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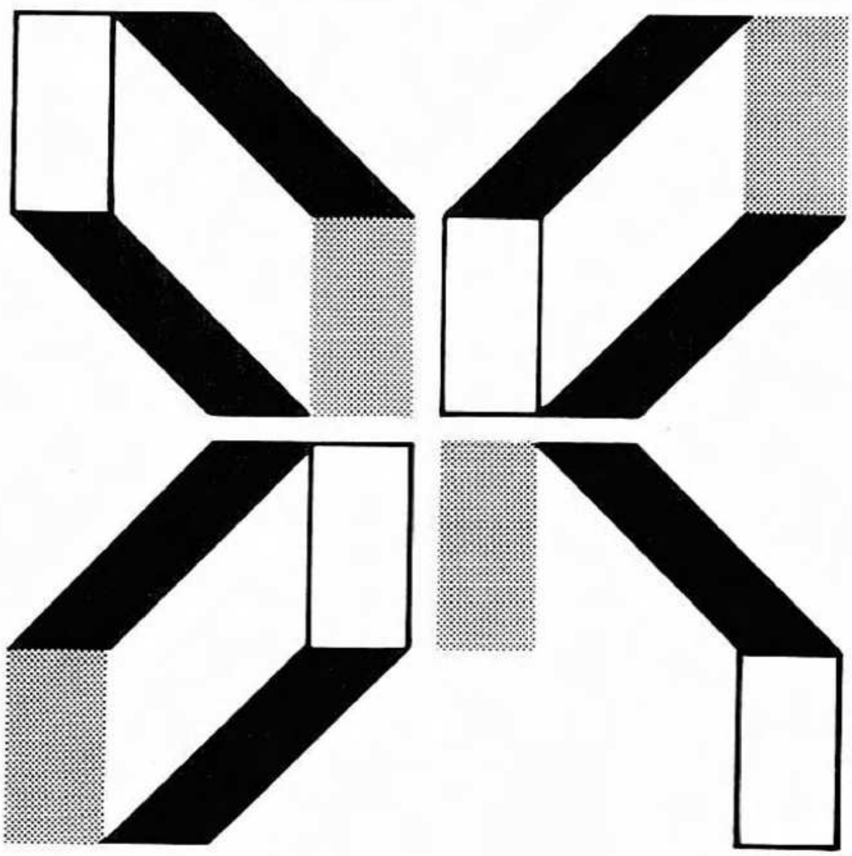
by A.C.C. Warnock



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FIELD SOUND TRANSMISSION LOSS MEASUREMENTS

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ABSTRACT

Measurements of field sound transmission loss in a number of buildings are presented, together with commentary pointing out where design errors were made and how the designs could have been improved.

RÉSUMÉ

Cette note présente les résultats des mesures de la perte de transmission du son dans un certain nombre de bâtiments. L'auteur discute également des erreurs au niveau de la conception et propose des méthodes pour améliorer l'acoustique du bâtiment.

INTRODUCTION

When the sound transmission losses of a partition are measured in a laboratory, great care is taken to ensure that the only significant sound path is through the partition being tested. This is important so that meaningful comparisons can be made among measurements in different laboratories. In contrast, when a partition is installed in a building, there are many additional paths for the sound to follow as it travels between apartments. If the transmission along these additional or "flanking" paths is large enough, the sound transmission loss measured in the building will be less than that measured in the laboratory. Occupants in such buildings will not enjoy the privacy the designer intended. Good acoustical design considers all of these flanking paths and ensures that flanking transmission is reduced to a minimum.

Among the other reasons for poor sound isolation in buildings are design or construction errors. Measurement of sound transmission loss for partitions in buildings provides valuable experience about all of these factors and interesting comparisons with laboratory measurements. Ideally a quantitative measurement of the sound transmission along every path in a building could be made but that is not yet possible. There is hope that new sound intensity measurements will allow us to approximate this ideal but the data described here were collected before advanced technology made it possible to measure sound intensity easily.

In some of the investigations described, design errors occurred through a lack of understanding of the fundamental principles of acoustics. Materials were placed in wrong positions inside walls, or inappropriate methods of attachment were used. In other cases there is no obvious reason why the wall or floor did not function as well as similar walls in laboratory or other field tests. The problem could have been some construction error concealed behind the finishing layers of the partition, or excessive flanking transmission caused by poor design, or both. It was not always practicable to investigate these constructions fully.

Some of the fundamental rules of thumb that should be followed when designing a partition are stated here. In the examples that follow, some of these rules are broken repeatedly.

Elements of Good Acoustic Design

1. Walls, floors and all elements of partitions should be thoroughly caulked so that no holes or fissures act as sound leaks. This applies to flanking structures as well as to the party wall, which is the obvious transmission path.

2. Solid layers in a wall should be far enough apart so that the mass-air-mass (m.a.m.) resonance between them exceeds about 80 Hz. The frequency of this resonance can be calculated from the equation:

$$f_{mam} = 1897\sqrt{(m_1 + m_2)}/\sqrt{dm_1 m_2}$$

   where m_1 and m_2 (kg/m^2) are the masses of the layers and d (mm) is the thickness of air gap between them. (In some applications, such as with concrete block, the face of the material is not completely impermeable and sometimes the effective air space seems to increase beyond the obvious physical space. It is not a good idea to rely on this effect unless sound transmission tests have been made with identical materials in a laboratory or a building.) If this rule is not followed, there is a serious risk of reducing the sound transmission losses of the partition at low frequencies because of the resonance effect.

3. Lightweight layers, such as wallboard, must not be connected rigidly. There should always be some resilient device or material between them to reduce the transmission of acoustical vibrations. A common error in this respect is attaching layers of wallboard directly to each side of wood studs. This should never be done if good sound insulation is the goal. Some kind of resilient connection should also be used when attaching layers of wallboard to concrete block or other heavy walls, but in practice this seems to be less important than for two lightweight layers. For example, measurements show that the transmission losses obtained by using wood furring strips to directly attach wallboard to concrete blocks are high enough for most purposes.

4. Put sound-absorbing, fibrous material in the cavity between two layers in a wall. Sound absorbing material inside the wall cavity damps out the various resonances that can occur in a double layer wall; this will be fully effective only if the two sides of the wall are not connected rigidly.

Other factors that determine the sound transmission through partitions are dealt with in a forthcoming Canadian Building Digest. As with many rules of thumb there are exceptions. To ensure that a wall or floor system is functioning properly it is best to make measurements on a representative specimen as soon as possible during the construction. Quick methods of measurement [1] can determine whether a problem exists or not.

The data presented here are not necessarily free of the effects of flanking. The comments for each case give some idea of whether the measured transmission losses can be regarded as typical or whether they are uncharacteristically low. Even the highest field sound transmission class (FSTC) value shown for a particular construction is not necessarily the best that can be done with that construction. It is simply the best that was measured in this set of measurements but it can be considered as a reasonable expectation when good design procedures are followed. In most cases there is a spread in the FSTC ratings obtained for nominally identical structures. This is a normal feature of field testing and reflects the variability of the construction process as well as that of the test.

Measurements were not always made in strict compliance with ASTM method E336 [2], but the final results should not be seriously affected by any small deviations from the required methods. The measurements were made over a period of about ten years by several members of the Noise and Vibration section, as well as the author. Sound transmission class ratings are assigned in accordance with the requirements of ASTM E413 [3].

MEASUREMENTS

Poured Concrete Walls and Floors

From the acoustical point of view, poured concrete has an inherent advantage over other forms of construction because it is a dense material. A poured concrete floor slab or wall 150 mm thick should provide an FSTC rating of about 55, simply because of its mass. The data in Fig. 1 for 150 mm concrete floor slabs are in accord with expectations.

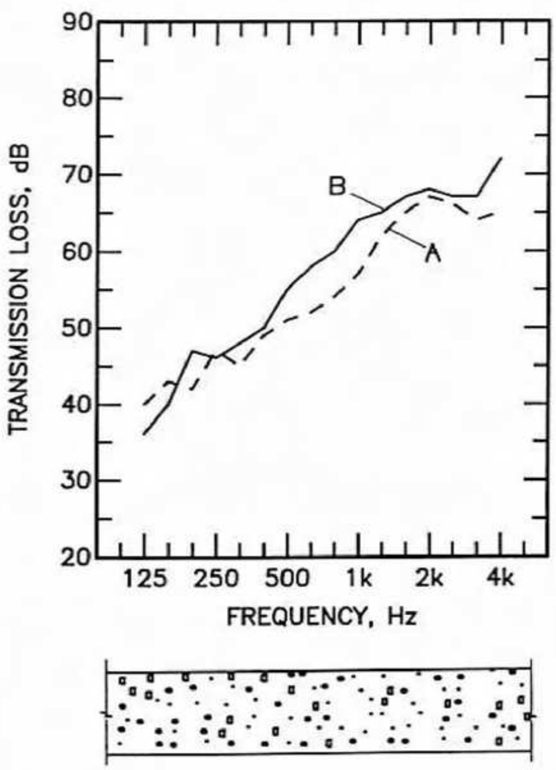

FIG. 1. Sound transmission loss, 150 mm nominal thickness, reinforced concrete slab floors. A - FSTC 55, B - FSTC 57.

It might seem that poured concrete construction would offer few opportunities to go wrong acoustically. Unfortunately faults are possible. Figure 2 shows measured data for two poured concrete walls (thicknesses 190 mm and 150 mm) with wallboard glued to each side. The sound transmission losses are significantly lower than those in Fig. 1. Investigation of wall B showed that when the concrete was poured it had not flowed properly and there were voids around the aggregate that penetrated completely through the wall. This fault was detected acoustically and was visually obvious when the wallboard on one side was removed. Sound was entering the space behind the glued-on wallboard, passing through the voids and then down behind the wallboard on the second side of the wall.

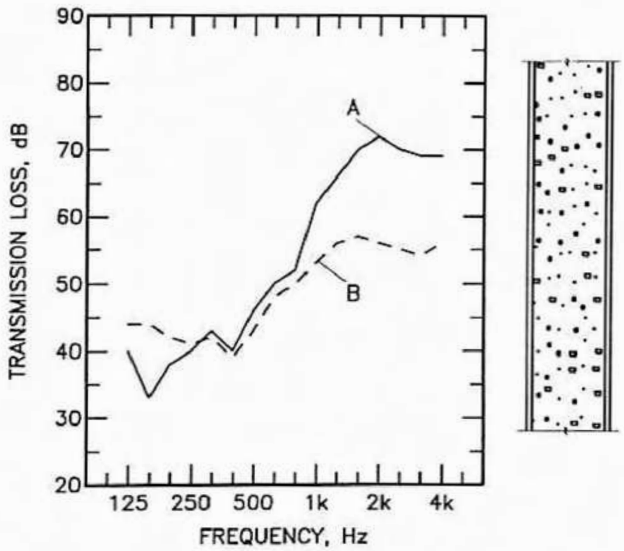

FIG. 2. Sound transmission loss, poured concrete walls with 12 mm wallboard cemented to each side. A - 190 mm thick, FSTC 49; B - 150 mm thick, FSTC 48.

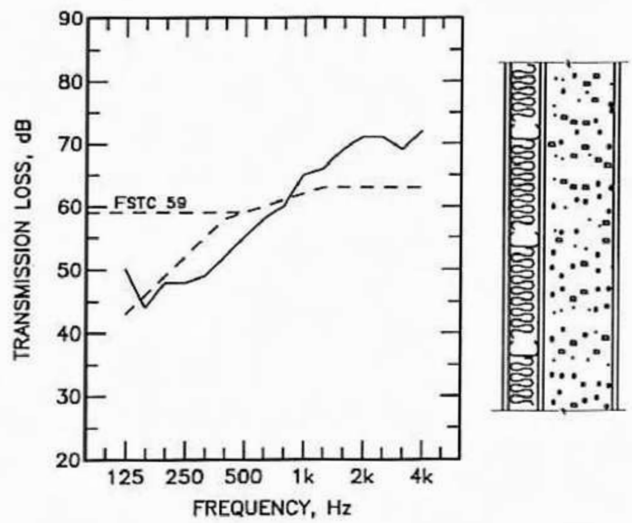

FIG. 3. Sound transmission loss, 150 mm poured concrete wall with 12 mm wallboard cemented to each side. On one side metal studs, glass fibre and 12 mm gypsum board were added to reduce the sound transmission.

For practical reasons wall B was fixed by adding metal studs, glass fibre and another layer of wallboard on one side. The data for the repaired wall are shown in Fig. 3. The FSTC is 59, only a few points better than the properly poured floor slabs in Fig. 1.

No investigations were made on wall A (Fig. 2) to verify the cause of its poor performance but the shape of the TL curve suggests a problem similar to that of wall B.

Inspection of the walls by someone knowledgeable before the wallboard was added would have prevented this problem. It would have been easy to fill the obvious crevices in the wall with plaster. If poured concrete construction is to provide the protection that it should, then inspection of the walls before the wallboard is applied is essential. Later in this note, it is pointed out that gluing wallboard directly to concrete blocks can cause reductions in sound transmission loss because of the thin film of air trapped behind the wallboard. This can result in an m.a.m. resonance, as mentioned above. The same effect could occur with poured concrete.

Constructions With Solid Concrete Cores

Figure 4 shows two examples of a wall system that incorporates a 100 mm thick poured concrete layer. The FSTC values for these walls are quite low and they illustrate a problem that arises with stiff materials such as concrete and wallboard. At a frequency called the coincidence frequency, which is determined by the mass and stiffness of the layer, a resonance occurs causing a reduction in the transmission loss in this frequency region. The coincidence frequency for the central layer in this case should be about 180 Hz. The figure indicates reduced transmission losses in this area for the two curves. The coincidence dip for the wallboard is seen around 2500 Hz. The thicker a given material, the lower the coincidence frequency. The coincidence effect will be seen in other systems that use thin layers of concrete. Even so the measured FSTC values appear low, suggesting that the main reason for the poor performance is the presence of flanking transmission.

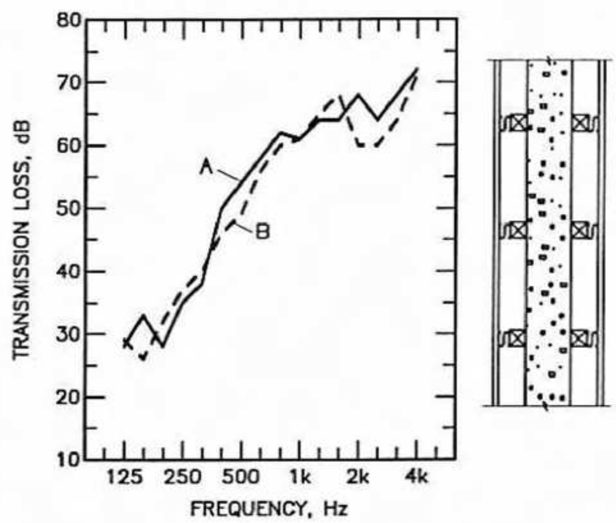

FIG. 4. Sound transmission loss, two 100 mm poured concrete core walls, 38 mm furring, resilient channels, and 12 mm drywall finish on both sides. Concrete weighed about 1680 kg/m^3. A - FSTC 46, B - FSTC 47.

The rather unusual construction in Fig. 5 achieved a respectable FSTC rating of 57, showing that some care had been taken during the design and construction phase. There is still room for improvement however. The wood joists are in direct contact with the concrete and there is no sound absorbing material in the cavity below the plywood floor. One of the most serious acoustical problems with floors is the transmission of footstep and other impact noises. If the wood joists had rested on a layer of semi-rigid glass fibre insulation, the construction would have become a floating floor and both the impact and airborne noise transmission would have been significantly reduced. It is better to prevent the entry of the impact sound energy into the building structure rather than trying to prevent its re-radiation at some other place. No impact tests were made on the floor and with the use of a carpet on top of the wood floor, the impact sound transmission may not have been bothersome. In some cases however, occupants like to have parquet or other hard surfaced floors. In such cases and in kitchens and bathrooms the use of a floating floor is the most effective way of reducing impact noise.

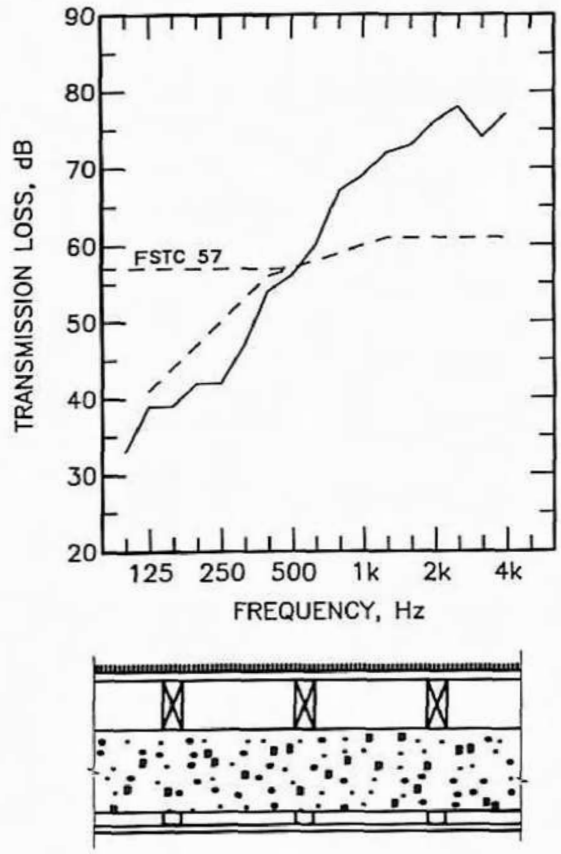

FIG. 5. Sound transmission loss, 150 mm precast concrete floor with steel U-channels on the underside supporting 12 mm wallboard. 38 × 140 mm joists on 400 mm centres supporting 16 mm tongued and grooved plywood floor. 20 ounce carpet on underlay on top of floor.

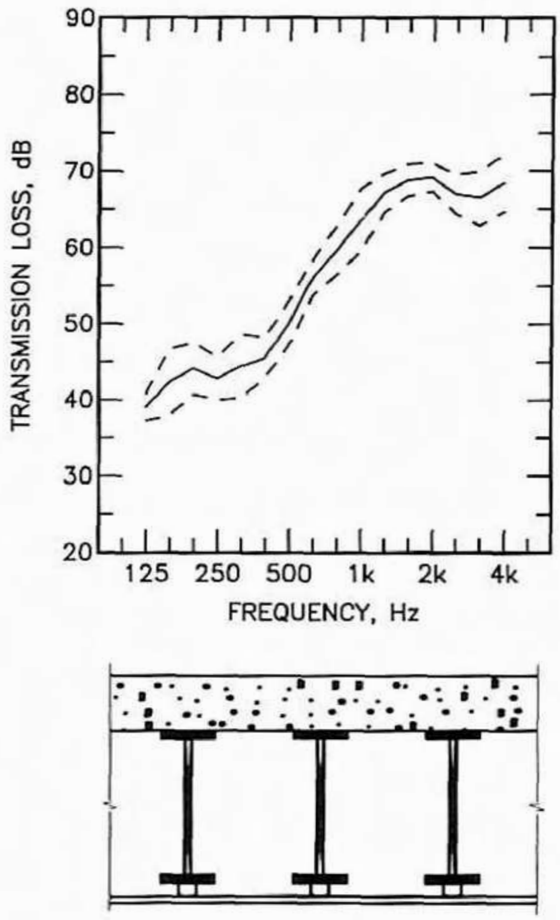

FIG. 6. Sound transmission loss, open web steel floor joists, 250 mm deep. Concrete slabs from 65 to 100 mm nominal thickness. Metal U-channels wired to bottom of joists. 12 mm gypsum wallboard screwed to channels, sealed and painted.

Concrete Floor Slabs Supported on Steel Joists

This kind of construction, as it is a double layer with a large air space, should be able to provide very good sound insulation. But because the top layer of concrete is usually rather thin, there are reduced transmission losses around the coincidence frequency. The data presented here are for floors with top slabs ranging in nominal thickness from 65 to 100 mm. The calculated coincidence frequencies for such concrete slabs lie in the range from 250 to 400 Hz. Figure 6 shows the mean of eight different floors of this type, plus or minus one standard deviation about the mean. The expected differences between floors due to differences in the upper layer thickness are not large; the measured differences are much greater. For this reason it was considered more useful to present the mean as typical of what one can expect from this type of construction. The minimum FSTC measured was 51 and the maximum was 57. Three of the floors in the group had glass fibre in the cavity. This did not seem to make a significant improvement to the FSTC in any of the cases.

This type of floor could be improved by increasing the thickness of the top layer of concrete. The coincidence effect would move to lower frequencies and the transmission loss would increase because of the increased weight, but the floor would no longer be a lightweight floor, which is one of its attractive features. Another possible improvement that would require research to prove its effectiveness, would be to use two layers of concrete on top separated by a layer of glass fibre. This would have the double advantage that impact sound transmission would be reduced and flexural waves in the layers of concrete would be damped to some extent, thus reducing coincidence effects. Since the addition of glass fibre in the cavity does not significantly affect the transmission losses, there may be too much coupling between the concrete on top and the ceiling layer. This might be remedied by using resilient channels instead of the rather rigid U channels, which are usually attached by wires in this system. Again, research would determine whether this would be effective.

Walls With Concrete Block Cores

Wallboard glued to both sides. Figure 7 shows results for three 190 mm concrete block walls with 12 mm wallboard glued to each side. This method of application can leave an air layer of irregular thickness behind the wallboard, with the result that a mass-air-mass resonance can occur and reduce the sound transmission losses at the frequencies around 400 Hz.[4] The combination of 12 mm wallboard and an air layer of about 3 mm would produce a resonance at this frequency. All of the walls in Fig. 7 show reduced transmission losses in this frequency region. They would probably have performed better if they had been plastered or painted. The m.a.m. resonance will be less of a problem if the air space is eliminated or increased enough to move the resonance to a much lower frequency.

Wallboard on furring strips. The air space between the outer layer of wallboard and the block can be increased using furring strips of wood or metal. Figure 8 shows data for a 190 mm block wall with 12 mm wallboard on 17×64 mm wood furring strips on each side. A resonance would be expected around 150 Hz and there is indeed a dip in the transmission loss curve around that frequency although there is no obvious explanation

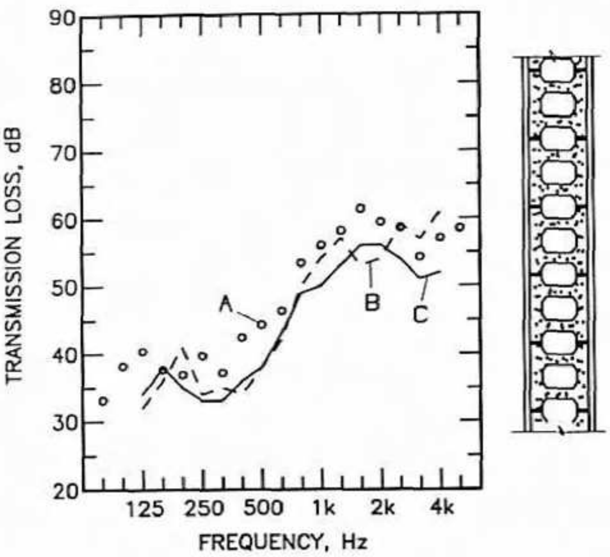

FIG. 7. Sound transmission loss, 190 mm concrete block walls with 12 mm gypsum wallboard cemented to each side. A - FSTC 49, B - FSTC 43, C - FSTC 45.

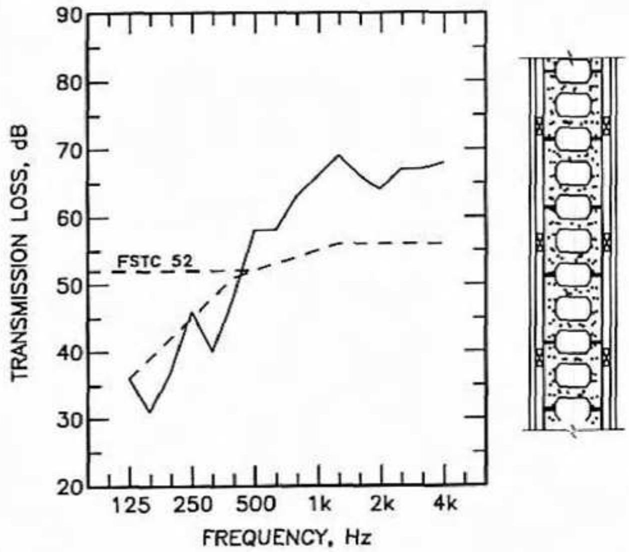

FIG. 8. Sound transmission loss, 190 mm concrete block wall, 17 × 64 mm wood furring, 12 mm gypsum board on each side.

for the dip at 315 Hz. The dotted line in this and following figures represents the FSTC contour fitted to the transmission loss data.[3]

Figure 9 is for a 140 mm block wall with 12 mm wallboard on 38 × 38 mm wood furring strips. In this case the resonance is expected at 100 Hz and, as the measurements show, the transmission loss curve is dropping rapidly at the low frequencies. The FSTC rating does not take TL values below 125 Hz into account, but the rating of 58 in this case is determined by the 8 dB rule in ASTM E413 and the transmission loss at 125 Hz, which is in turn influenced by the resonance below 125 Hz.

It is not known how important low frequency transmission losses are subjectively, but a common complaint is that bass notes from stereo systems are too easily heard. When adding layers of wallboard to concrete block, poured concrete or any wall, it therefore seems prudent to use a combination of heavier wallboard, or multiple layers and a larger air space so that the resonance frequency is well below the normal measurement limit of 125 Hz. The use of 65 mm steel studs instead of wood furring strips would provide a bigger air space and the wallboard would also be decoupled from the concrete blocks.

Measurements presented in Building Research Note (BRN) 217 [4] showed that the addition of glass fibre in the cavity behind the wallboard had a significant beneficial effect throughout most of the frequency range except at the very lowest frequencies. The wall in Fig. 10 (with glass fibre batts) does not appear to be any better than that in the previous figure, so there was probably some flanking transmission reducing the overall performance somewhat. Nevertheless, the FSTC is a quite satisfactory 59.

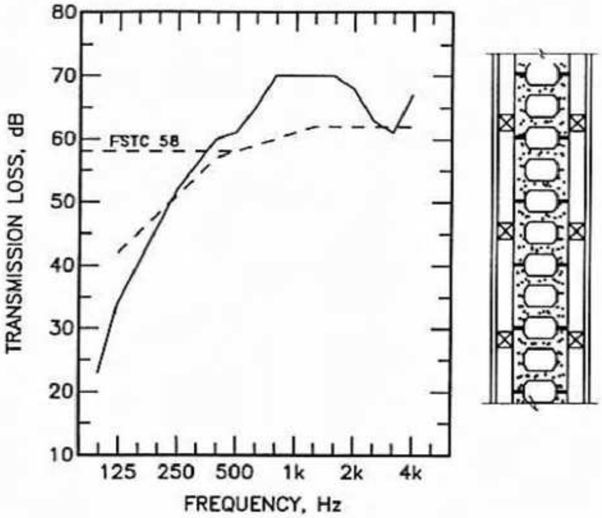

FIG. 9. Sound transmission loss, 140 mm concrete block wall, 12 mm wallboard, 38 × 38 mm wood strapping on each side.

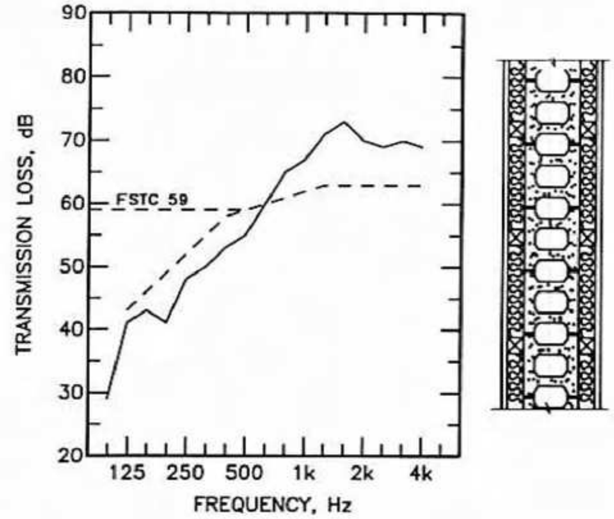

FIG. 10. Sound transmission loss for a 190 mm concrete block wall, 38 × 38 mm wood strapping plus glass fibre batts, 13 mm wallboard on each side.

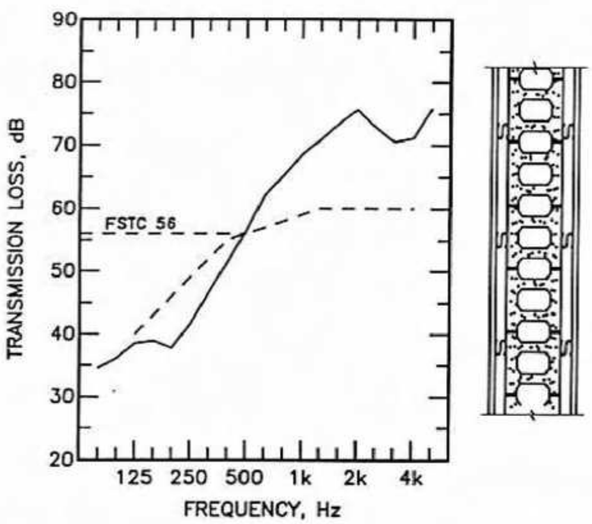

FIG. 11. Sound transmission loss for a 190 mm concrete block wall with resilient channels, 12 mm gypsum wallboard on each side.

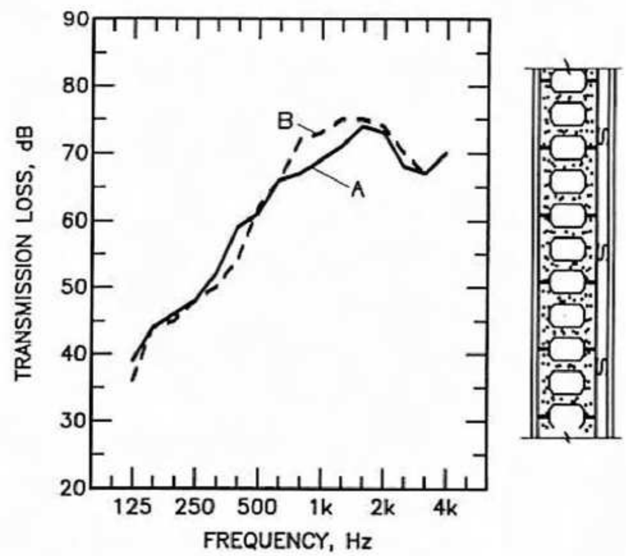

FIG. 12. Sound transmission loss for a 190 mm light concrete block walls, wallboard cemented to one side. The second side had wallboard supported on resilient channels. A - FSTC 61, B - FSTC 60.

Wallboard on resilient channels. For 12 mm wallboard mounted on resilient channels applied directly to a block wall the expected m.a.m. resonance frequency is about 180 Hz. In the wall shown in Fig. 11, although the FSTC is 56, the rating is controlled by the frequencies around this predicted resonance frequency. The FSTC would have been higher if the wallboard had been further from the wall.

In BRN 217 some results demonstrated that having two layers too close to the concrete block, one on each side (as in the wall in Fig. 11), was worse than having one layer too close. A comparison of Fig. 12 and Fig. 11 supports this conclusion. With only one layer of wallboard on resilient channels there is no serious dip in the transmission loss curve around 200 Hz as there was in Fig. 11 and the FSTC is about five points higher. At times in building acoustics adding more material can lead to reduced system performance. The blocks in this case were lightweight blocks and might also have been more porous, giving an effective increase in air space and some absorption in the cavity.

The wall in Fig. 13 differs from those in Fig. 12 only by having the wallboard attached by screws on one side and having a blanket of glass fibre under the wallboard on the other. A glass fibre blanket in the cavity is recommended but in this case does not appear to make any difference to the results; however, these data are not from controlled laboratory experiments and no firm conclusions should be drawn.

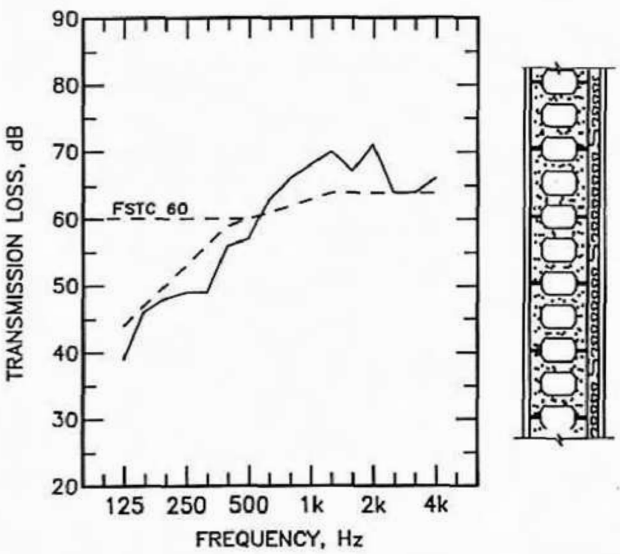

FIG. 13. Sound transmission loss for a 190 mm concrete block wall, 12 mm gypsum wallboard screwed to one side. The second side had a 25 mm glass fibre blanket, resilient channels on 600 mm centres and 12 mm gypsum wallboard screwed to the channels.

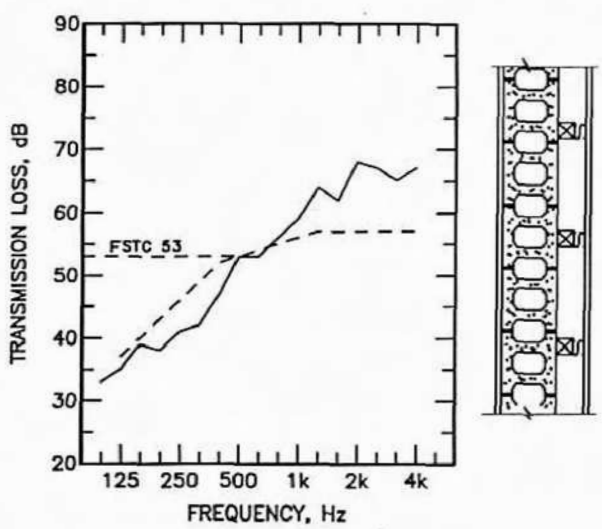

FIG. 14. Sound transmission loss for a 190 mm concrete block wall with 12 mm wallboard on one side. Second side has 38 mm vertical strapping, resilient channels, 12 mm drywall.

As another warning that flanking paths should always be considered, Fig. 14 shows data for a wall that should have performed at least as well as, if not better than, those just discussed, but did not. This is probably due to flanking transmission along the floor, which was 65 mm of concrete resting on steel joists. This hypothesis was not confirmed by measurement but is quite likely on theoretical grounds.

Double Wood Stud Constructions

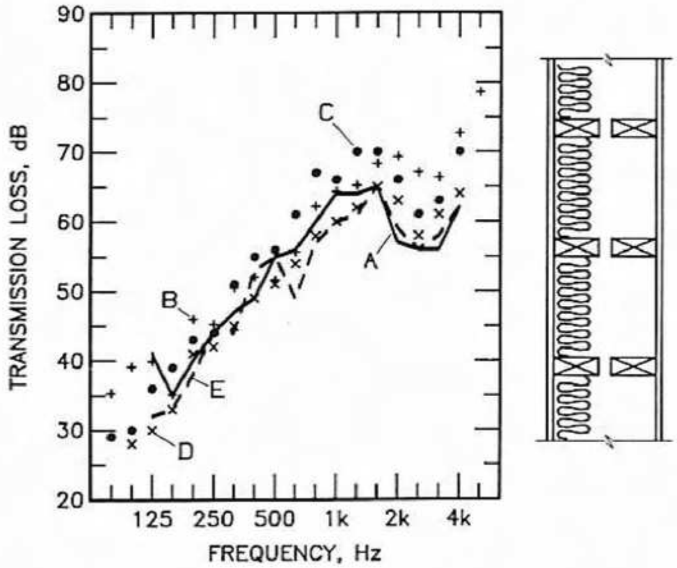

FIG. 15. Sound transmission loss, double stud walls (38 × 89 mm) with 25 mm between the sole plates. A - 65 mm glass fibre in one cavity, 16 mm drywall on both sides for finish, FSTC 54. B,C - 65 mm glass fibre in both cavities, 16 mm drywall on both sides for finish, B - FSTC 56, C - FSTC 58. D - 65 mm glass fibre in both cavities, 13 mm drywall on each side for finish, FSTC 53. E - 75 mm glass fibre in one cavity, 13 mm drywall on each side, FSTC 53.

In laboratory tests double wood studs give good results because they provide mechanical separation between the layers and the air space is larger than for wood stud walls using staggered studs, metal studs, or wood studs and resilient metal channels. Figure 15 shows measurements of five such walls in buildings where the FSTC ranges from 53 to 58. This type of wall can be improved still further by the addition of extra layers of drywall on one or both sides.

The data in Fig. 16 are in marked contrast with Fig. 15 and indicate severe leakage or flanking in this installation. No reason for the poor performance was found but inspection and measurement before tenants move in would prevent such acoustical disasters from being expensive embarrassments.

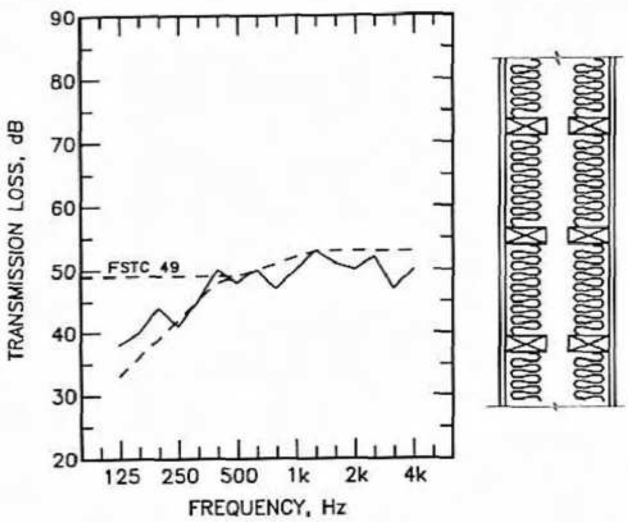

FIG. 16. Sound transmission loss, double wood stud wall (38 × 90 mm), 25 mm between sole plates. 65 mm of glass fibre in each side of cavity. 16 mm drywall on each side for finish.

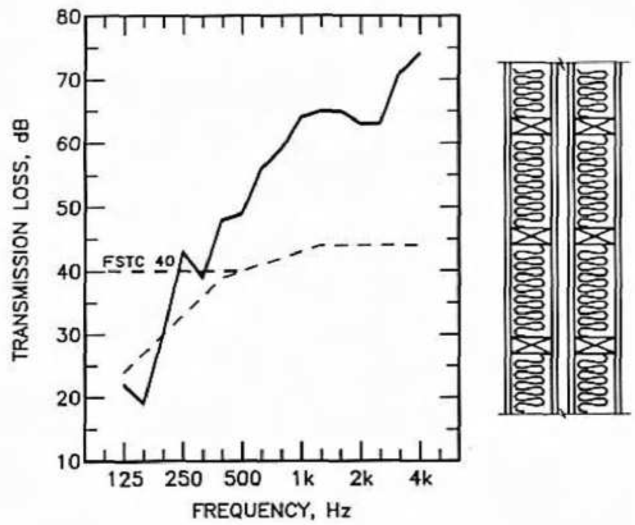

FIG. 17. Sound transmission loss, double walls, each side comprising 38 × 89 mm wood studs, 16 mm gypsum on one side, 12 mm wallboard on the other side, 65 mm of glass fibre in the cavity. The walls were separated by a distance of 25 mm.

Even with the use of double wood studs it is possible to produce a wall design that has a poor sound transmission loss. Figure 17 gives an example of the misuse of materials. A number of errors have been made in this wall design. The attachment of the layers of wallboard directly to both sides of the wood studs means that there is a continuous solid path for vibration; i.e., an acoustical short circuit, through each element of the wall. In addition, the glass fibre is not fully effective. The rather small air gap between the inner layers of wallboard introduces a resonance between them at a frequency within the range of the measurements. This can be seen as the severe dip in the transmission loss curve at 160 Hz, which determines the FSTC of 40 for this construction because of the 8 dB rule in ASTM E413.

If the interior layers of wallboard had been omitted, the FSTC rating would have been increased with a saving in material. If the interior layers had been attached on the outside of the wall, the FSTC would have been increased greatly, to about 60.

Another poor design is shown in Fig. 18. The inclusion of a central layer of wallboard attached directly to the wood studs is an error, for the reasons given above. The FSTC would have been higher if it had been attached to one of the outer faces of the wall. The use of the "Noise-stop" board under one layer of the wallboard is not necessary since double studs are being used and it would have been better to use an extra layer of wallboard or more glass fibre in the cavity.

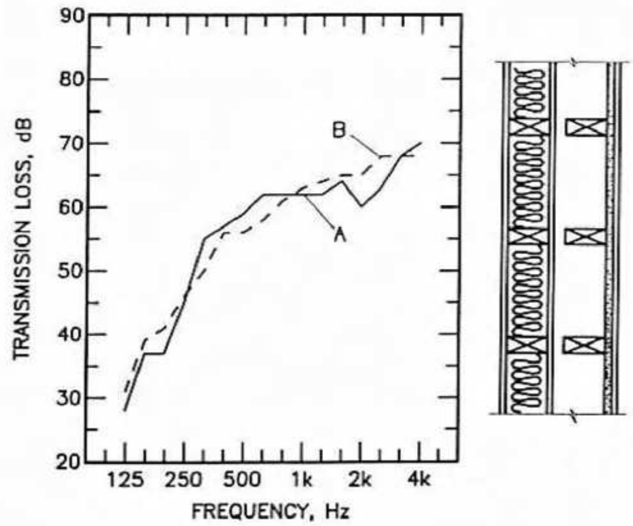

FIG. 18. Sound transmission loss, double stud walls, 38 × 89 mm. One set of studs has wallboard nailed directly to both sides and glass fibre in the cavity. The second set of studs has a 12 mm layer of semi-rigid glass fibre "Noise stop" board under another layer of wallboard. A - FSTC 52, B - FSTC 55.

STAGGERED WOOD STUDS

Staggered wood stud walls will not perform quite as well as double wood stud walls for two reasons. The air space between the layers of wallboard is usually about 50 mm less and there is better mechanical coupling between the layers, due to the continuous plates at the top and bottom of the wall. Figure 19 shows the mean of seven measurements (plus or minus one standard deviation) on staggered stud walls with nominally identical constructions, all measured in similarly designed homes. The FSTC for this mean curve (45) is about 5 dB less than would be expected for the same wall in a laboratory. The available data does not make it clear whether this was due to a design flaw causing flanking to be present in every unit, or to poor installation.

During the measurement series one wall that had an FSTC rating of 36 was found. This is another example of what can happen if care is not taken all through the construction process from inception to completion. A wall like this will very quickly be detected by the occupants once they have moved in, but it would be preferable to have its faults detected by acoustical measurements before that happens.

One special construction that was examined during this series is shown in Fig. 20. Here resilient channels were added to reduce any possible solid transmission of acoustical energy through the structure and to increase the air space slightly. The figure shows a general improvement relative to Fig. 18 but the FSTC was only two points better.

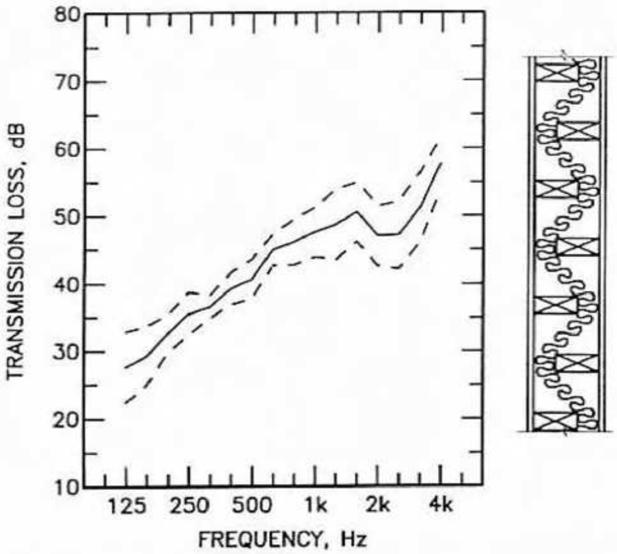

FIG. 19. Sound transmission loss, staggered wood stud walls, 38 × 89 mm. One layer of 16 mm wallboard each side, 75 mm glass fibre in cavity.

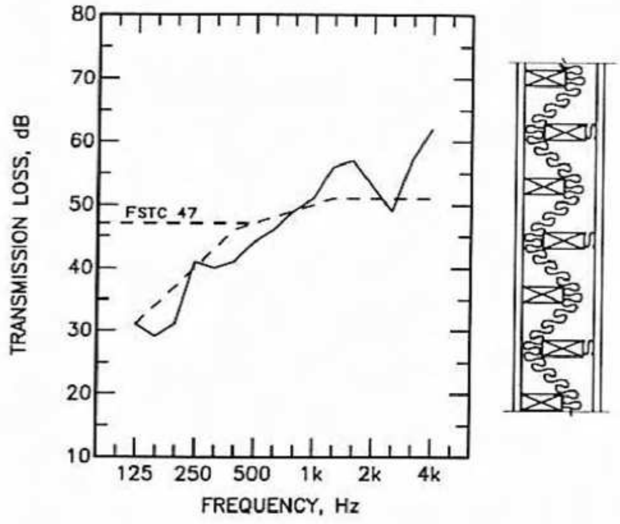

FIG. 20. Sound transmission loss, staggered wood stud wall, 38 × 89 mm. One layer of 16 mm wallboard on each side. On one side the wallboard was mounted on resilient metal channels.

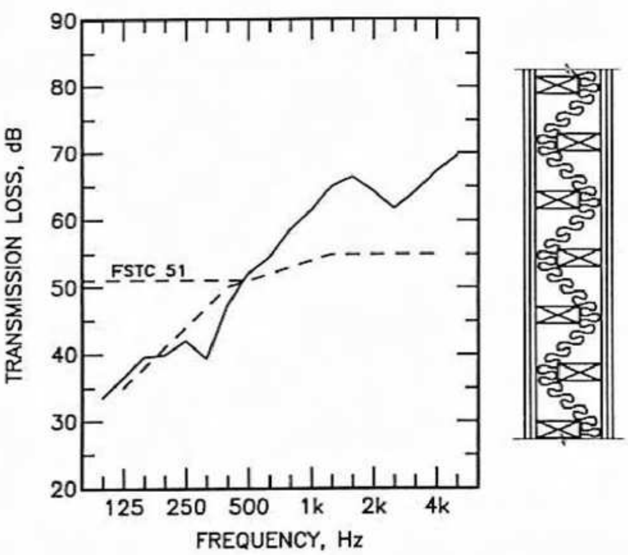

FIG. 21. Sound transmission loss, 38 × 89 mm staggered wood stud wall with 38 × 140 mm sole and top plates. 50 mm glass fibre in the cavity. Two layers, 16 and 12 mm wallboard on each side.

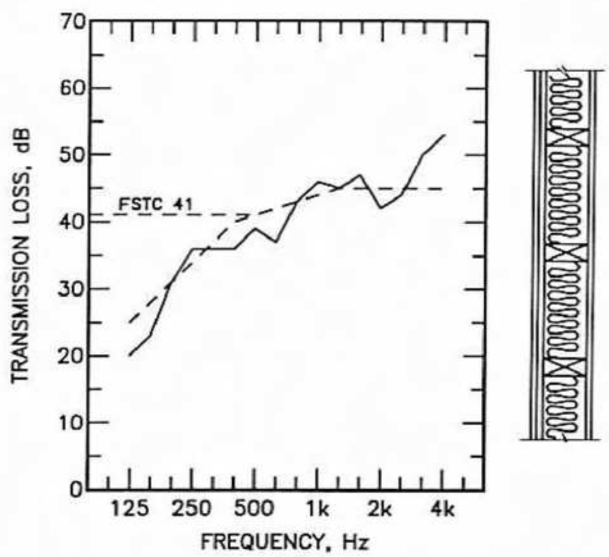

FIG. 22. Sound transmission loss, single wood stud wall, 38 × 89 mm studs on 600 mm centres, 1 layer of 16 mm wallboard nailed to one side and 2 layers to the other side. Cavity filled with mineral fibre batts.

When the number of layers of wallboard in this type of wall is doubled, the expected increase in FSTC is about 6. Figure 21 shows data for just such a case and the measured FSTC is 51, six points better than the mean in Fig. 19.

SINGLE WOOD STUD WALL

The wall in Fig. 22 betrays a serious lack of appreciation of the basic factors controlling sound transmission losses. If resilient metal channels had been used to attach the wallboard, the FSTC would have been about 10 points higher.

STEEL STUD WALLS

Only two examples of steel stud walls are presented here. The first (Fig. 23) has only a single layer of 16 mm wallboard on each side and achieves an FSTC rating of 49. Laboratory tests for similar walls show a large range of FSTC values, with typical high values around 50. This type of wall is sometimes limited by the application of the 8 dB rule in ASTM E413. The coincidence dip that occurs at 2500 Hz can be very much deeper than shown in this figure and the measured transmission losses in this region can entirely determine the FSTC rating. The depth of the dip depends on the vibrational damping in the wallboard.

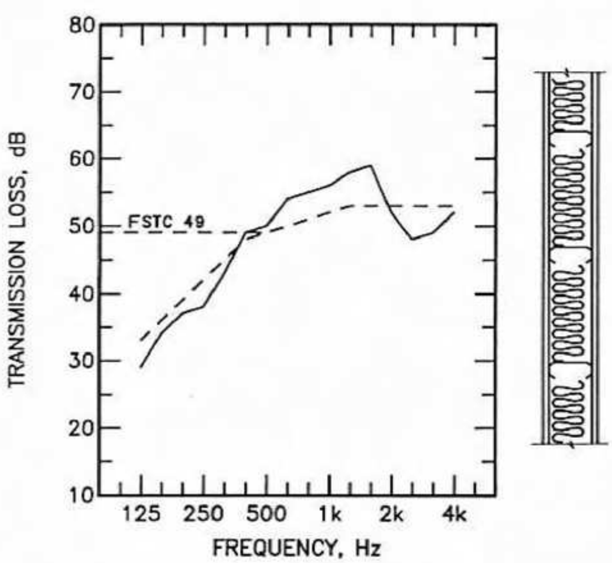

FIG. 23. Sound transmission loss, 90 mm steel stud wall, one layer of 16 mm wallboard on each side, 65 mm glass fibre insulation in the cavity.

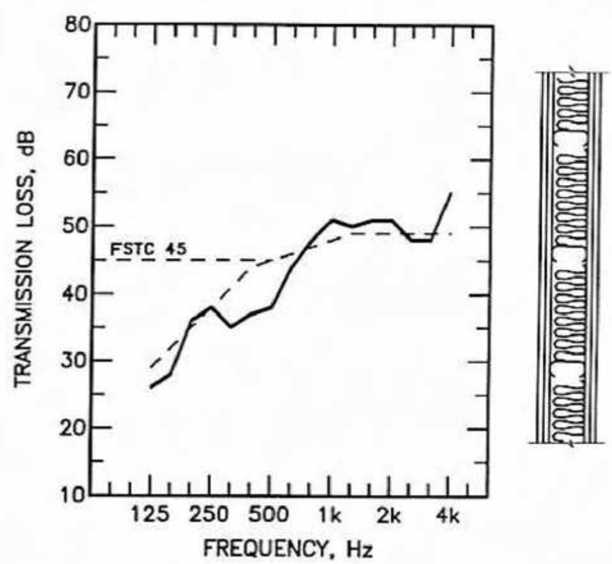

FIG. 24. Sound transmission loss, 90 mm steel stud wall, 2 layers of 12 mm wallboard on each side, 65 mm of fibrous insulation in the cavity. There was considerable flanking transmission through the outside walls on this site.

In another investigation with a wall having two layers of 16 mm wallboard on each side, the FSTC measured initially was 45. This is about 10 dB lower than expected. Inspection of the data in Fig. 24 shows that the TL curve does not have the expected shape. Further investigations showed significant flanking transmission along the outer wall of the building, which consisted of only a single layer of wallboard with an air gap behind it and no sound absorbing material in the gap. Some other flanking contributions were identified but the primary cause of the problem was focussing on the party wall during the design without considering all possible flanking paths and how to deal with them.

WOOD JOIST FLOORS

The same acoustical principles apply to floors as to walls and it should be easier to get high FSTC ratings for floors than for walls because the separation between layers is usually much larger. Figure 25 shows another example where the fundamental principles have not been understood and the bottom layer of wallboard has been attached directly to the wood trusses. Resilient metal channels to support the ceiling would have given a great improvement.

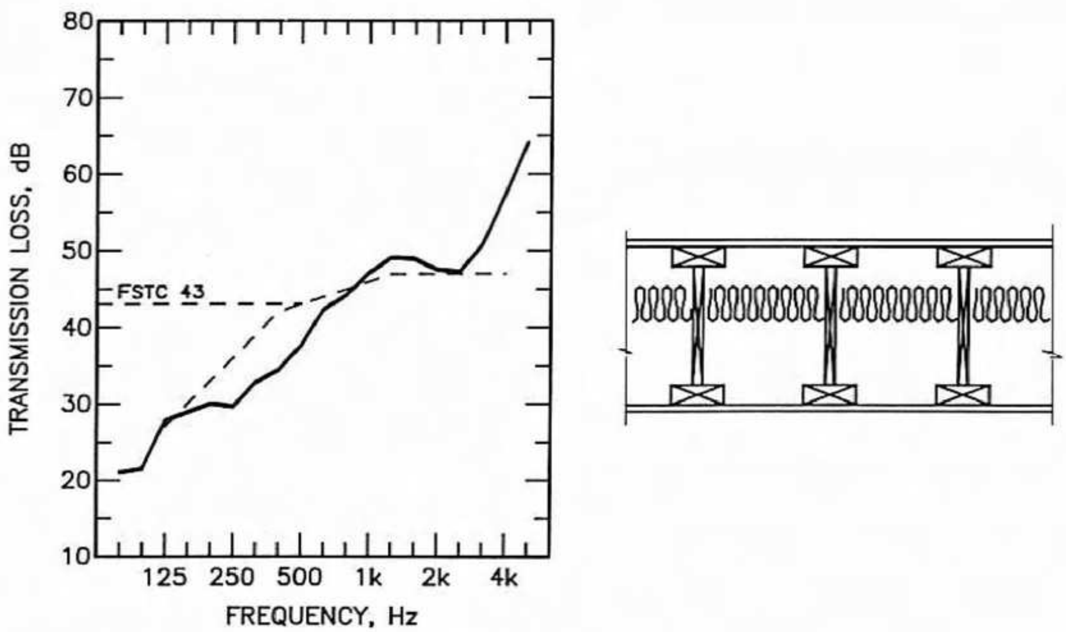

FIG. 25. Sound transmission loss, 430 mm wood truss floor joist system, 16 mm chipboard floor and 16 mm wallboard attached directly to the wood trusses. 65 mm glass fibre in the cavity.

Figure 26 is included as an example of what can be achieved even in a single family home. Often an acoustically isolated room is needed so that some musical member of the family can practice without disturbing everyone else. The construction used here provides a reasonable degree of sound isolation and the sound absorbing tiles control the reverberant

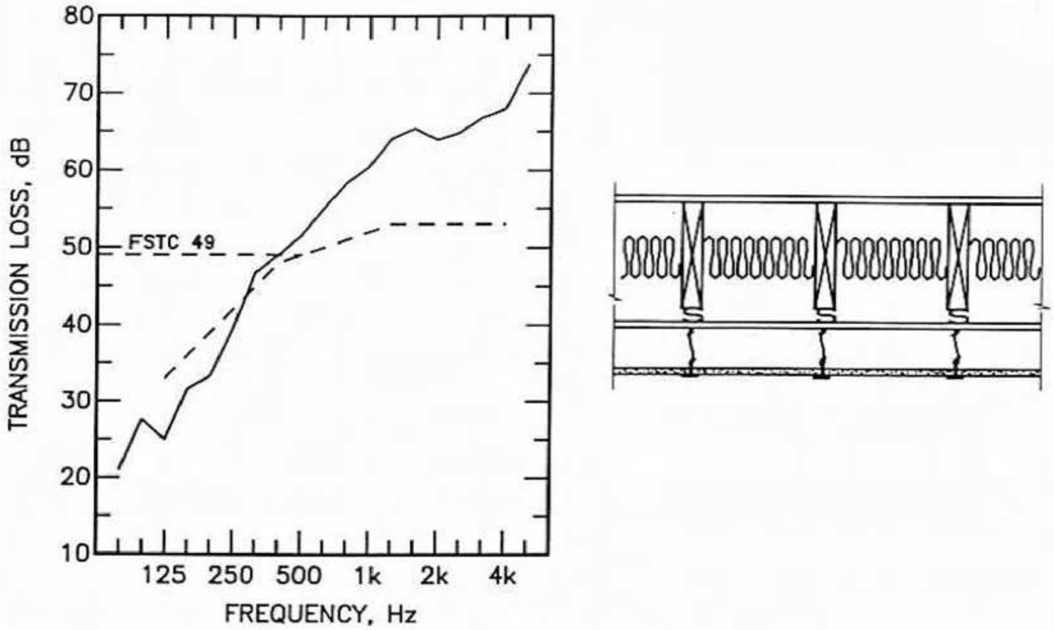

FIG. 26. Sound transmission loss, 16 mm plywood floor, 38 × 235 mm wood joists, 75 mm glass fibre in cavity. 16 mm wallboard attached to resilient channels screwed at right angles to the joists. 12 mm mineral fibre acoustical ceiling tiles suspended on a T-bar system attached by wires to the underside of the wallboard.

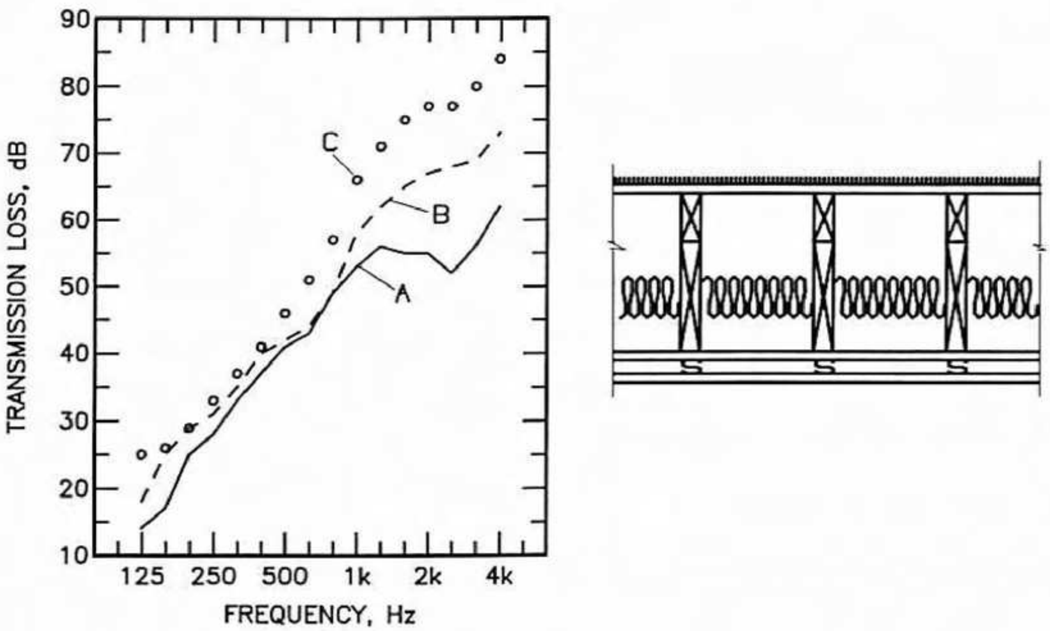

FIG. 27. Sound transmission loss, 38 × 235 mm wood joist floor, 38 × 89 mm studs at right angles to it supporting a 16 mm plywood subfloor. Cross braced in places. Wallboard applied directly to the undersides of the 38 × 235 mm joists. A second layer of wallboard was attached to the first using resilient metal channels. A - No carpet on floor, FSTC 38. B,C - Underlay and carpet on floor, FSTC 42 and 45, respectively.

sound within the music room in the basement. In cases like this, the doors in the home are often found to be the weak points and need special care.

The data in Fig. 27 are for a wood joist floor where enough material was used to provide a fairly decent floor but once again the fundamental rules of good acoustical partition design were violated. The design errors here are the same ones seen in other cases in this note. Attaching a layer of wallboard directly to the joists short circuits the glass fibre and it does not provide as much benefit as it should. Having the outer layer of wallboard so close to the internal one can give rise to a deleterious m.a.m. resonance. Thus the construction as originally designed got an FSTC rating of 38 to 45 in the three cases measured, not at all a satisfactory result. In this figure the effect of adding a carpet and underlay to the floor can be seen—improved transmission losses at high frequencies for floors B and C.

The first most obvious step to improving this floor is to remove the interior layer of wallboard entirely. The data shown in Fig. 28 for two floors constructed in this way show an improvement of about five FSTC points over the best of the floors in the previous figure.

Figure 29 shows three measurements on floors where an attempt was made to improve the sound transmission losses of the original design without removing the ceiling. To do this a layer of 18 mm wallboard was laid on top of the floor. The original faults of the floors still existed but the extra mass helped to increase the FSTC ratings to about 50 in each case.

The last set of measurements in this particular investigation shows the effect of adding a layer of 18 mm wallboard on top of the floor when there is no internal layer of wallboard (Fig. 30). This construction follows the general principles outlined for double layer construction. The FSTC ratings obtained in these two cases are 53 and 54. The masses of the outer layers in this final construction are about equivalent to three layers of wallboard and the measured FSTC is about what would be expected for a staggered wood stud wall. This is lower than what would be predicted for the floor, which has a larger air space between the outer layers than is normal in a wood stud wall. There was probably some flanking in the buildings but this was not investigated as there were more obvious problems to be dealt with.

This study provides a chastening example of how the same materials put together in different ways can lead to large differences in the measured sound transmission losses. An understanding of the basic design principles is essential to achieving good sound isolation.

UNUSUAL CONSTRUCTIONS

Multiple independent wall constructions are not too common. They offer no practical advantages over a well built double wall or a concrete block wall with finishing layers of wallboard. They are usually built with the laudable intent of providing good sound insulation but unfortunately, good intentions are not always enough.

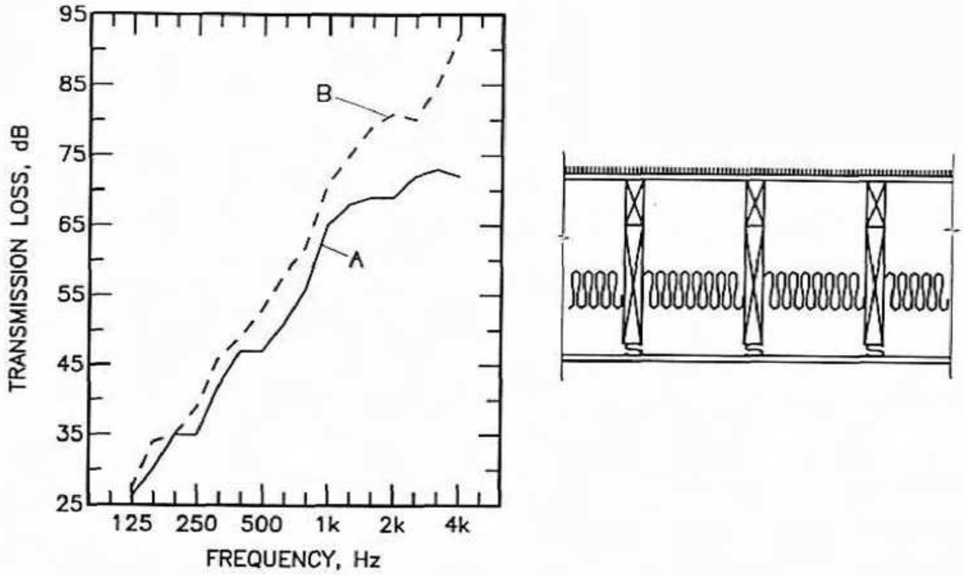

FIG. 28. Sound transmission loss, 38 × 235 mm wood joist floors, 38 × 89 mm studs at right angles supporting a 16 mm plywood subfloor. Cross braced in places. A layer of wallboard was attached to the undersides of the joists using resilient metal channels. 75 mm glass fibre in the cavity. Floor covered with thick underpad and carpet. A - FSTC 49, B - FSTC 51.

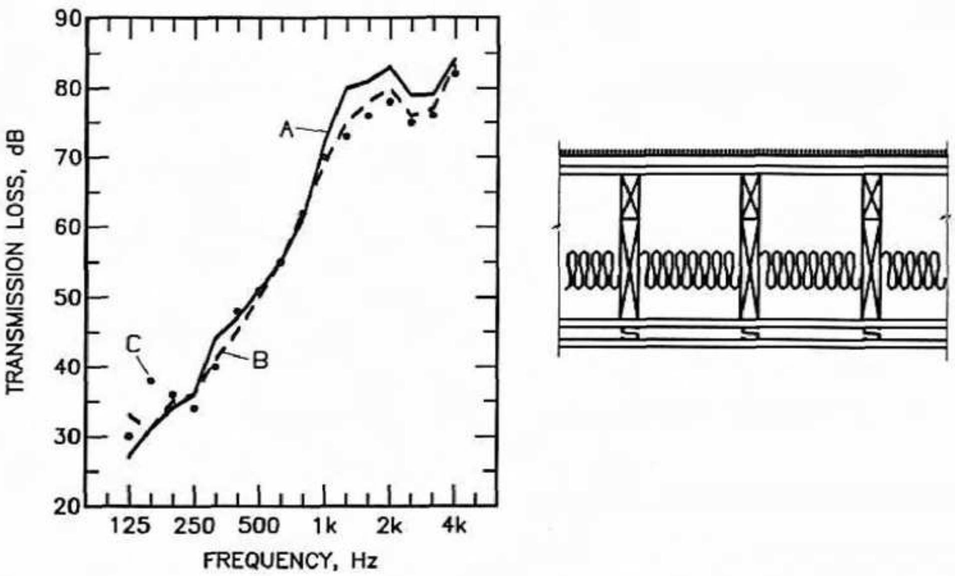

FIG. 29. Sound transmission loss, 38 × 235 mm wood joist floors, 38 × 89 mm studs at right angles supporting a 16 mm plywood subfloor. Cross braced in places. 18 mm gypsum core board laid directly on top of the subfloor. Wallboard applied directly to the undersides of the joists. 75 mm glass fibre in the cavity. A second layer of wallboard was attached to the first using resilient metal channels. Carpet and underpad on floor. A,B - FSTC 50, C - FSTC 49.

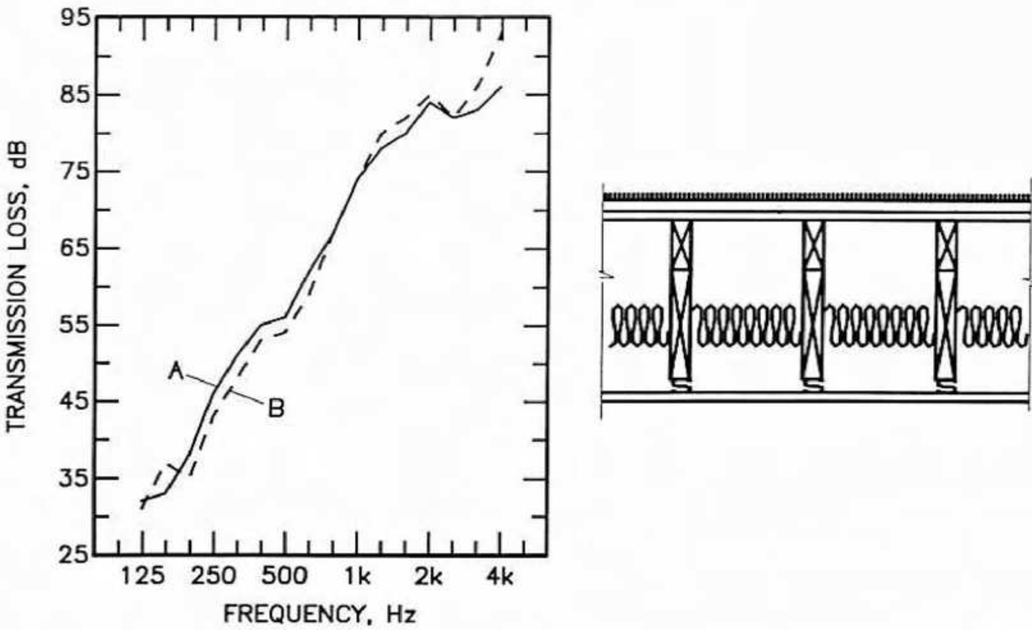

FIG. 30. Sound transmission loss, 38 × 235 mm wood joist floors with 38 × 89 mm studs at right angles, supporting a 16 mm plywood subfloor. Cross braced in places. 18 mm wallboard laid on top of the floor. Layer of wallboard attached to the undersides of the joists using resilient metal channels. 75 mm glass fibre in the cavity. Floor covered with thick underpad and carpet. A - FSTC 54, B - FSTC 53.

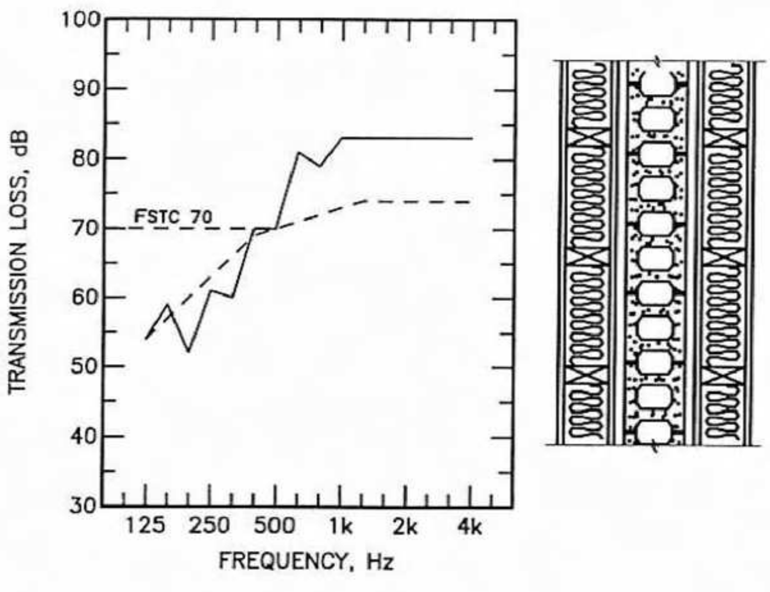

FIG. 31. Sound transmission loss, triple wall with 190 mm concrete block core. The outside walls were formed from 38 × 89 mm studs, 16 mm wallboard on each side and 65 mm of glass fibre batt in each cavity.

The construction in Fig. 31 gets a very high FSTC for a practical installation but reveals some ignorance of the fundamentals of building acoustics. The complete wood stud walls on each side contain glass fibre, which is not as effective as it might be because of the solid connection through the wood studs. This wall would have been easier and cheaper to build and more effective if the internal layers of wallboard had been omitted. The stud size could also have been reduced a little so that the air gap was less. Nevertheless the final FSTC attained is excellent. It was not possible to make measurements above 800 Hz because the transmission losses were so high.

Sand is occasionally used in partitions in the belief that it has unusual acoustical properties. The wall in Fig. 32 must have been difficult to construct. The FSTC is quite high but had the internal plywood and sand been replaced with more glass fibre, and had extra layers of wallboard been applied on the exterior, the sound transmission losses would have been at least as good if not better. Once again the glass fibre in the cavity is not able to provide full benefit because it is being short circuited by the wallboard layers attached directly to the wood studs. Despite the high FSTC rating for this wall, impact noise was transmitted through the sand in it. Cupboard doors being closed on one side of the wall were clearly audible on the other. It violates the principles of good acoustical design to put a cupboard on a party wall, but the problem would have been less severe if the outer layers of the wall had been mechanically isolated from each other.

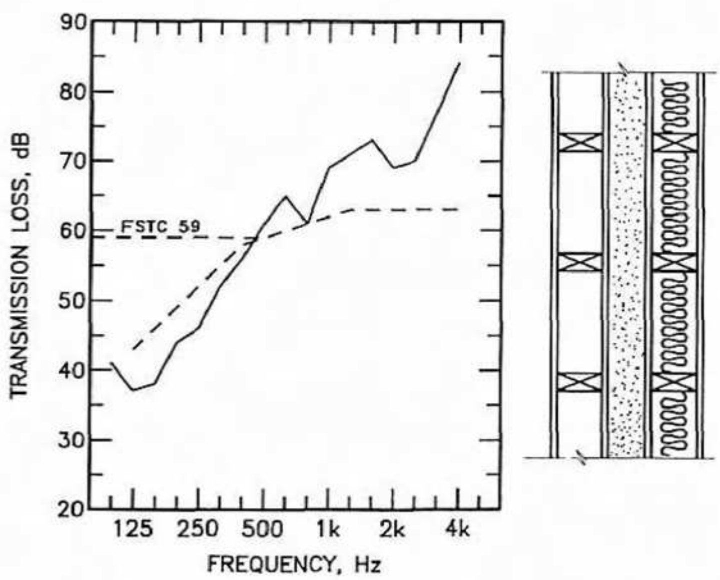

FIG. 32. Sound transmission loss, 16 mm gypsum wallboard attached directly to one side of 38 × 89 mm wood studs. 12 mm plywood attached directly to the other side. A second wall the same as the first formed a 75 mm internal cavity, filled with cementitious sand. Outer wall contained 50 mm glass fibre batts in the cavity.

SUMMARY

Sixty-three tests were performed to obtain the data presented here. The individual measurements are presented in Table 1. Figure 33 shows the distribution of the FSTC values for this set of data. The mean value of FSTC measured was 50.7 and the standard deviation was 6.5 dB. Only 13 of the walls had FSTC values less than 45, the value required in the National Building Code of Canada. Eighteen of the walls with FSTC values less than 50 could have had values around 55 with proper care. The provision of FSTC values 10 or even 15 points higher than NBC requirements does not require walls that are in any way extreme. It only requires some understanding of rather elementary acoustics and attention to detail during the design and contruction process. Unfortunately the examples also show that the basic design principles are often misunderstood. It is hoped that the commentary will dispel some of that misunderstanding.

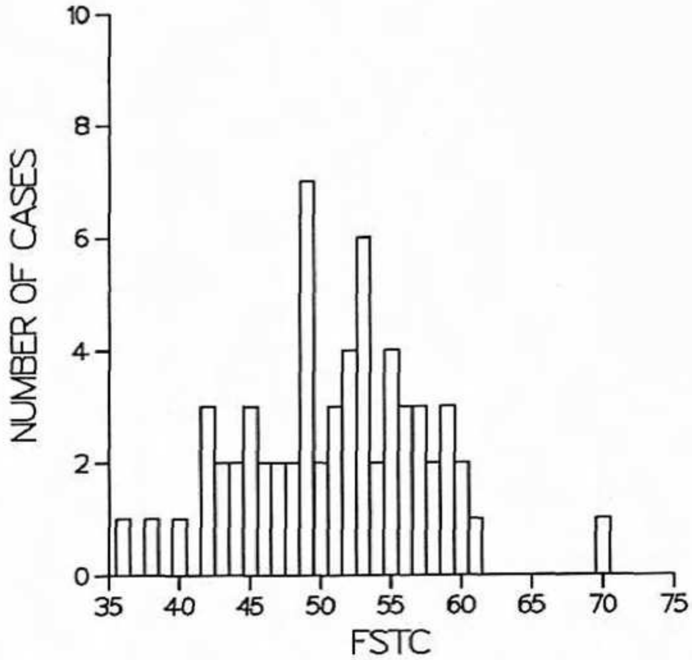

FIG. 33. Distribution of FSTC values for the 63 partitions measured. The mean value is 50.7 and the standard deviation is 6.5.

To ensure good sound insulation in projects where a fairly large number of homes are to be built, it is safer to measure the sound transmission class for a representative unit at an early stage. If the measured data does not meet expectations, skilled advice can usually provide a solution for the problem.

Table 1. Measured Field Sound Transmission Losses for all Specimens.

		Frequency																		
		Hz											kHz							
FIG.	FSTC	80	100	125	160	200	250	315	400	500	630	800	1.0	1.2	1.6	2.0	2.5	3.2	4.0	5.0
1A	55	-	-	40	43	42	47	45	49	51	52	54	57	62	65	67	66	64	65	-
B	57	-	-	36	40	47	46	48	50	55	58	60	64	65	67	68	67	67	72	-
2A	49	-	-	40	33	38	40	43	40	46	50	52	62	66	70	72	70	69	69	-
B	48	-	-	44	44	42	41	42	39	43	48	50	53	56	57	56	55	54	56	-
3	59	-	-	50	44	48	48	49	52	55	58	60	65	66	69	71	71	69	72	-
4A	46	-	-	28	33	28	35	38	50	54	58	62	61	64	64	68	64	68	72	-
B	47	-	-	29	26	32	37	40	46	49	56	60	61	65	68	60	60	64	71	-
5	57	-	33	39	39	42	42	47	54	56	60	67	69	72	73	76	78	74	77	-
6	55	-	-	39	42	44	43	44	46	50	56	60	64	67	69	69	67	66	68	-
7A	45	-	-	34	38	35	33	33	36	38	43	49	50	53	56	56	54	51	52	-
B	43	-	-	32	36	41	34	35	34	38	42	50	54	57	53	54	59	57	61	-
C	49	33	38	40	38	37	40	37	42	44	46	53	56	58	61	59	59	54	57	59
8	52	-	-	36	31	37	46	40	48	58	58	63	66	69	66	64	67	67	68	-
9	58	-	23	34	40	46	52	56	60	61	65	70	70	70	70	68	63	61	67	-
10	59	-	29	41	43	41	48	50	53	55	60	65	67	71	73	70	69	70	69	-
11	56	35	36	39	39	38	42	47	51	56	62	65	69	71	73	76	73	71	71	76
12A	61	-	-	39	44	46	48	52	59	61	66	67	69	71	74	73	68	67	70	-
B	60	-	-	36	44	45	48	50	54	62	66	72	73	75	75	74	70	67	70	-
13	60	-	-	39	46	48	49	49	56	57	63	66	68	70	67	71	64	64	66	-
14	53	-	33	35	39	38	41	42	47	53	53	56	59	64	62	68	67	65	67	-
15A	54	-	-	41	35	40	44	47	49	55	56	60	64	64	65	57	56	56	62	-
B	53	-	-	32	33	38	44	44	53	55	49	57	60	61	65	59	56	58	62	-
C	56	35	39	40	35	46	45	51	52	52	56	62	64	65	68	69	67	66	73	79
D	58	29	30	36	39	43	44	51	55	56	61	67	66	70	70	66	61	63	70	-
E	53	-	28	30	33	41	42	45	49	51	54	58	60	62	65	63	58	61	64	-
16	49	-	-	38	40	44	41	45	50	48	50	47	50	53	51	50	52	47	50	-
17	40	-	-	22	19	30	43	39	48	49	56	59	64	65	65	63	63	71	74	-
18A	52	-	-	28	37	37	45	55	57	59	62	62	62	62	64	60	63	68	70	-
B	55	-	-	31	39	41	46	50	56	56	58	61	63	64	65	65	68	68	68	-
19	45	-	-	28	29	33	36	37	39	41	45	46	48	49	51	47	47	51	58	-
20	47	-	-	31	29	31	41	40	41	44	46	49	51	56	57	53	49	57	62	-
21	51	-	34	37	40	40	42	39	47	52	55	59	61	65	67	64	62	64	67	70
22	41	-	-	20	23	31	36	36	36	39	37	43	46	45	47	42	44	50	53	-
23	49	-	-	29	34	37	38	43	49	50	54	55	56	58	59	52	48	49	52	-
24	45	-	-	26	28	36	38	35	37	38	44	48	51	50	51	51	48	48	55	-
25	43	21	22	28	29	30	30	33	34	38	42	44	47	49	49	48	47	51	57	64
26	49	21	28	25	32	33	40	47	49	52	55	58	61	64	65	64	65	67	68	74
27A	38	-	-	14	17	25	28	33	37	41	43	49	53	56	55	55	52	56	62	-
B	42	-	-	18	25	29	31	35	40	42	44	49	58	62	65	67	68	69	73	-
C	45	-	-	25	26	29	33	37	41	46	51	57	66	71	75	77	77	80	84	-
28A	49	-	-	26	30	35	35	42	47	47	51	56	65	68	69	69	72	73	72	-
B	51	-	-	27	34	35	39	46	49	53	58	62	71	75	79	81	80	85	92	-
29A	50	-	-	27	31	34	36	44	47	51	55	61	72	80	81	83	79	79	84	-
B	50	-	-	33	31	35	36	41	45	50	55	62	69	75	78	80	76	77	83	-
C	49	-	-	30	38	36	34	40	48	51	55	62	70	73	76	78	75	76	82	-
30A	54	-	-	32	33	38	46	51	55	56	62	67	74	78	80	84	82	83	86	-
B	53	-	-	31	37	35	43	48	53	54	59	67	74	80	82	85	82	86	93	-
31	70	-	-	54	59	52	61	60	70	70	81	79	83	83	83	83	83	83	83	-
32	59	-	41	37	38	44	46	52	56	61	65	61	69	71	73	69	70	77	84	-

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