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PLASTERBOARD ON MASONRY: THE EFFECTS OF DIRECT FIXING

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ABSTRACT
The method of directly attaching plasterboard by adhesive daubs to both sides of a masonry wall will result in increased sound transmission which can occur at low, mid, or high frequencies. The proximity and the magnitude of reduction in transmission loss over the frequency bands is dependent on combinations of the number of fixing points and the depth of the cavity behind the plasterboard. The effect on the determined Sound Transmission Class (STC) ranged from a 1 to 8 dB decrease over that of the bare wall. Measurements were conducted on a 110 mm hollow block wall with the plasterboard bonded by various configurations in the adhesive daub centres and thickness. This paper will discuss contrasts in measurement results of airborne sound insulation which show that relatively small structural changes can make large differences to the transmission losses, and hence the STC, when plasterboard is directly fixed to both sides of a block wall.

INTRODUCTION
This paper presents results from a series of measurements of sound transmission through a 110 mm calcium silicate hollow block wall with plasterboard directly attached both sides by adhesive. Six variations of adhesive daub spacing and thickness were tested.

The method of attaching plasterboard directly to masonry walling by adhesive application has been around for many years, and in fact is a widely utilised and preferred system in multi-residential construction today. Acceptance is based on cost and not on acoustic performance. Published data[1,2] provide test results and guidelines that show the nett effect to the Sound Transmission Class (STC) for various single-leaf concrete masonry walls when plasterboard is attached directly on both sides is ± 1 STC.

Based on this 'guideline', acoustical opinions guarantee an STC 45 for drywall masonry systems where the bare wall achieves an STC 46 or greater. This rationalism impacts directly on partition system selection to comply with the Building Code of Australia (BCA)[3] which states that a party wall separating two habitable rooms in adjoining units must have an STC of not less than 45. The results presented here will show that adopting this 'rule-of-thumb' may inadvertently result in non-compliance with the BCA.

This study began with a commercial consideration where the primary objective was to try and satisfy the BCA requirement of STC 45 starting off from a base of STC 42 for a block wall. The attempt was to, by empirical methods, try and understand the influence of different application rates of adhesive used to fix plasterboard to block and accordingly adopt an optimised method that would enhance the acoustic performance and increase the STC.

Warnock[4] presented data for a block wall with a single layer of plasterboard screwed directly to both sides. The result was analogous with published data where a reduction of 1 STC was obtained. He concluded that the plasterboard can vibrate fairly independently of the block when attached by the 'normal' number of screws or daubs of adhesive and that a mass-air-mass resonance still occurs. Although not defined, 'normal' does relate to manufacturers recommendations of approximate daub size and maximum spacing. The fact that tradespersons follow recommendations does not mean identical workmanship occurs. The intention of this paper is to address the effects that minor variations in application rate of the adhesive has (by varying both centres and thickness) on the sound insulation properties whilst still remaining within the confines of the definition 'normal'. Although a significant amount of past and current test data exists, none has addressed the possible effects slight variations in the (direct) application of plasterboard on masonry walling might have on airborne sound insulation properties.

For this series of tests the smallest air gap was determined by the physical parameter of how much the adhesive daub could be compressed. This represents the smallest air gap achievable by a tradesperson. The largest air gap was set by the manufacturers[5] recommendation of a 17 mm cavity width limit between the back of the plasterboard and the block surface when using the method of adhesive application. A furred system using metal channel is recommended for attaching plasterboard for cavity widths (air gaps) in excess of this limit.

MATERIALS

The block used for these measurements was a hollow core 110 mm thick lightweight block manufactured from calcium silicate. The surface density of the completed block wall was nominally 144 kg/m^2. The volumetric density of the block is 2200 kg/m^3. The face dimensions of the block were 162 mm high by 230 mm long. Blocks were laid hollows down, in a running bond pattern with full bed mortar joints, which were ironed.

The 10 mm plasterboard used was nominally 6.8 kg/m^2. Adhesive used for plasterboard attachment was a proprietary cornice masonry and stud adhesive. Cornice masonry adhesive is a gypsum based compound whereas stud adhesive is acrylic based.

METHODS OF ATTACHING DRYWALL

Ten millimetre plasterboard was attached to the block wall by the same technique for each test; which was directly to the block wall with daubs of adhesive compound but with variation to the application rate. Table 1 shows the nominal daub centres and thickness, viz. air gap between the block face and back of the plasterboard that was adopted. Daubs of adhesive were applied to the block wall surface according to plasterboard manufacturers recommendations of nominal size 50 mm diameter by 10 mm thickness. The smallest air gap was attained by tamping down the board until compression of the daub was no longer possible. The large air gap was achieved by means of attaching a 75 mm x 75 mm pad of 10 mm plasterboard to the block wall by means of adhesive. The plasterboard sheet was then attached to the pad. This is a common procedure for irregular wall surfaces. The resulting cavity between the block and back of plasterboard was then measured. For Test 8, the plasterboard was laminated to the block wall by applying cornice adhesive to the whole of the back surface using a 5 mm x 5 mm notched trowel.

Except for Test 6, which used the stud adhesive, all other tests with attached drywall used the cornice adhesive.

Table 1 Daub centres for adhesive and nominal air gap adopted between the block face and back of plasterboard. The numbering also denotes the order of testing.

TEST	TREATMENT	AIR GAP
1	Daubs of cornice adhesive at 450 x 450 mm centres	Small as possible (average measured 2 to 3 mm)
2	Bare wall	N/A
3	Daubs of cornice adhesive at 225 x 225 mm centres	Small as possible (average measured 2 to 3 mm)
4	Daubs of cornice adhesive at 450 x 450 mm centres	Large as possible (average measured 16 to 18 mm)
5	Daubs of cornice adhesive at 225 x 225 mm centres	Large as possible (average measured 16 to 18 mm)
6	Daubs of stud adhesive at 450 x 450 mm centres	One side small (2 to 3 mm) One side large (16 to 18 mm)
7	Bare wall	N/A
8	Complete coverage cornice adhesive	N/A

DESCRIPTION OF MEASUREMENT FACILITIES AND PROCEDURES

Measurements were made in the sound transmission loss suite at the Royal Melbourne Institute of Technology (RMIT); a NATA[6] accredited laboratory, in accordance with AS 1191[7]. The chambers consist of a reverberant source room of volume 116.96 cubic metres and a reverberant receiving room of volume 119.48 cubic metres. Wall specimens measure 2.85 m long x 3.75 m high. Both rooms are constructed of 305 mm reinforced concrete, supported on laminated-rubber isolators, and acoustically decoupled from one another by a layer of cork 50 mm thick. Each room has fixed diffusers and the irregular room shape has been chosen to assist in the production of diffuse sound fields. The sound source, placed in a corner of the source room, is a single loudspeaker, which is driven by an integrated stereo amplifier and fed with random noise using a noise generator.

Pink noise is fed to the loudspeakers to measure transmission loss in the source room and decays in the receive room. In each third octave band of centre frequency 100 to 5000 hertz the mean sound pressure level in each room is found by the use of a condenser microphone mounted on a tripod at four discrete stationary positions. Microphone signals were analysed using a Bruel & Kjaer Dual Channel Frequency Analyser Type 2133.

RESULTS FOR 110 MM BLOCK WALLS

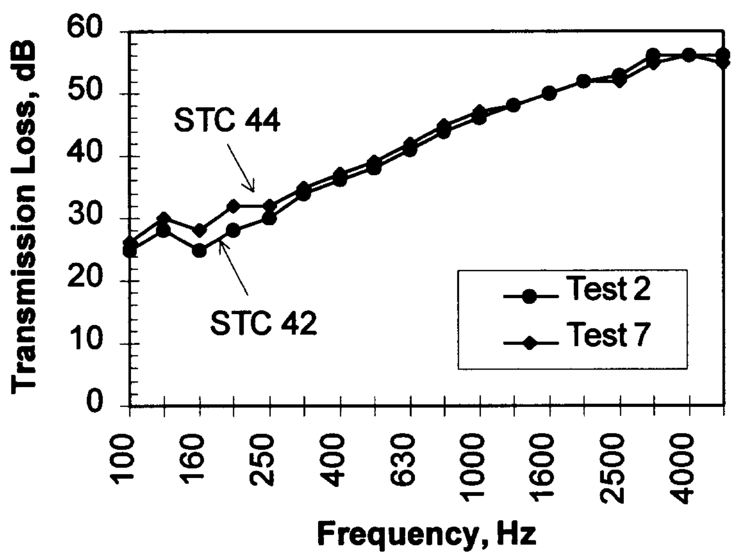
The complete set of transmission loss values for all walls tested are given in Table 2.
The stated STC values have been determined in accordance with AS 1276[8].

SOUND TRANSMISSION LOSS FOR BARE BLOCKS

As indicated in Table 1, sound transmission through the bare wall was measured twice. The two tests were conducted nineteen days apart. The first test was carried out after the wall had cured for six days. The reason for repeat testing was to ensure the acoustic integrity of the block wall had not been compromised after the series of tests; between each subsequent test the daubs of adhesive had to be chiseled off which may have distressed the wall. The transmission loss (TL) results are shown in Fig. 1. The result obtained was certainly not expected. Differences in the low frequency region translated in a difference of 2 STC. Fig. 1 shows that the latter tested wall achieved higher transmission losses of 2 to 4 dB between 125 and 240 Hz. The largest difference of 4 dB occurring at 200 Hz. It is not known whether the latter test result was a real improvement e.g. attributable to the longer curing time or due to repeatability errors although this is unlikely. In any case, the initial test (Test 2) is used for the purposes of comparison to the added drywall measurements. The lower obtained STC is what is typical for a wall of this surface weight.

It should be noted that AS 1191 does not specify or reference documents that provide aging periods for test specimens that incorporate materials for which there is a curing or drying process. This is unlike ASTM Designation: E 336 -90[9] which recommends a minimum 28 day curing period for masonry walls.

Figure 1. Results for 110 mm bare block wall tested twice. Tests were conducted after a 6 day and a 25 day curing period.



SOUND TRANSMISSION LOSS FOR BLOCKS WITH ADDED PLASTERBOARD

Calculated effect of mass-air-mass resonance

The type of construction in this investigation is prone to a dip in performance caused by the mass-air-mass resonance. This is the frequency at which the plasterboard over the springy air pocket prefers to vibrate. The frequency at which this occurs may be calculated from the expression:[10]

$$f_{mam} = 60 / (md)^{1/2}$$

where,
m = mass per unit area of the plasterboard, kg/m^2
d = the distance from the plasterboard to the block surface, in metres

Due to the vast weight difference, the block wall has no bearing on the location of the resonance frequency.

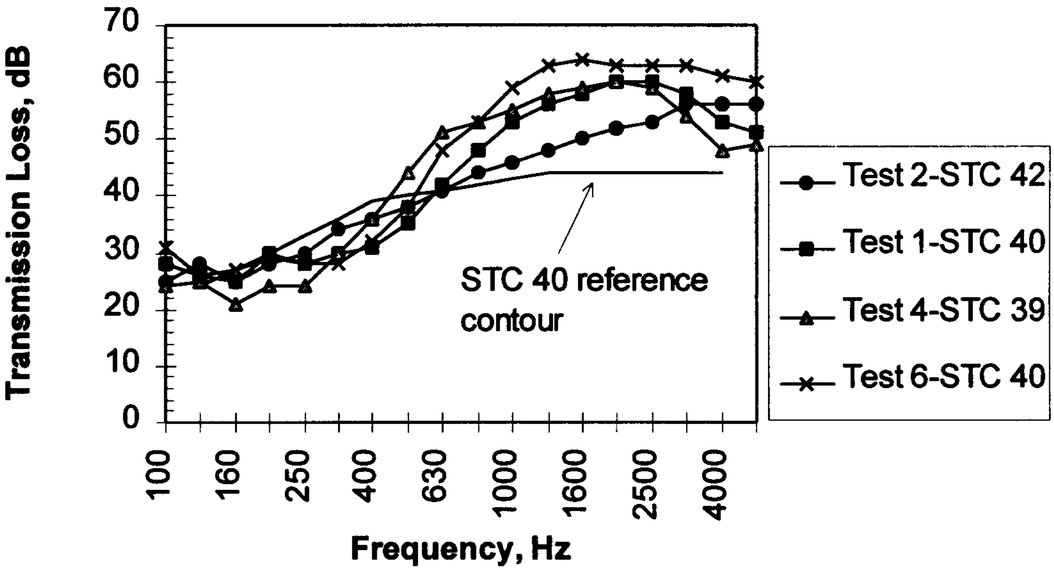
For the small air gap (2 - 3 mm), f_{mam} has been calculated at nominally 430 Hz.
For the large air gap (16 - 18 mm), f_{mam} has been calculated at nominally 180 Hz.

Effect of increasing airspace for daubs of adhesive spaced at 450 x 450 mm centres

Figure 2 shows the effect of increasing the airspace equally on both sides and offsetting the air gap on both sides when plasterboard is attached to the block wall by daubs of adhesive at 450 x 450 mm centres. Compared to Test 1, it is clear that the mass-air-mass resonance due to the larger air gap in Test 4 reduces the transmission loss at the low frequencies (100 - 250 Hz) and increases the transmission losses at the mid (315 - 1000 Hz) to high (1250 - 5000 Hz) frequencies. A cross-reference between Fig 2 and Table 2 show there is good correlation between the measured and predicted mass-air-mass resonance frequency. The coincidence dip due to the plasterboard is evident when the plaster based adhesive is used; the solid connections to the plasterboard reduce the transmission loss at the coincidence controlled region below that for the bare wall. Previous measurements on 10 mm plasterboard have shown that the coincidence dip occurs at 4 kHz. Results in Fig 2 show reasonable agreement with this. Test 6 was an attempt to ascertain the effect of offsetting the mass-air-mass resonance by having different air gaps on each side. The nett effect was marginal in the low frequency region being similar to Test 1. Interestingly, the mass-air-mass resonance now lies between the two predicted values. The coincidence dip in this case is not so evident which may be attributable to the flexible adhesive used. Generally, there is a 6 dB average improvement in the high frequencies over Test 1 and 4.

The vast contrast evident between the TL curves does not reflect in the STC ratings, which are very similar.

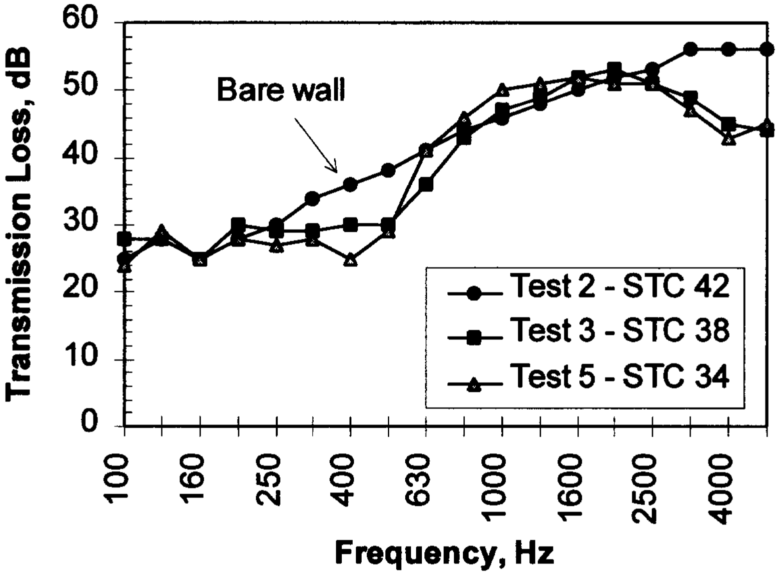
Figure 2. Results for 110 mm block with plasterboard attached both sides by daubs of adhesive at 450 x 450 centres. Test 1 with 2 - 3 mm air gap. Test 4 with 16 - 18 mm air gap. Test 6 with 2 - 3 mm air gap one side, 16 - 18 mm other.
The STC 40 contour is included to illustrate derivation of the rating for Test 1 and 6.



Effect of increasing airspace for daubs of adhesive spaced at 225 x 225 mm centres

Figure 3 shows the effect of increasing the airspace equally on both sides when plasterboard is attached to the block wall by reduced adhesive daub centres. The shape of the graph is entirely different to that in Fig 2. Results in Fig 3 are categorised by a distinct plateau between 200 and 500 Hz. Obviously, the addition of extra daubs of adhesive is the cause of this phenomenon. Cross-referencing between Fig 3 and Table 2 show that for Test 3 there is general agreement between the measured and predicted mass-air-mass resonance frequency although the effect seems to occur over a number of bands. There seems to be no such agreement for Test 5. There appears to be some other mechanism occurring masking the effects of mass-air-mass resonance. An explanation may be that the increase of connection points means an associated increase in the stiffness of the plasterboard, where now the panel no longer vibrates at that resonance mode of mass-air-mass. In other words, the plasterboard is no longer vibrating independently of the block wall and therefore the mass-air-mass resonance is no longer the influencing factor. The cause of the dip at 400 Hz for Test 5 cannot be explained, but some form of panel resonance cannot be ruled out. It is due to this dip, however, that results in a substantially lower STC compared to Test 3. Above 500 Hz the TL increases markedly for both Test 3 and 5 but not much beyond the bare wall. The coincidence dip due to the plasterboard is again evident, where this time increasing the number of solid connections to the block wall reduces the transmission loss at the coincidence controlled region significantly below that for the bare wall. This is highlighted by an average 10 dB reduction between 3150 to 5000 Hz inclusive to that of the bare wall.

**Figure 3. Results for 110 mm block with plasterboard attached both sides by daubs of adhesive at 225 x 225 centres. Test 3 with 2 - 3 mm air gap.
Test 5 with 16 - 18 mm air gap.**



Effect of constant air gap for varied daub spacings
Fig 4 & 5 shows the trend when the daub centres are reduced whilst maintaining a constant air gap. Fig 4 with the 2 - 3 mm air gap and Fig 5 the 16 - 18 mm air gap. Test 6 was also included for comparison in both cases.

In Fig 4, results with the added plasterboard are very similar to one another up until 400 Hz. Thereafter a contrast in performance is clearly evident. The closer daub spacings is clearly the inferior performing wall in the mid to high frequency region. Test 6 is clearly the best performing wall in this region. Test 1 & 6 share the same STC rating although there is a clear difference in TL values in the mid / high frequency region.

Fig 5 unveils a very different trend when examining the larger air gap results. As expected, the extra daubs of adhesive in Test 5 has successfully reduced the amplitude of the mass-air-mass resonance and increased the TL at the lower frequencies. It appears that offsetting the air gap on both sides has a similar effect. The extra daubs has also meant a corresponding decrease in performance in the mid to high frequencies; increasing the number of connecting points fourfold generally equates to a 6 dB increase in energy going through those points which will affect the performance in these bands.

Effect of no air gap
Figure 6 shows the effect of removing the air gap by filling the void with cornice adhesive. Test 7, the bare wall result, is also included for comparison since the relevance lies in that Test 8 followed. When compared to Test 7, the loss in the low and high frequency bands in Test 8 indicates the plasterboard was not perfectly laminated; the deleterious effect of mass-air-mass and coincidence would be removed and the two curves would somewhat overlay if the plasterboard was perfectly laminated.

Figure 4. Results for 110 mm block with plasterboard attached both sides by daubs of adhesive at different centres whilst maintaining a 2 - 3 mm air gap. Test 1 with 450 x 450 mm daub centres. Test 3 with 225 x 225 mm daub centres. Test 6 with 450 x 450 mm daub centres and 2 - 3 mm air gap one side, 16 - 18 mm other.

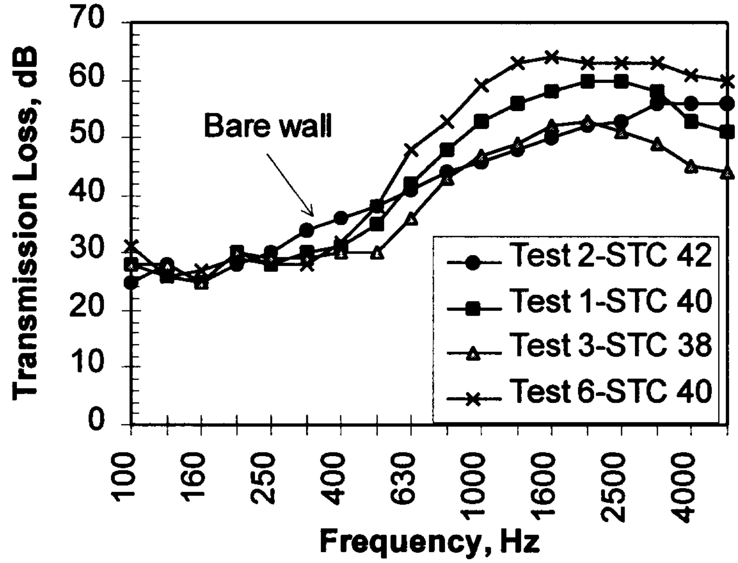


Figure 5. Results for 110 mm block with plasterboard attached both sides by daubs of adhesive at different centres whilst maintaining a 16 - 18 mm air gap. Test 4 with 450 x 450 mm daub centres. Test 5 with 225 x 225 mm daub centres. Test 6 with 450 x 450 mm daub centres and 2 - 3 mm air gap one side, 16 - 18 mm other.

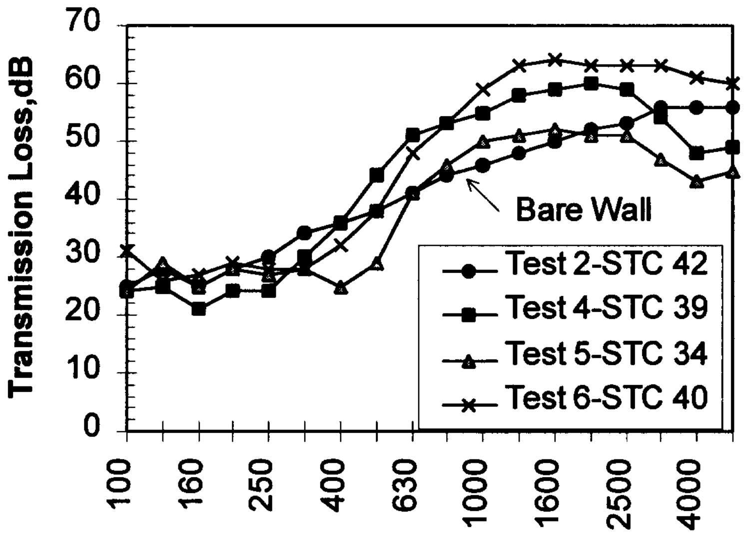


Figure 6. Results for 110 mm block with plasterboard completely laminated to both sides using cornice adhesive. Both bare wall results are shown for comparison.

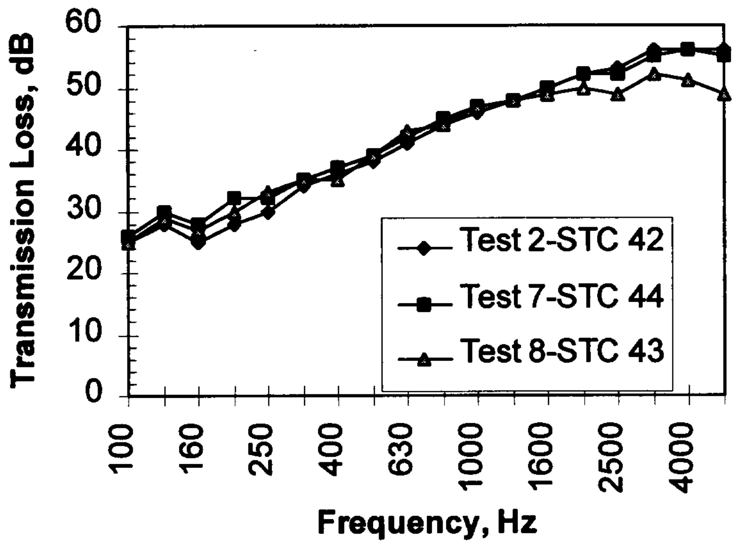


Table 2
Sound Transmission Losses for 110 mm lightweight calcium silicate block wall bare and with attached plasterboard both sides.

Frequency Hz	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8
100	28	25	28	24	24	31	26	25
125	26	28	28	25	29	26	30	29
160	25	25	25	21	25	27	28	27
200	30	28	30	24	28	29	32	30
250	28	30	29	24	27	28	32	33
315	30	34	29	30	28	28	35	35
400	31	36	30	36	25	32	37	35
500	35	38	30	44	29	38	39	39
630	42	41	36	51	41	48	42	43
800	48	44	43	53	46	53	45	44
1000	53	46	47	55	50	59	47	47
1250	56	48	49	58	51	63	48	48
1600	58	50	52	59	52	64	50	49
2000	60	52	53	60	51	63	52	50
2500	60	53	51	59	51	63	52	49
3150	58	56	49	54	47	63	55	52
4000	53	56	45	48	43	61	56	51
5000	51	56	44	49	45	60	55	49
STC	**40**	**42**	**38**	**39**	**34**	**40**	**44**	**43**

CONCLUSION

The data presented here show that there is a detrimental effect on the transmission loss for a lightweight block wall with plasterboard directly fixed to both sides. In some cases, this translated in a substantial drop in the STC over the bare block wall. It was found that altering the adhesive daub centres and thickness can affect the transmission loss in any of the frequency bands. For the elected air gaps, the position of the mass-air-mass resonance occurred at undesirable frequencies. Reduced daub spacing has an unfavourable effect; reduced performance in the mid to high frequency region, and an unexplained mechanism in the low frequencies substantially lowering STC ratings. The combination of normal daub spacings (450 x 450 mm centres) with a small as possible air gap (Test 1) was the best combination in terms of relative STC performance to the bare wall. Although not listed as a recommended material, the use of stud adhesive showed improvement in the high frequency region with no benefit in the lows. The combination that gave the least reduction, complete lamination, is not an economical option.

Great care must be exercised if walls of this type of construction are to be used. The wrong combination of daub spacing and thickness, especially the use of leveling pads can result in reduced acoustic performance that cannot be predicted.

Unfortunately, the primary objective of this study had not been achieved. By the addition of 10 mm plasterboard direct fix to both sides of a block wall, it was not possible to increase the STC in order to achieve the BCA requirement of STC 45. Therefore, the system is not a viable option for use as a party wall separating adjoining units. Other techniques of fixing plasterboard, such as on a furring system, would need to be investigated to fulfill this requirement.

Further work is needed to examine whether the same effects found in this investigation would occur on normal weight blocks.

ACKNOWLEDGMENT

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REFERENCES

1. "Design for Sound Attenuation - Masonry Walling - Manual 8," Concrete Masonry Association of Australia, 25 Berry Street, North Sydney, NSW, 2060.
2. C.M. Harris, *Noise control in Buildings, A Practical Guide for Architects and Engineers*, (McGraw-Hill, New York, 1994), p. 5.20.
3. "Building Code of Australia," Australian Building Codes Board, Part F5, Sound Transmission and Insulation, 1996.
4. A.C.C. Warnock, "Sound transmission through concrete blocks with attached drywall," J. Acoust. Soc. Am. **90**, 1454-1463 (1991).
5. "Installation Reference Manual," Boral Plasterboard, 2.01, Issue No. 2, September 1995.
6. National Association of Testing Authorities, Australia.
7. AS 1191 - 1985, "Acoustics - Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions."
8. AS 1276 - 1979, "Methods for Determination of Sound Transmission Class and Noise Isolation Class of Building Partitions."
9. ASTM E336 - 90, "Standard Test Method for Measurement of Airborne Sound Insulation in Buildings."
10. A.C.C. Warnock, "Sound Transmission Loss Measurements Through 190 mm and 140 mm Blocks with Added Drywall and Through Cavity Block Walls," IRC Internal Rep. 586, National Research Council of Canada, 1990.