SUBJECTIVE RATING OF PARTY WALLS

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ABSTRACT

Results of a field survey of 98 subjects have been analysed and sound isolation measures have been compared to establish the influence of residential noise levels and non-acoustical factors on subjective judgements. A procedure is considered for estimating the properties of an ideal wall.

SOMMAIRE

Les résultats d'une étude in situ réalisée auprès de 98 ménages ont été analysés et des mesures d'isolation acoustique ont été comparées en vue de déterminer l'influence des niveaux de bruits et de facteurs non-acoustiques dans une habitation sur l'opinion subjective. Une méthode est envisagée pour évaluer les propriétés du mur idéal.

Standard procedures for measuring the transmission loss of party walls have existed for many years, but until quite recently no comprehensive field studies have attempted to relate adverse subjective responses to acoustical measures of sound insulation. Indeed, it has not been clear that it would be possible to establish strong correlations between acoustical measures such as STC and subjective responses. The present paper reports the results of a pilot survey consisting of interviews with 98 subjects and acoustical measurements of their 49 common walls. A more complete description is available.[1] In the absence of previous North American studies of this type the results of such a pilot study may be of general interest; it will be some time before complete results will be available from the more extensive studies now in progress.

PROCEDURE

After an introductory letter, subjects, if agreeable, were interviewed in their homes by trained personnel. The survey was presented as a building satisfaction survey, and initial questions made no mention of noise or acoustical problems. The responses to most subsequent questions were in the form of seven-point Likert-type scales. After each successful interview, permission to make acoustical measurements at a later date was requested. Finally, when interviewed subjects in adjacent homes both gave their consent, the acoustical measurements were made. These included the recording of A-weighted noise levels for one 24-hour period in each subject's living room. The transmission loss of each party wall was measured in 1/3 octave bands from 100 to 4000 Hz, in general following the approach of ASTM E336.[2] By tape recording test levels on each side of the wall, using a rotating microphone as well as sound decays in the receiving rooms, subjects were disturbed for less than half an hour. Acoustical data were processed by computer and several sound isolation measures were calculated.

Sound transmission loss in each 1/3 octave band is calculated as the difference in the space-averaged reverberant field sound levels in source and receiving rooms plus ten times the logarithmic ratio of the common wall area to the total receiving room sound absorption. From these individual transmission loss values an over-all Sound Transmission Class, STC, was calculated according to ASTM E413.[3] The Noise Isolation Class,[2] NIC, was calculated from the noise level differences between the two rooms. Also calculated were A-weighted level differences measured between the two rooms, referred to as DA when using a pink source spectrum and as DAS when using the source spectrum proposed by Schultz and incorporated in ASTM method E597.[4] An A-weighted sound transmission loss, STA, was calculated by summing the A-weighted transmission loss values as described in the equation below:

$$STA = 10 \log \left\{\frac{1}{17} \sum_{i=1}^{17} 10^{(-TL_i + W_i)/10}\right\}$$

Values of the British Aggregate Adverse Deviation, AAD,[5] were also calculated. This measure is the sum of all deviations below a fixed two-segment reference contour and ignores bands where measured performance is above the reference contour. Statistical analyses of the combined data were carried out using the Statistical Package for Social Sciences.

SAMPLE CHARACTERISTICS

All subjects were residents of condominiums in the Ottawa area. Most were owners (91.8%) and lived (83.7%) in two-storey row-housing type developments. A satisfactory split between male (42.9%) and female (57.1%) respondents was obtained. In the summer of 1981, when data were gathered, the mean reported value of the homes was $41,433, the mean family income was $27,245, and the average subject was 37.4 years old, had 13.7 years of formal education, and had lived in his home for 45.6 months.

Measured STC values ranged from 39 to 60, with a mean of 51.2. Figure 1 shows the mean measured transmission loss characteristics of the 49 walls. Mean A-weighted L_{eq} values in the subjects' living rooms were 55.2 dBA for daytime (7 a.m. to 10 p.m.), 45.2 for night time (10 p.m. to 7 a.m.), and 53.0 dBA for the complete 24-hour period. Although a quite large range of measured party wall sound isolation values was obtained, the responses of this relatively small sample of subjects cannot be confidently generalized to large populations.

RELATIONS WITH ACOUSTICAL FACTORS

Figure 2 shows the results of correlations for four survey responses and various measures of party wall sound isolation. Among transmission loss type measures the British AAD tended to produce slightly higher correlations than the A-weighted STA, which in turn produced higher correlations than did STC values. The level difference measures DA, DAS, and NIC tended to produce lower correlations than the corresponding transmission loss measures. Although it is often suggested that actual differences in sound level would correlate best with subjective responses, the present results contradict this hypothesis. Level difference measures assess the steady-state

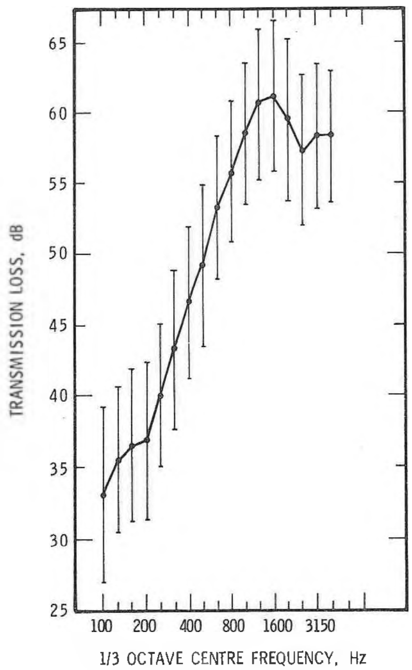

Figure 1. Mean, ± standard deviation transmission loss vs frequency

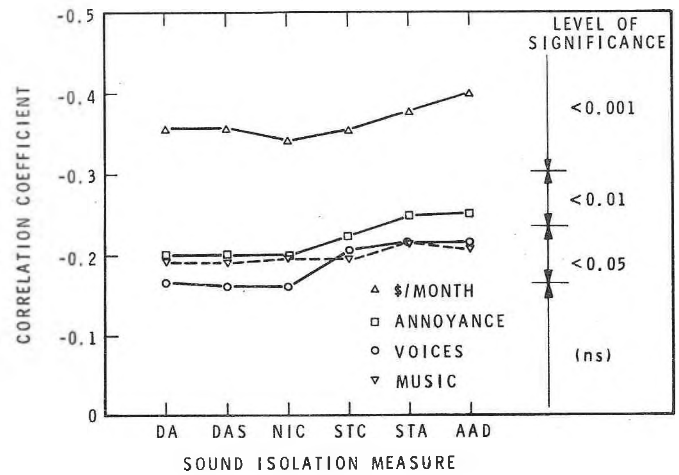

Figure 2. Correlations of four responses and six sound isolation measures

reverberant field sound levels in each room. It may be that the transient peak levels and the intervening common wall transmission loss are the more important parameters. This would explain the greater success of the transmission loss measures.

As in a recent study by Langdon,[6] more factual, less emotional responses correlated better with acoustical measures. In Fig. 1 it may be seen that the number of dollars per month that subjects are willing to spend to reduce annoying noises from neighbours correlates much more strongly with acoustical isolation measures (up to a correlation coefficient of 0.40) than do annoyance responses. In Langdon's study the highest correlations were obtained with responses to a question that simply asked subjects to rate the quality of their sound isolation. In the present study the interviewer came to believe that although some subjects acknowledge excessive noise intrusion, they are reluctant to say (in effect) that a particular neighbour is annoying. The situation is quite different from that for environmental noise surveys, such as those concerning traffic noise,[7] where subjects readily describe noise as annoying because there is usually no personal connection with the source of the noise.

Table 1 shows a selection of responses: some significantly relate only to measured STC values, others significantly relate only to L_{eq} values measured in the neighbour's home, and yet others significantly relate to both STC and L_{eq} values. Each annoyance response is thus related to a different set of predictor variables. The over-all annoyance measure was obtained as a result of a factor analysis of 22 annoyance and sleep disturbance responses. In traffic noise studies[8] this widely used technique produced composite response scales that were more reliable than single

Table 1

Correlations of Responses and STC, 24-hour L_{EQ}, and Combinations of STC and 24-hour L_{EQ}

Response	STC	L_{EQ}^{24}	STC+L_{EQ}^{24}
Satisfaction with Building	(ns)	-0.208	
Annoyance, Neighbours Either Side	(ns)	0.254	0.283
Annoyance, Neighbours' Voices	-0.210	0.213	0.316
Annoyance, Neighbours' Music	-0.196	(ns)	0.346
Annoyance, Neighbours' Children's Sounds	(ns)	0.331	0.333
Over-all Annoyance	-0.222	0.245	0.350

Table 2

Multiple Correlations with 24-hour L_{EQ} and Three Different Transmission Loss Measures

Type of Annoyance	STC+L_{EQ}^{24}	STA+L_{EQ}^{24}	AAD+L_{EQ}^{24}
Neighbours' Voices	0.316	0.316	0.312
Neighbours' Music	0.246	0.260	0.252
Neighbours' Children	0.333	0.334	0.332
Over-All Annoyance	0.350	0.359	0.358

item responses. In the present study the resulting composite annoyance scale (overall annoyance) was less successful in increasing correlations with STC values. The present responses, each having somewhat different characteristics, were unlike those observed in traffic noise surveys where many annoyance responses seem to be somewhat similar parallel measures.

The results of multiple correlations of several responses and combinations of acoustical measures are given in Table 2. It may be seen that all three transmission loss measures produced very similar correlation coefficients when combined with the neighbour's L_{eq}. Tables 1 and 2 show that it is not only the properties of the common wall but also the amount of noise the neighbour creates that influence negative responses. Neither the noise level measured in the subject's own home nor the difference in L_{eq} values between two homes was significantly related to annoyance responses. Thus, it is not possible to conclude that one's own noise produces a masking effect that reduces annoyance with neighbours' noises.

COMPARISONS WITH OTHER STUDIES

While the present work was being carried out, the results of two similar but larger studies were published.[6,9] By converting the Dutch and British sound isolation measurements to approximate STC values, comparisons were made with the present work. Figure 3 compares the percentage of subjects "moderately or more annoyed" from the present study with subjects "bothered quite a lot" or "very much" from Langdon's study and subjects bothered ("Hinder") from the Dutch study. Although the Dutch study showed reasonable agreement with the present results, Langdon's results suggested greater annoyance for lower STC values. This may be due in part to the difficulty of making even approximate conversions from AAD values to STC values. Accordingly, Langdon's results were compared with the present results in terms of measured AAD values for both surveys, as shown in Fig. 4. Here, the agreement is improved and the three studies seem to indicate reasonably similar trends, although there were differences in the questions asked.

NON-ACOUSTICAL FACTORS

Multiple regression analyses were performed to determine which non-acoustical variables were significant predictors of subjective responses. The two acoustical variables, STC and the neighbour's 24-hour L_{eq}, were forced in first, then non-acoustical predictors were added in a step-wise manner according to the amount of unexplained variance for which each accounted. Although the significant predictor variables varied for each response, several non-acoustical variables were consistently related strongly to annoyance responses. Negative responses increased with: length of occupancy, reported value of the home, number of daytime periods home per week, and Spielberger's measure of stress.[10] Increased feelings - of satisfaction with their building, of considerate neighbours, and of help from building officials - led to decreased annoyance in a number of responses.

The fact that annoyance increased with length of occupancy contradicts the concept of noise-sensitive people moving away from noisy homes. This and the influence of the number of daytime hours at home per week suggest that increased exposure to annoying neighbour noises leads to increased annoyance. Although more considerate neighbours would be expected to lead to reduced annoyance, it was also noted that perceived considerateness was significantly related to the measured STC of the party wall, suggesting that the acoustical quality of the wall influences the

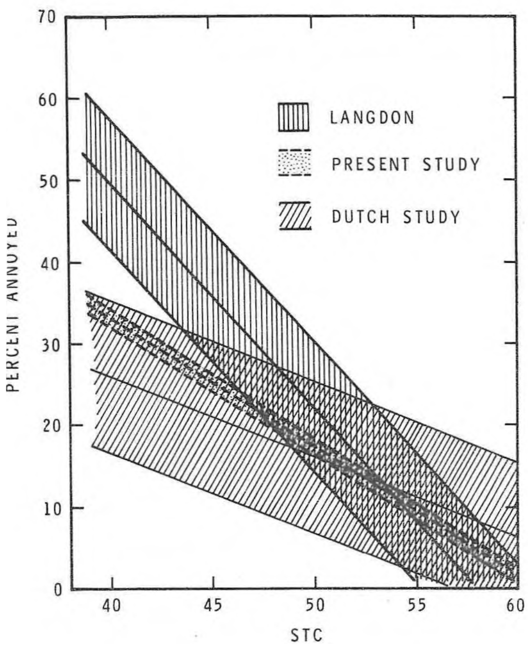

Figure 3. Comparison of mean ±1 standard deviation of percentage annoyed vs STC for three studies

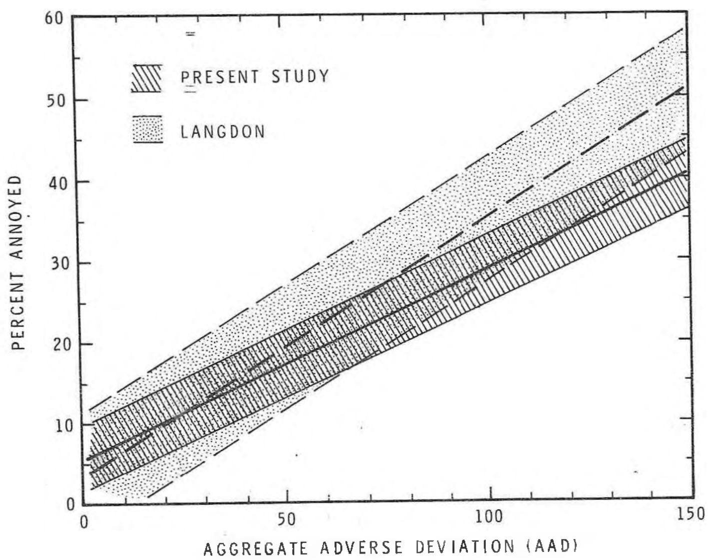

Figure 4. Comparison of mean ±1 standard deviation of percentage annoyed vs AAD for two studies

perceived considerateness. One might expect in the present context that inconsiderate neighbours would have noisier homes; the L_{eq} of the neighbour's home was not, however, significantly related to how considerate each was thought to be. This is strong evidence that in this study at least the inadequacy of the party wall was a source of social disruption in that neighbours were thought to be inconsiderate when it was really the party wall that was at fault.

The cost of improved party-wall sound isolation is frequently given as a reason for not building better walls. Although cost analyses relating wall costs to STC values have not been performed, the present results indicate clearly that subjects are prepared to pay for improved sound isolation. Figure 5 plots the reported dollars per month that subjects were prepared to spend to reduce annoying neighbour noises as a function of measured STC of the wall. As in all individual subject responses of this type, the scatter is quite large, but in this case there is a highly significant trend. The mean result shows a decrease from about $9 per month (1981 dollars) at STC 45 to essentially zero at STC 60. This suggests that an STC of about 60 is nearly ideal.

AN IDEAL WALL

Further analysis of the data produced another tentative suggestion for what is required of an ideal party wall. Correlations of responses and individual 1/3 octave transmission loss values reveal that significant correlation coefficients are generally found only in the approximate region of 100 to 1000 Hz. Correlations were strongest from 125 to 400 Hz, as shown in Fig. 6, for the dollars per month response.

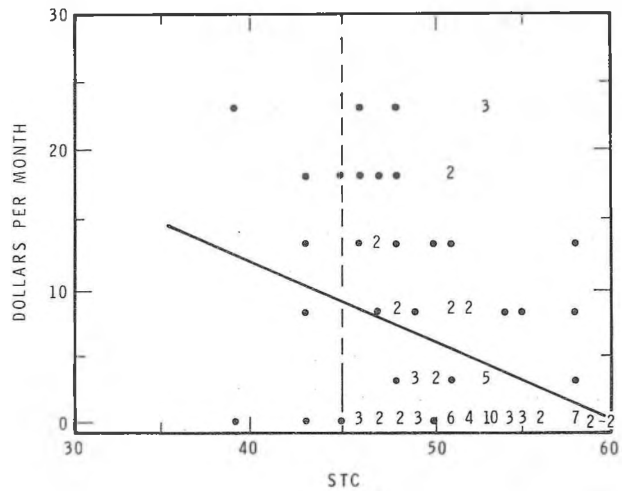

Figure 5. Regression of dollars per month vs STC values

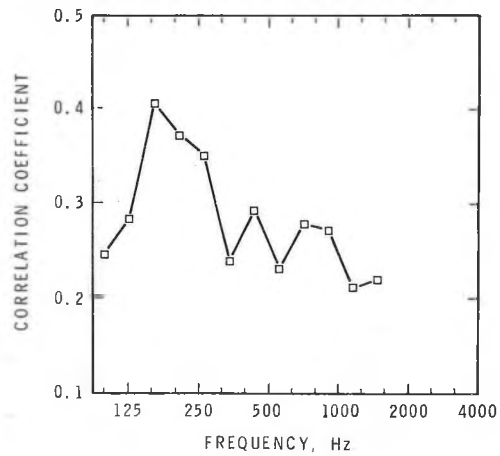

Figure 6. Correlations between dollars/month response and 1/3 octave TL values

The reason for this appears to be that it is only in this 100 to 1000 Hz frequency region that, on average, subjects will hear their neighbours.

Figure 1 shows that the mean measured transmission loss increases with frequency in the 1000 Hz region. One can assume that at 1250 Hz the mean transmission loss has reached an approximately ideal value; above this point responses were generally not related significantly to 1/3 octave transmission loss values, presumably because subjects could not hear their neighbours. This leads to the conclusion that at 1250 Hz a transmission loss of 60 dB can be considered ideal. Above this frequency a conservative estimate is that 60 dB transmission loss is required in all bands. The mean measured values were lower than this in most bands.

Determining an ideal wall transmission loss at lower frequencies requires a maximum typical source room spectrum and a threshold of detectability in the receiving room. The difference between the two would lead to the necessary transmission loss values for an ideal wall in the frequency region up to 1000 Hz. The 10 phon equal-loudness contour[11] was taken as the threshold of detectability in the receiving room. Although normal background sound levels would exceed this level, such noises are usually variable in nature and the 10 phon contour would be a better estimate of the threshold above which, over long time periods, intruding noises could be detected. Knowing that at 1250 Hz an ideal transmission loss of 60 dB is required, one can calculate a maximum typical source room level of 73 dB. This is composed of a 10 dB threshold of detectability (from the 10 phon contour), a 60 dB transmission loss, and an average 10 log (S/A) of 3 dB. If a reasonable maximum typical source spectrum shape is assumed, the maximum source room levels in the other bands can be determined. The maximum typical source spectrum was assumed to be pink because this is generally thought to be typical of music, and measurements of appliance noise[12] indicate that equal maximum levels are possible in all of these bands from a combination of appliances. Thus, the maximum typical source room levels are 73 dB in the bands from 100 to 1250 Hz. If one subtracts the 3 dB average 10 log (S/A) correction, then the difference between these levels and the 10 phon threshold gives the transmission loss values required of an ideal wall. If a higher hreshold of detectability had been selected, the various levels would be higher but he calculated ideal wall TL values would be quite similar.

The resulting ideal wall transmission loss characteristic is plotted in Fig. 7 nd compared with the STC contour. If, instead of assuming that a 60 dB transmission oss is required in all bands above 1000 Hz, one assumes a source spectrum that drops ff at 6 dB per octave above 1600 Hz, the plotted points in Fig. 7 result. The two pproaches give very similar high frequency results. Below 800 Hz the calculated deal wall closely follows the STC contour. The ideal wall characteristics orrespond to an over-all STC of 59, which is close to the STC 60 value obtained for n ideal wall (Fig. 5). Such a wall would be ideal in that responses would no longer e significantly related to measures of party wall sound isolation, and in a ractical sense subjects would no longer hear intruding neighbour noises.

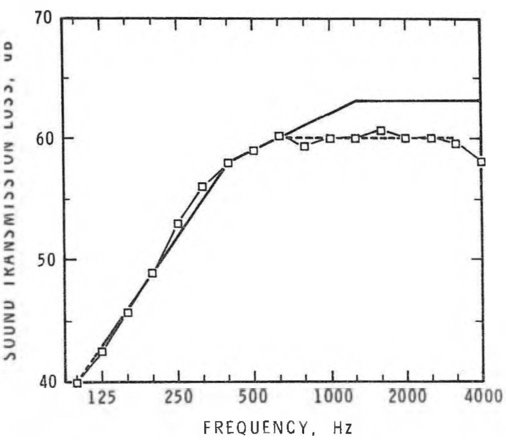

Figure 7. Calculated ideal wall transmission loss characteristic (points), STC contour (solid line), and modified STC countour (dashed line)

An alternative approach that led to some agreement with these results was also considered. Regression analyses were performed with the dollars per month response as the dependent variable and the 1/3 octave transmission loss values as predictors. It was thus possible to calculate the transmission loss in each band for which the mean trend indicated that subjects were prepared to pay zero dollars per month to reduce annoying neighbour noises. This approach produced remarkable agreement with the results of Fig. 7 for the few bands where the correlation coefficients shown in Fig. 6 were highest. Thus, it seemed to substantiate the calculated ideal wall characteristics within the limits of the present data.

One is tempted to suggest modifications to improve the STC contour shown by the dashed contour in Fig. 7: change the frequency range one band lower to include bands from 100 to 3150 Hz, and lower the high frequency plateau by 3 dB. Lowering the over-all range covered by one band would also bring it into agreement with the ISO rating scheme.[12] Such suggestions are only very tentative and will be explored more thoroughly when data from the complete main survey become available.

CONCLUSIONS

This pilot survey shows that subjective responses to noise from neighbours can be related in a statistically significant manner to both measures of party wall sound isolation and noise levels in the neighbour's home. Future studies should elicit more factual, less emotional responses (e.g., how frequently subjects hear their neighbours) that correlate more strongly with acoustical measures. Transmission-loss type measures tend to be superior to the corresponding noise level difference type measures, and noise levels in a subject's own home were not found to reduce annoyance by masking neighbours' noises. Inadequate party wall sound isolation is clearly recognized by residents as a degradation of the quality of their homes, and may be a source of social disruption in multiple residence buildings. It is demonstrated that the results of this type of survey can be used to derive the characteristics of an ideal party wall.

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