CRITERIA FOR AIRBORNE SOUND INSULATION BETWEEN DWELLINGS

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Experience indicates that the most disturbing of intrusive sounds in apartment dwellings are voices, either live or by way of radio or television. Closely related are other airborne sounds including music reproduced on radio, TV or stereo. Next on the list are impact sounds including slamming of doors and footsteps on the floor adjacent or above. Finally there are mechanical or plumbing noises.[1,2] All of these need consideration, but only the first topic, insulation against airborne sounds, is considered here.

1. The Sound Transmission Process

The physical process of sound transmission is epitomized in the familiar formula:

$$TL = NR + 10 \log (S/A_2) \qquad (1)$$

This equation applies to the case of a partition separating two rooms, one of which contains a sound source.

- TL is the sound transmission loss, which is defined as the ratio of incident sound power on the source side to the radiated sound power on the other side of the assumed partition
- NR is the noise reduction or difference in average sound pressure level in the two rooms
- S is the area of the transmitting surface
- A_2 is the absorption in the receiving room.

A number of assumptions are implicit in this formula: for example, the sound fields are assumed to be relatively uniform and diffuse; in particular, the sound field incident on the partition is assumed to consist of a uniform distribution of sound waves from all possible directions. Published values of sound transmission loss are usually obtained in a special laboratory facility where the environment is made to fit the theoretical assumptions as closely as possible.

In typical dwellings the rooms may be too small for the theory to apply. They may contain so much sound absorption that the assumption of a "reverberant field" is not met; indeed there may not even be well-defined rooms or a well-defined partition. Another complication is the fact that sound may be transmitted by paths other than through the nominal partition. For these reasons, although the level difference between two spaces can be measured in a defined way, one should be cautious about inferring the transmission loss of the nominal partition. In sum, laboratory measurements can provide definitive information about the primary separating elements in a building, whereas field measurements provide information on the assembly comprising a specific building.

The interest of the building occupant is, in any case, two stages removed from the mere question of transmission loss of partitions. He is interested in the extent to which he is bothered by intrusive noises. This depends on the sound insulation between his neighbour and himself, and also the range of noise levels in the two places. Whether there is a sound insulation problem may thus depend on the specific building and on the occupants thereof. Nevertheless the first step in providing adequate sound insulation is to provide adequate separating walls and floors.

Simple homogeneous wall

The transmission loss of a simple homogeneous wall is well understood theoretically, at least for the infinite wall case. For reasonably large partitions, experimental evidence fits the theory quite well if one makes an appropriate adjustment for the finite dimensions of the partition and the associated rooms. Typically the transmission loss increases with frequency by about 5 dB per octave, except for a "coincidence dip," at the frequency for which the velocity of transverse flexural waves in the wall equals the velocity of sound in air. Above the coincidence dip the transmission loss again increases with frequency at a rate dependent on internal damping in the wall.

Doubling the thickness or mass of a single wall increases the TL by about 5 dB. On the other hand, two or more leaves, relatively independent of each other, can provide substantially higher transmission loss for the same total weight of material.

An important type of wall in Canada is the two-leaf wall consisting of gypsum board on either side of a framing system. Then sound is transmitted in two stages: through the first leaf into the cavity and then from the cavity through the second leaf. The best walls provide a structural break in the framing system (flexible metal studs or flexible furring over wood studs) together with sound absorbing material in the cavity. There is no simple theoretical approach to this rather complicated system, but there is sufficient empirical information that most constructions of this type can be accurately predicted. When well constructed, they give very good performance for relatively light weight at low cost.

In the ensuing discussion four representative walls, shown in Fig. 1, will be used for illustrative purposes. The brick wall has a slow monotonic frequency characteristic, whereas the gypsum-faced masonry is spoiled by a coincidence dip in the mid-frequencies. The two-leaf gypsum walls, although quite good in the mid-frequency range, drop off rapidly toward the lower frequencies and are limited by coincidence dips at high frequencies. The numbers given correspond to the single-figure rating known as the sound transmission class (STC).

2. Subjective Assessment of Sound Insulation

All attempts to deal quantitatively with sound insulation requirements face the fact that requirements differ widely with time, place and people. A practical criterion might be limited to satisfying a reasonably large proportion of the occupants at least to the point where lack of sound insulation is not a major complaint.

A number of ways of assessing the problem will be considered. One of these is to examine the record of complaints from occupants of multidwelling buildings. The material derived in this way is limited, of course, to a study of existing structures and does not permit a detailed identification of the various physical parameters.

A series of British social surveys involving buildings where the party walls were of 9-in. brick indicated that about one quarter of the occupants of such buildings are disturbed by intrusive noise.[2] Hence the 9-in. brick wall might be regarded as an example of fairly adequate sound insulation. In considering other types of construction, however, there is a problem in knowing how to make a detailed comparison with the 9-in. brick wall: specifically, how should the insulation vary as a function of frequency? Auxiliary studies of this question [3,4,5] support the view that in fact the TL curve for the brick wall provides about the right frequency weighting. A slightly better criterion would give more emphasis to the middle frequencies as, for example, in the contour used in deriving the ASTM sound transmission class (Fig. 1).

In terms of the STC rating system, the brick wall rates STC 53, and one can infer from British social surveys of row housing that STC 53 would satisfy about three-quarters of the building occupants. Surveys of apartment buildings[2] showed that insulation as low as STC 47 resulted in disturbance of about 36 per cent and noise intrusion moved from being a minor dissatisfaction to a major one.

One source of Canadian evidence consists of a compilation of complaints investigated by NRC. These data reflect in part the fact that the legal minimum in many parts of Canada is STC 45, which is therefore the design objective for much Canadian dwelling construction. The compilation shows a relatively small number of complaints for separations better than STC 50 and none above STC 55. By far the most complaints are in the category from STC 45 to 50. The evidence is thus consistent with that of the British social surveys: complaints about intrusive noise are common when sound insulation is below STC 50.

Other approaches to the problem involve calculations for the kinds of noise known to be troublesome. Briefly, one considers the extent to which intrusive sounds are perceived above the existing accepted "background noise." Background noise is itself very similar in character to the noises identified as disturbing, differing mainly in that it is sufficiently garbled that it does not carry a specific message. Studies of domestic noise levels suggest that during quiet periods, which are the periods when intrusive noise is likely to be objectionable, the background level may fluctuate from about 25 to 35 dB A, the latter figure being applicable when there is a certain amount of outdoor traffic and minor indoor sounds such as a refrigerator. For purposes of this discussion a reference spectrum of background noise will be assumed to correspond to the NC-25 contour, which is equivalent to an A-weighted level of 35 dB. This level is just low enough that most quiet activities are not normally interfered with.

An important noise is speech and an important criterion of disturbance is the extent to which transmitted speech is intelligible. Speech sounds may be considered to fluctuate over a range of about 30 dB and to comprise important frequency components from 200 to about 4000 Hz. It is the fluctuations that carry the intelligence in speech; the proportion of these fluctuating sounds that protrudes above background noise is a measure of speech intelligibility. There is an established procedure for calculating the Articulation Index (AI), but the application of this procedure near the threshold of intelligibility is in some doubt. For purposes of this analysis it will be simpler and nearly equivalent to assume that transmitted speech is not disturbing if no more than the top 5 per cent of speech sounds protrudes above background.

Calculations for the four representative walls shown in Fig. 1 and for typical room configurations yield results given in Table I, where what is calculated is the level of background noise required to mask all but the top 5 per cent of speech sounds. For a background level of 35 dB A, all four walls are seen to be adequate to mask "conversational" speech, but only Walls A and C are adequate protection against "loud" speech.

TABLE I - BACKGROUND NOISE REQUIRED TO MASK TRANSMITTED CONVERSATIONAL SPEECH

		Required Masking Level	
Wall	STC	Conversational Speech	Loud Speech
A	53	24	34
B	45	33	43
C	50	25	35
D	47	30	40

A similar approach by van den Eijk[3] considered the transmission of typical radio and TV sounds from which it appeared that the STC 50 wall would reduce transmission to the point that only the top 5 per cent peaks emerged above the reference background level.

Nowadays it is found that the noise from stereo recording equipment is a major source of complaint. An analysis of such sounds indicates that the main difference as compared to radio and TV sounds is the operating level, the implication being that users of such equipment tend to play it at higher levels than is normal for radio or TV. Certainly the commercially available equipment has the potential of producing very high levels, and some users will choose to exercise this potential. Data suggest that a wall corresponding to about STC 60 would be necessary to bring typical levels of stereo sound down to the background level of 35 dB A.

These are but a sampling of studies suggesting that a modest objective for separation of dwellings would be a sound insulation corresponding on the average to STC 50. This might be apportioned so as to provide higher insulation, say 53 to 55 for protection of bedrooms, and perhaps about STC 45 for separation of noncritical spaces such as kitchens, bathrooms and utility spaces. These requirements would not eliminate all noise problems, but perhaps three quarters of dwelling occupants would be satisfied most of the time. A common noise source not adequately guarded against by these requirements would be a stereo system played at high level.

Specification of Sound Insulation

Having established sound insulation criteria, the next step is to try to achieve them in buildings. The usual mechanism for specifying the properties of buildings, especially multi-unit dwellings, is a set of building specifications or regulations administered by municipal building authorities, lending institutions or other agencies. Generally the control point is the issuance of a building permit or equivalent, which is done on the basis of a set of plans and specifications. At this stage one cannot guarantee that the difference in sound level between units in the finished building will conform to a particular requirement, but one can at least require that the major separating components -- the party walls and floors -- are potentially adequate. To ensure that these potentials are realized in the final construction is somewhat more difficult. It seems possible, however, to introduce some qualitative requirements to prevent the partitions being ruined by service openings, lack of caulking and similar defects.

Finally it should be reiterated that, in addition to airborne sound insulation which is the subject of this note, similar considerations now apply also to the impact noise insulation provided by floors. Plumbing noise, which is also of major importance, cannot yet be handled by quantitative noise limits, but at least it might be possible to specify installation of the plumbing equipment in such a way as to minimize transmission from one dwelling unit to another.

References

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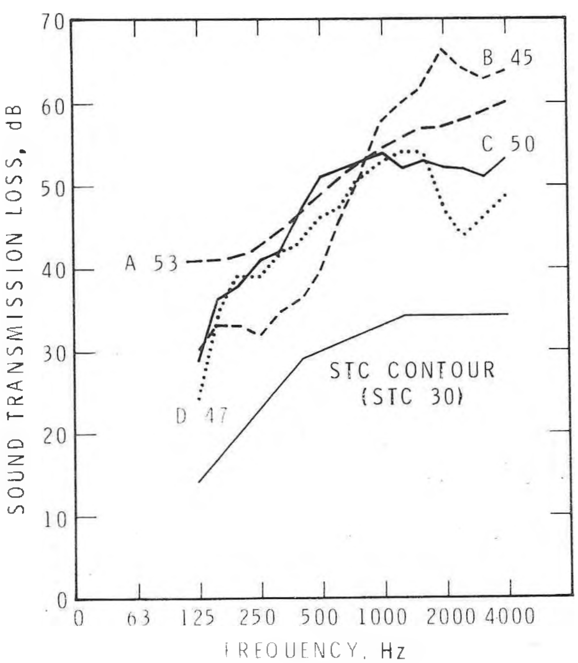

FIG. 1. SOUND TRANSMISSION LOSS CURVE OF FOUR REPRESENTATIVE WALLS.

A. 9-in. block wall, plastered both sides. 80 lb/sq ft.

B. 6-in. lightweight block, aggregate, gypsum board adhered to both sides. 46 lb/sq ft.

C. Two leaves, 1/2-in. and 2- x 1/2-in. gypsum board, metal studs, absorption. 6.7 lb/sq ft.

D. Two leaves, 5/8-in. gypsum board, metal studs, absorption. 5.4 lb/sq ft.