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Sound transmission through concrete blocks with attached drywall

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The furring system for attaching drywall to concrete block walls must be chosen with care if sound transmission is not to be increased at low frequencies. Once drywall is attached to a normal-weight block wall, sound transmission loss is increased above a frequency f_x given by $f_x = K/(Md)^{1/2}$. (M is the surface mass of the drywall, kg/m^2 , and d is the depth of the cavity behind it, m. K is 108 for an empty cavity and 60 for a cavity filled with fibrous sound-absorbing material.) Sound transmission loss data measured for a number of 190-mm normal-weight concrete block wall systems are presented to support the above result. Walls were measured with drywall systems mounted on different furring types on one side and on both sides. The cavities behind the drywall were either empty or filled with glass fiber. A simple, limited prediction scheme that can be used to recreate the data is described. The measurements in this paper present a consistent picture of the influence of the depth of the air space between the drywall and the block, and the presence of sound-absorbing material in the cavity.

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INTRODUCTION

This paper presents results from a series of measurements of sound transmission through concrete block walls with drywall attached on five types of furring systems. Although block walls have been in use for many years, there was and still is a need for new measurements. There are several reasons for this.

There are differences among the transmission loss (TL) data presented in the literature for block walls.¹⁻⁵ Improvements in measurement techniques that render old data obsolete, and differences in materials, construction and laboratory facilities, explain some of these differences. Whatever the reason, these differences make it difficult to see trends and draw conclusions from published data.

Many building codes in North America require relatively low values of sound transmission class (STC) for party walls (usually 45 or 50), but recently there has been an increased demand for greater sound insulation between homes. A preliminary survey in Canada suggested that occupants of apartments would prefer to have walls with STC 55 or greater separating them from their neighbors.⁶ Preliminary, unpublished results from a larger survey confirm this value. In response to the demand for increased acoustical privacy, STC requirements for party walls and floors in California⁷ and Canada⁸ have been increased to 50.

There is a lack of published data on block walls with high sound transmission class (STC) ratings. Many of the results in the literature are for bare blocks or blocks that have simple finishes such as paint or plaster and do not usually have very high STC ratings. Block walls are commonly finished by attaching layers of drywall to them, either directly to the block surface or supported on furring strips. Using furring strips can increase transmission loss and sound transmission class. The literature provides no consistent set of transmission loss data for comparing different finishing methods, especially at low frequencies. The measurements in this paper present a consistent picture of the

influence of the depth of the air space between the drywall and the block, and the presence of sound-absorbing material in the cavity.

Measurements reported in the literature typically only extend down to 125 Hz [100 Hz if the tests were done according to ISO 140 (Ref. 9)]. Low-frequency sound, however, is commonly audible and a cause for complaint in apartment buildings. Also, to reduce sound from very noisy machine rooms, walls with high sound transmission loss at low frequencies are often necessary. To meet this need for low-frequency data, results presented here extend down to the 63-Hz one-third octave band.

I. EXPECTED EFFECTS CAUSED BY ADDING DRYWALL

A. Mass-air-mass resonance

The transmission loss curve for a cavity wall shows a dip at a frequency called the mass-air-mass resonance frequency, f_{mam} . At and around this resonance, sound transmission losses fall below those predicted by mass law for the total mass in both layers. For an air-filled cavity, this frequency may be calculated from the expression:¹⁰

$$f_{\text{mam}} = (1/2\pi)(\rho_0 c^2/M_{\text{eff}}d)^{1/2}, \quad (1)$$

where ρ_0 = density of air, kg/m^3 ; c = speed of sound in air, m/s ; d = the distance between the two layers, m; and M_{eff} is the effective mass of the wall, kg, and is given by:

$$M_{\text{eff}} = m_1 m_2 / (m_1 + m_2), \quad (2)$$

where m_1 and m_2 , kg, are the masses of the two layers forming the cavity.

Substituting typical values of physical constants gives

$$f_{\text{mam}} = 60/(M_{\text{eff}}d)^{1/2}. \quad (3)$$

The mass-air-mass resonance frequency, in typical construction, occurs at mid or low frequencies. With block walls, it is often the reason for a reduction in transmission loss and STC when drywall is supported too close to the

block on furring strips. The effect is not always obvious if the range of measurement frequencies is not low enough.

In data presented by Quirt,¹¹ the position of the mass-air-mass resonance is predicted correctly by Eq. (3). In Ref. 12, however, readers are advised to use a constant of 90 instead of 60 to predict resonances that agree better with measurement.

According to Ref. 13, adding drywall supported on furring to a wall increases sound transmission loss relative to the bare wall above the mass-air-mass resonance frequency. There is, however, no mention of a decrease in transmission loss below this frequency.

B. Effect of sound-absorbing material on mass-air-mass resonance

Adding sound-absorbing material to the cavity in a double wall lowers the mass-air-mass resonance frequency; how far is not clear. In Ref. 13, the caption to Fig. 11.24 states that f_{mam} should be multiplied by 0.85 when sound-absorbing material is present in the cavity. This assumes a reduction in sound speed because the behavior of the air in the cavity changes from adiabatic to isothermal. This would change the constant in Eq. (3) from 60 to 51. Elsewhere in the same textbook, Schultz¹⁴ says that the resonance frequency will be lowered by a factor $1/\sqrt{2}$ because of isothermal conditions in the sound-absorbing material. This factor changes the constant in Eq. (3) from 60 to 43.

The work of Fothergill and Alphey¹⁵ shows many of the same effects to be discussed here, but the authors conclude that Eq. (3) can be used to predict the mass-air-mass resonance frequency to within a one-third octave band even when there is mineral fiber in the cavity.

Fahy¹⁰ discusses the influence of sound-absorbing material in a cavity wall and shows that transmission loss will depend on the flow resistance of the sound-absorbing material. He does not give a simple formula for predicting the shift in mass-air-mass resonance. Sharp's model¹⁶ for a cavity wall assumes there is sound-absorbing material in the cavity and does not predict any reduction of sound transmission loss around the mass-air-mass resonance. The expression he gives for the mass-air-mass resonance gives a result about 1.33 times higher than that given by Eq. (3). He denotes this frequency as f_0 and uses it to calculate where the transmission loss curve for the double wall begins to increase above that for the single layer wall of equivalent weight. Thus Sharp's f_0 functions in the same way as the crossover frequency, f_x , defined later.

The damping due to sound-absorbing material reduces the effect of cavity resonances on transmission loss at mid and high frequencies. Fibrous materials in the thicknesses normally used in wall cavities are not very absorptive at low frequencies and may have little influence on the depth of the mass-air-mass resonance. There is, however, no information available in the literature on this point.

The frequency of the mass-air-mass resonance and the depth of the resonance are important pieces of information for designing block and other types of cavity walls. It is unfortunate that the literature does not give clear information on this topic.

II. DESCRIPTION OF MEASUREMENT FACILITIES AND PROCEDURES

Measurements were made in the sound transmission loss suite at the National Research Council Canada in accordance with ASTM E90 (Ref. 17). For wall transmission loss measurements, the source room has a volume of 65 m³ and the receiving room has a volume of 250 m³. Wall specimens measure 2.44 × 3.05 m and are constructed on a steel, wheeled frame that fits between the rooms. The frame is lined with wood and is not rigidly attached to either room. Each room has fixed and rotating diffusers and four corner-mounted loudspeaker systems fed with independent pseudorandom noise sources. To measure transmission loss, white noise is fed to the loudspeakers in the source room. Pink noise is used to measure decays in the receiving room. Nine electret condenser microphones sample the sound fields in the central volume of each room. Measurements are controlled by a computer system interfaced to a GenRad 1921 real time analyzer and cover the one-third octave band frequencies from 63–6300 Hz.

A. Low-frequency measurements

The influence of small room volumes on transmission loss measurements is not well understood. According to ASTM E90, for valid transmission loss measurements, room volumes should exceed 80 m³. This number is based on a somewhat arbitrary requirement that the rooms should have about 20 modes in the lowest band used for measurement. The lowest frequency used in the calculation of STC is 125 Hz, which leads to the 80-m³ figure. Rooms smaller than this are permissible according to ISO 140 (Ref. 9) where the lowest frequency band required is 100 Hz.

Earlier work at NRC (Ref. 18) compared conventional techniques for transmission loss measurement with a technique based on sound intensity. For sound intensity transmission loss measurements, the 250-m³ room was the source room. In the 63-Hz one-third octave band, there are about 8 modes in the 250-m³ room and 3 in the 65-m³ room. Conventional measurements gave greater transmission loss values at low frequencies than did intensity-based measurements. Differences found were about 4 dB at 63 and 80 Hz and about 2 dB or less up to 500 Hz. The intensity-based technique might be considered more reliable because only the large room influences the measurements; however, the conventional technique is fully automated in the NRC laboratory. The convenience and the consistent differences between the two techniques justifies the use of the conventional technique for the purposes of the work and at the frequencies used here.

TABLE I. Physical data for the concrete blocks used in the measurements.

Thickness (mm)	Weight per block (kg)	Wall weight (kg/m ²)	Flow resistance (mks ohms)
190	17.5	236.2	1.8×10^6
140 (75% solid)	17.8	240.1	1.6×10^6
140 (100% solid)	22.3	300.7	2.2×10^6

TABLE II. Sound absorbing material used in cavities.

Type	Thickness (mm)	Surface weight (kg/m ²)
AF300	19	0.4
AF300	38	0.7
R8	65	0.83
R12	90	1.16

Bias errors should be constant for the laboratory. Microphones, speakers, and other equipment are in fixed positions and measurements repeat within 0.5 dB. Thus trends in and differences between the low-frequency transmission loss measurements for the different specimens should be valid.

III. MATERIALS

The face dimensions of the blocks were 190 mm high by 390 mm long, the standard size. Table I gives some other physical parameters including flow resistance. Blocks were laid in a running bond pattern. On every second course, wire trusses were embedded in the mortar to give horizontal reinforcement. The 13- and 16-mm drywall used weighed 9.2 and 10.7 kg/m², respectively. The glass fiber materials used were manufactured by Fiberglas Canada Ltd. The designations and properties are given in Table II. The flow resistivity of the materials was not measured.

FIG. 1. Cross sections of the furring and studs used to support drywall. (a) 13-mm resilient metal channels, (b) 40-mm wood strapping, (c) 65-mm steel studs, (d) 50-mm Z bars, and (e) 75-mm Z bars.

A. Methods of attaching drywall

Four types of furring were used to attach drywall to the blocks. These were 13-mm resilient metal channels, 40-mm wood furring, and 50- and 75-mm resilient metal Z bars. All metal furring systems were formed from 0.5-mm-thick galvanized sheet metal. Furring strips were installed 600 mm apart. Z bars are not commonly used for acoustical purposes but they offer an alternative to more common techniques, such as steel studs. They are no more difficult to install than 13-mm resilient channels yet, as will be seen, offer better system transmission loss because of the greater cavity depth. 65-mm steel studs with top and bottom tracks were also used

FIG. 2. Transmission loss for 190-mm block wall with a single layer of 16-mm drywall on one side only. There is no sound-absorbing material in the cavities. (a) RC13—13-mm resilient channels; ZC50 and ZC75—50- and 75-mm Z bars; and (b) WF40—40-mm wood furring; SS65—65-mm steel studs.

to support drywall. The studs were not in contact with the blocks and were installed 600 mm apart. Figure 1 shows cross sections and dimension of the furring and the studs. For each method of drywall attachment, the wall was tested with the cavity empty or filled with sound-absorbing material. Drywall was also screwed directly to the blocks.

IV. RESULTS FOR 190-MM BLOCK WALLS

Complete details and transmission loss values for all the wall systems measured can be found in Ref. 19. Selected results are presented here to illustrate the effects found.

A. Effect of increasing air space

Figure 2 shows the effect of increasing the depth of the airspace when a single layer of drywall is attached to the

block on one side only. It is clear that the mass-air-mass resonance can seriously reduce the transmission loss of the wall at the important low frequencies, even if this does not always result in a lower STC. Increasing cavity depth clearly moves the mass-air-mass resonance to lower frequencies, as predicted. Note the peak in the transmission loss curve at 200 Hz for the 40-mm wood furring case. Screwed to the stiff wood furring, the drywall behaves differently than it does when connected to the resilient metal supports. There are no similar peaks in the transmission loss curves for the resilient steel furring.

The coincidence dip due to the drywall is evident in the figures. In the case of the wood furring, the solid connections to the drywall reduce the transmission loss at the coincidence dip to about the same as that for the bare block wall.

FIG. 3. Transmission loss for 190-mm block walls with a single layer of 16-mm drywall on one side only. Results are for the cavity empty and filled with glass fiber (gf). In each case the bare block result is the dotted line (STC 50). (a) 13-mm resilient metal channels, (b) 40-mm wood strapping, (c) 50-mm Z bars, and (d) 75-mm Z bars.

B. Effect of adding sound-absorbing material

Figure 3 shows a selection of results for drywall finishes with and without sound-absorbing material in the cavity. The presence of the sound-absorbing material moves the mass-air-mass resonance to a lower frequency, as expected. The magnitude of the change in frequency of the mass-air-mass resonance is discussed later. The addition of sound-absorbing material in the cavity usually results in higher STC ratings and improved transmission loss at frequencies above the mass-air-mass resonance.

C. One-side versus two-side treatment

Figure 4 shows a selection of results for the block wall with 16-mm drywall applied on one side and on two sides of

the block using the same furring method. The addition of the drywall to the second side further decreases the low-frequency transmission losses and further increases the high-frequency transmission losses. Thus, in some instances it might be better to leave one side of the blocks unfinished, except for paint or plaster, to ensure good low-frequency transmission loss.

D. Attaching drywall directly

It might be thought that drywall screwed or glued directly to the surface of the blocks would effectively become one with the block. This is not normally so. There is usually an air gap behind the drywall, although it is small. With the normal number of screws or patches of glue used to attach

FIG. 4. Transmission loss for 190-mm block walls with a single layer of 16-mm drywall on one side and on both sides using different furring methods. In each case the bare block result is the dotted line (STC 50). (a) 13-mm resilient metal channels, (b) 40-mm wood strapping, (c) 50-mm Z bars, and (d) 65-mm steel studs.

FIG. 5. Transmission loss for 190-mm block walls with a single layer of 16-mm drywall screwed directly to one side only and to both sides. The bare block result is the dotted line (STC 50).

the drywall, it can vibrate fairly independently of the block. As shown in Fig. 5, a mass-air-mass resonance still occurs and transmission loss and sound transmission class can be reduced. As in the case of the solid wood strapping transmission loss around and above the coincidence frequency is markedly reduced: in this case to below that for the bare wall.

V. DISCUSSION OF 190-MM BLOCK RESULTS

A. Crossover frequency

In the data presented here, it is not always easy to say precisely at what frequency the mass-air-mass resonance, f_{mam} , occurs. Sometimes the resonance is not well enough defined; sometimes it is below the lowest frequency measured. Data from other measurement series usually do not extend to low enough frequencies to allow estimation of this frequency either. To get around this difficulty, the idea of a crossover frequency, f_x , was used. This is defined as the frequency where the transmission loss curve for the block wall with drywall attached crosses the transmission loss curve for the bare wall. For cavities without added absorptive material, f_x was found to be about 1.8 times higher than f_{mam} calculated using Eq. (3). The crossover frequency for absorption-filled cavities was found from a regression analysis of data in this study and in Refs. 2-5. The factor of $1/\sqrt{2}$ given by Schultz¹³ applied to Eq. (3) to account for the effect of sound absorbing material gave a reasonable fit to the data but a factor of $1/1.8$ was best. Thus the following equation was used to predict the crossover frequency:

$$f_x = K / (M_{\text{eff}} d)^{1/2}, \quad (4)$$

where K is 108 for an empty cavity and 60 for a cavity filled with sound-absorbing material. M_{eff} is given by Eq. (2) but, for block walls, it can be taken as the mass of the drywall because the blocks are so much heavier than the drywall.

FIG. 6. Measured versus predicted crossover frequency for empty wall cavities (○) and those containing sound-absorbing material (●).

Figure 6 plots measured values of crossover frequency against values calculated using Eq. (4).

Equation (4) should apply to blocks with material having similar flow resistivities to those used here, that is normal-weight blocks. It is likely that with more porous blocks the effective depth of the cavity will be increased, but this was not investigated in this work. This equation can be used to select cavity depths to ensure that the transmission loss is not reduced at important frequencies, for example at 125 Hz to ensure that STC is not reduced.

The presence of sound-absorbing material in the cavity might have been expected to effectively reduce the depth of the mass-air-mass resonance. As Fig. 3 shows, this is not the case for the materials used here.

The data reported in Ref. 15 does not show any influ-

TABLE III. Measured STC ratings for 190-mm block wall systems. Letter codes in column 1 identify methods of attaching 16-mm gypsum wallboard in column 2. In column 2, the following codes are used: WF—wood furring, GFB—glass fiber batts, RC—resilient metal channels, ZC—Z bars, SS—steel studs. The number following these codes is the thickness of the material or the airspace, in mm.

Side 1	Side 2								
	Bare	A	B	C	D	E	F	G	H I
Bare	50								
A Direct	50	49							
B WF40	53		54						
C WF40_GFB40	55	57	58	59					
D RC13	51			58	49				
E RC13_GFB19	54				52	49			
F ZC50	52	52					52		
G ZC50_GFB50	59					59	59	64	
H SS65	58								57
I SS65_GFB65	60	61							65 72
J ZC75	57	57							59 68
K ZC75_GFB75	61	62	66						73

FIG. 7. Average difference in transmission loss between the bare wall and the wall with different surface treatments on one side only. The dotted curves are the mean ± 1 standard deviation for each treatment. The type of drywall support is indicated in the figure.

FIG. 8. Average difference in transmission loss between the bare wall and the wall with different surface treatments on one side only. The dotted curves are the mean ± 1 standard deviation for each treatment. The type of drywall support is indicated in the figure.

ence due to the presence of glass fiber. There were, however, only three cases where there should have been an effect, and the type of glass fiber used was probably quite different from that used here since it was laminated to the drywall.

VI. SIMPLE METHOD FOR PREDICTION OF 190-mm BLOCK RESULTS

A. Explanation of the method

Sharp's model¹⁶ calculates sound transmission loss for double or triple walls by simply adding terms to the trans-

mission loss for the bare wall. This additive approach to prediction was investigated with this data set. The assumption was made that each time a layer of gypsum wallboard on some support is added to a bare block wall surface, it has the same relative effect no matter what is on the other side of the wall. That is, if some method of drywall attachment gives a change in transmission loss of X dB in some frequency band when used on one side of the wall, it will give a change of $2X$ dB when used on both sides. Thus for each drywall mounting technique there exists a difference transmission loss (ΔTL)

TABLE IV. Mean change in transmission loss, ΔTL , relative to the bare block for different methods of adding 16-mm gypsum wallboard. Letter codes to identify furring methods are the same as those used in Table III.

Frequency	B	C	D	E	F	G	H	I	J	K
63	-1.3	-3.4	-0.2	-2.3	-3.7	-5.1	-4.7	-4.0	-5.7	-5.2
80	-4.4	-5.3	-0.3	-3.6	-5.1	-5.5	-3.8	-0.8	-6.2	-2.1
100	-7.4	-5.5	-2.3	-5.8	-6.8	-2.3	-3.0	2.5	1.6	4.2
125	-1.7	2.3	-1.6	-3.5	-3.3	4.2	1.0	7.1	1.9	8.1
160	-1.1	5.7	-3.6	-1.1	-1.9	5.5	2.5	8.3	3.8	10.6
200	3.1	9.7	-4.0	2.5	-1.0	7.7	6.4	11.8	4.4	12.3
250	3.1	8.5	-3.6	5.8	1.6	8.4	8.8	13.7	7.8	12.9
315	1.2	5.7	-0.2	7.6	4.1	10.2	10.0	14.3	10.5	12.5
400	4.7	7.8	4.5	9.0	7.6	12.5	14.6	15.4	12.9	16.0
500	5.0	6.3	6.6	8.9	9.3	12.2	16.6	14.8	14.2	16.1
630	6.4	5.9	6.2	7.8	9.2	11.9	15.5	13.9	14.4	15.1
800	6.5	5.9	6.8	8.0	9.6	11.7	15.1	13.1	13.3	13.4
1000	5.6	5.7	5.8	7.8	10.0	10.3	13.3	11.0	11.5	11.2
1250	5.4	6.4	6.2	7.7	9.9	9.5	10.7	9.0	10.9	10.3
1600	4.5	6.0	5.7	6.5	8.6	6.5	8.6	8.2	10.0	10.0
2000	3.3	3.5	4.6	5.1	6.6	5.1	7.7	7.8	6.3	8.4
2500	0.0	0.1	3.9	5.2	4.3	4.5	7.0	7.7	3.7	5.3
3150	0.4	1.1	3.4	4.7	3.4	4.2	7.3	9.0	4.4	6.2
4000	1.1	2.2	3.4	4.7	3.8	4.6	7.6	8.4	6.6	7.4
5000	2.5	3.5	3.9	4.7	4.2	4.5	7.1	7.2	6.3	6.1
6300	4.3	4.7	3.4	3.6	2.7	2.5	4.2	4.7	5.5	4.2

spectrum that can be added to the transmission loss spectrum for an existing wall to predict the effect of adding another layer of drywall to a bare block surface using the particular construction technique. To understand this idea more clearly, observe in Fig. 4 that the addition of the second layer further improves transmission loss at higher frequencies and further reduces it at lower frequencies.

Table III shows the measured STC values for all the 190-mm block wall systems that were tested. This table shows the data that were available for calculation of the ΔTL spectra. Walls on the diagonal had both sides finished in the same way. Other walls had mixed finishes that can be identified from the row and column headings in the table.

Table III shows that there were usually several ways to calculate the difference transmission loss (ΔTL) spectrum

for a given mounting technique. These included the obvious: the one-side result minus the bare result, and the two-sided result minus the bare result divided by two. Results not on the diagonal or in the first column were also used. For example, subtracting the spectrum corresponding to the result in the Bare column, row D from the result corresponding to column C, row D gave an estimate of ΔTL corresponding to 40-mm wood furring with 40 mm of glass fiber in the cavity. Several ΔTL spectra were calculated in this way for each surface treatment and averaged to get a mean and a standard deviation.

Figures 7 and 8 give examples of ΔTL curves for some of the wallboard mounting methods tested. The mean ± 1 standard deviation curves are also shown in the graphs. Some mounting methods gave more variable results than

FIG. 9. Comparisons of measured (solid line) and predicted (●) transmission loss for 190-mm concrete block walls. (a) 40-mm wood furring, glass fiber and drywall on both sides. (b) 40-mm wood furring and drywall on both sides. (c) 13-mm resilient metal channels and drywall on both sides, glass fiber on one side only. (d) 50-mm Z bars, glass fiber, and drywall on both sides.

others. That for the 13-mm resilient channels was most variable; the wood furring result was least variable. Table IV lists the ΔTL values calculated from the measured data for all drywall mounting methods.

B. Comparison of measurement with prediction

The ΔTL spectra can be added to the bare block result to predict measured results. It is hardly surprising that the predicted STC ratings agree well with those measured. Of the 31 values predicted, 15 agreed with measurement, 11 differed by 1 point, and 5 differed by 2. What is more useful is that the method predicts the shape of the transmission loss curve quite well, especially at low frequencies, as Fig. 9 shows.

The ΔTL spectra can be used to calculate transmission loss and STC values for all the unmeasured cases in Table III, although many of the constructions are unlikely to be used in practice. More important, one can assume that the same ΔTL spectra can be used to predict transmission loss and STC for other normal-weight block walls. The block weight is so much greater than that of the added wallboard that it does not significantly affect the calculated mass-air-mass resonance frequency. Only the transmission loss for the bare block wall changes. Measurements were also made with 140-mm block walls and provided an opportunity to find how well this assumption works.

C. Application to other blocks: 140-mm blocks with added gypsum wallboard

Two types of 140-mm block were measured, a 75% solid block and a 100% solid block. Figure 10 shows the measured and predicted transmission loss values for three configurations. There were four configurations tested. The predicted STC in each case was 1 point lower than that measured, which is acceptable agreement considering the fact that in three of the constructions 13-mm gypsum wallboard was used in place of 16-mm gypsum wallboard. The STC ratings are determined in this instance by the transmission loss values from about 200–800 Hz. The predicted values are markedly low at high frequencies, but the agreement is fairly good in the important low-frequency range.

This prediction scheme is obviously very limited. Changing the thickness of the drywall, the number of screws attaching the drywall to rigid furring, the spacing of the furring, the thickness or the flow resistivity of the sound-absorbing material can all be expected to influence the position of the mass-air-mass resonance frequency or the increment in transmission loss at the higher frequencies. Another complication is block porosity. The prediction scheme should not be extended to blocks that are significantly more porous than the blocks measured here unless the surfaces are painted. If the block is sufficiently porous, the effective depth of the air cavity is increased and the mass-air-mass resonance frequency decreased. ΔTL spectra extracted from data in Refs. 2 and 5 showed reasonable agreement with those found here, but there were also changes in the position of the crossover frequency by one band or so. Above the crossover, changes of a few decibels in the increments in transmission loss were seen.

This prediction method sheds no light on the physical

FIG. 10. Measured (solid line) versus predicted (●) transmission loss for 140-mm concrete block walls. (a) 65-mm steel studs, glass fiber, and drywall on one side. (b) 65-mm steel studs on one side, 40-mm wood furring on the other. Glass fiber in both cavities. (c) 40-mm wood furring, glass fiber, and the drywall on one side.

mechanisms determining the transmission loss behavior of the wall and it has the obvious limitations just mentioned. It does deal with the mass-air-mass resonance and has the virtue of simplicity. By entering the ΔTL values from Table IV together with data for bare block walls into a spreadsheet, it becomes a simple matter to select walls and attachment techniques and to predict STC and transmission loss as needed. For many engineering calculations, this process should be adequate. Of course, simple models such as that in Ref. 16 could be empirically modified to include the mass-air-mass resonance.

VII. CONCLUSIONS

The data presented here show the important influence of the mass-air-mass resonance on transmission loss for block wall systems. This influence would not have been so apparent had the measurement frequency range extended to only 125 Hz as required by current standards.¹⁷ The low-frequency effects are important for selecting wall constructions to reduce noise transmission between homes or to reduce the transmission of low-frequency machine noise. Similar mass-air-mass resonance effects can be expected for cavity walls using studs and drywall where the masses of the layers are not so disparate. Again, systematic data extending to low frequencies is needed for such cases.

The location of the mass-air-mass resonance was not well established by these measurements. If one assumes that the crossover frequency is at some constant ratio above the mass-air-mass resonance, as is done here, then the data suggest that sound-absorbing material in the cavity lowers the mass-air-mass resonance by more than the 15% suggested in Ref. 13. The $1/\sqrt{2}$ factor suggested by Schultz¹⁴ gives better agreement with these data but an empirical factor of 1/1.8 is better still. More work is needed to clarify the effect of sound-absorbing material.

Possible interactions between structural resonances in the bare wall and the various attached panels were not investigated. Such interactions could influence the position of low-frequency resonances.

The prediction method presented here could be labeled simplistic. Nevertheless, it lets consultants and others predict block wall performance with reasonable accuracy for these particular drywall finishes. More work is needed to find out how factors such as block porosity will influence transmission loss for block wall systems such as these.

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