considered the major contributor to the poor performance in the 125 Hz and 160 Hz third octave bands. The tested wall did have 4" holes drilled in one side of the shear membrane but as discussed above, the 4" holes proved to be ineffective because of high flow resistance. In fact, tests of wall systems that only differ in that one wall has 4" holes drilled in a shear membrane and one does not have received STC ratings differing by only one point.

One final assembly tested consisted of a wall with a single layer of drywall and resilient channel on each side. This wall received a STC 48 rating. This rating was partially attributed to the inadvertent use of "standard" resilient channel, rather than the more flexible channel recommended. In fact, site coordination problems such as this highlighted the need for the simplest possible remedial action.

4. Conclusions

The behaviour of a standard double stud party wall below 300 Hz may be adequately modelled as a ten degrees-of-freedom system. Consideration of the net volume displacements of a typical stud section provided useful indications of wall motions.

There are treatments available to minimize the degradation in noise isolation that occurs in standard double stud party walls when shear membranes are applied to the interior of the studs. Venting of the encapsulated air space by means of holes in the shear membrane can be effective providing that the holes are large enough to overcome the flow resistance of insulation adjacent to the holes. Alternately, resilient channel and extra layers of drywall may be added to the wall to bring STC ratings up to minimum Code requirements.

5. References

Beranek, L. L. and Vér, I. L. (1992), *Noise and Vibration Control Engineering*, John Wiley & Sons, Inc., New York.

DuPree, R. B. (1981), *Catalog of STC and IIC Ratings for Wall and Floor/ Ceiling Assemblies With TL and ISPL Data Plots*, Office of Noise Control, California Department of Health Services, California

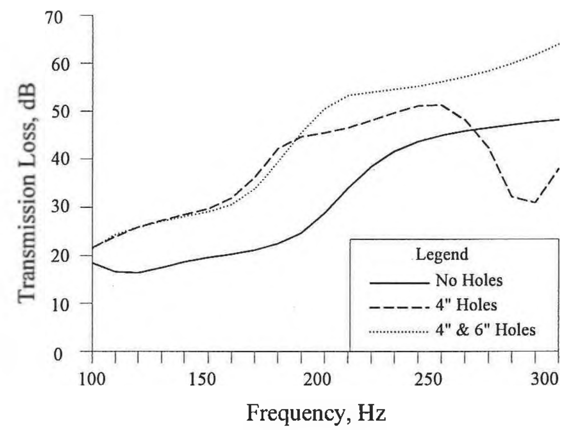

Figure 1: Predicted Transmission Loss of Various Wall Constructions

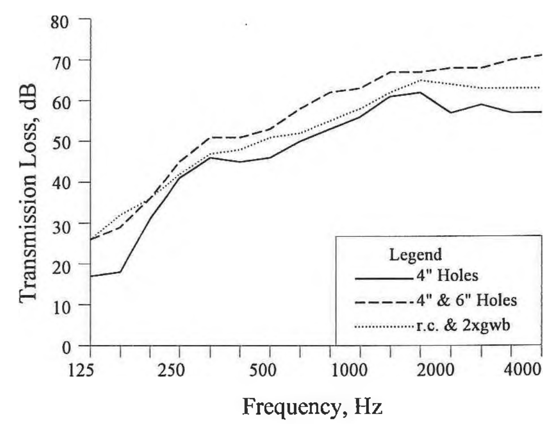

Figure 2: Field Transmission Loss Test Results for Various Wall Constructions