Curing time required to achieve stable sound transmission loss through masonry walls

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ABSTRACT

Airborne sound transmission through a masonry wall (150 mm thick clay bricks with 13 mm thick cement render on both sides) changes during the early curing period. Australian Standard AS1191-2002 states: "…masonry walls…should not be tested until after an adequate drying out period." However the 'adequate drying out period' or ageing period is not quantified. Reference may be made to ASTM E90 which recommends a minimum 'aging period' of 28 days before a masonry wall's sound transmission loss properties should be tested. However in the building industry, "time is money" and there are significant cost penalties in waiting 28 days before carrying out acoustical testing.

This paper provides support to reduce the accepted 28 days curing period to a much shorter period while still achieving a stable sound transmission loss.

INTRODUCTION

Airborne sound transmission through a masonry wall changes as the cement mortar cures. The generally accepted curing time after which the Sound Transmission Class (STC) of a masonry wall may be tested is 28 days, which is documented in ASTM E90. This however has practical disadvantages to the building industry due to the delay between construction and testing while the wall cures. This paper investigates the minimum "requirement" for a masonry wall to age 28 days before a stable sound transmission loss is achieved.

An extensive literature review did not uncover any research to substantiate the 28 day rule of thumb. Most likely, its origins are linked to concrete achieving 95% structural strength after 28 days of curing and this period was also applied to the acoustical integrity of concrete or masonry walls.

When a material's sound transmission loss properties are not known, ASTM E90 provides a testing method called "the repeat test procedure" to determine if a material's sound transmission loss results have stabilized. The testing procedure recommends "repeated (sound transmission loss tests) at intervals in the series 1, 2, 4, 7, 14 and 28 days from the date of construction, until no change is observed to the precision of the measurement, between successive tests."

ASTM E90 further notes that the airborne sound insulation index (R) described in ISO 717 is an approximately similar rating to the sound transmission losses (TL). This paper will refer to the internationally accepted Sound Insulation Index (R) and Weighted Sound Reduction Index (R_w).

The sound transmission loss results for two masonry walls (150 mm thick clay brick with 13 mm thick cement render on both sides) using the repeat test procedure will be used in order to verify if the R_w (or STC) of the wall may be accurately tested at some time shorter than the recommended 28 day curing period.

Uniquely, this paper shows the change in STL in the first 28 days after construction while the wall is still curing and provides support to reduce the accepted 28 days curing period to a much shorter period while still achieving a stable R_w.

METHODOLOGY

The sound transmission properties of two masonry walls were measured at various stages of curing in order to determine whether the sound transmission loss stabilises at any time before the "required 28 days of aging" recommended in ASTM E90.

The assumption is that each sound transmission test carried out in accordance with AS 1191 – 2002 will provide a stable sound transmission loss after the test partition has aged for 28 days.

Recommended upper limits for the 95% confidence interval in Table B1 of AS 1191-2002 are used to compare the repeated test results with the final (28+ days) stabilised transmission loss values, to determine at what age the wall stabilises at each individual third octave frequency.

By comparing the tests results over the aging period, the test wall will be considered to have a stable sound transmission loss once the change in R_w for earlier tests is no greater than 1 dB of the final stabilised result.

Measurement Procedure

The measurement of airborne sound insulation of each masonry wall was carried out in accordance with the Australian Standard AS 1191 – 2002 "Acoustics – Method for laboratory measurement of airborne sound insulation of building elements".

Pink noise was generated and amplified at frequencies between 50 Hz and 10 kHz. The sound pressure levels were measured using one-third octave band pass filters from 50 Hz to 10 kHz but calculations were based on 100 Hz to 3,150 z.

Reverberation time was measured in the receiving room according to AS 1045 "Acoustics - Measurement of sound absorption in a reverberation room."

The Weighted Sound Reduction Index R_w rating with spectral corrections C and C_{tr} as discussed in AS/NZS ISO 717.1:2004 "Acoustics – Rating of sound insulation in buildings and of building elements", were calculated using one third octave bands with centre frequencies ranging from 100 Hz to 3,150 Hz.

Two test walls were constructed in the acoustical laboratory. Each wall was aged for in excess of 28 days. During this period, the sound transmission loss of the wall was measured several times according to the "repeat test procedure" outlined in ASTM E90.

The two walls, designated "Wall A" and "Wall B" were both constructed from 150 mm thick clay bricks with 13 mm thick cement render on both sides, however the bricks used in each wall had a slightly different coring geometry.

Description of the Acoustic Testing Laboratory

The acoustic test laboratory within the Boral Masonry premises at Prospect, NSW is generally constructed in accordance with AS 1191-2002. It consists of a source room with volume 69 m^3, a receiving room with volume 226 m^3, and a test aperture with area 10.2 m^2. It is constructed from concrete with several hanging diffusers in three corners of the room.

Figure 1 below shows Wall A in the test aperture. One of several sets of hanging diffusers can be seen in the right of the aperture beside the test partition.

Figure 1. Test Wall and Receiver Room Diffusers.

Instrumentation

Noise level measurements and analysis were made with instrumentation as follows in Table 1.

The measurement system was calibrated prior to and after each noise survey. No adjustment for instrument drift during the measurement period was warranted.

Table 1. Noise Survey Instrumentation

Description	Model Number	Serial Number
Modular Precision Sound Analyser	B&K 2260	244 3406
Condenser Microphone 0.5" diameter	B&K 4189	244 0653
Acoustical Calibrator	B&K 4231	243 9033
Wireless Transmitter and Receiver	B&K 4231	243 9033
E-tone Loudspeaker with inbuilt amplifier	SUP 12SA	02 091 008

RESULTS

Two walls (A and B) were separately constructed, each comprising a single layer of 150 mm wide clay bricks with 13 mm thick cement render on both sides. The brick walls were laid according to AS 3700 Masonry Structures. Each test wall had a surface density of approximately 325 kg/m^2.

The accuracy of the sound transmission loss measurements is not easily assessed. Appendix B of AS 1191-2002 provides a method of indicating the precision of the measurements using statistical analysis and provides recommended upper limits 95 % confidence intervals δ_{max}, for each one third octave band.

If the measured 95 % confidence interval, δ, for each early repeat test when compared to the final stable test (28+ days curing), is less than δ_{max}, those test results are considered to be repeatable and therefore, the wall is considered to have sufficiently cured and provides an equivalent STL to a wall cured for 28+ days. In analysing the 95 % confidence interval for these tests, the difference between the repeat STL results and the final STL results for each Wall is given in Tables 3 and 5.

Wall A

Table 2 below shows the sound transmission loss for Wall A tested at three repeat test intervals within the aging period of 28+ days.

Table 2. Sound Transmission Loss of Wall A.

Frequency, Hz	STL for each Aging Period, dB			
	1 Day	4 Days	7 Days	31 Days
100	37	41	40	44
125	38	39	37	36
160	40	42	40	44
200	38	40	40	43
250	40	44	45	46
315	43	45	46	46
400	45	48	48	49
500	47	50	49	49
630	49	52	53	52
800	51	55	56	54
1000	55	57	57	56
1250	56	58	58	57
1600	60	61	61	60
2000	62	64	63	63
2500	61	65	65	64
3150	59	67	68	67
4000	59	64	67	67
5000	60	64	67	66
R_w	51	54	54	54
Unfavourable deviation	27	25	28	26

Figure 1 below graphs the sound transmission loss for Wall A at four repeat test intervals and shows the R_w 54 reference curve for the 28+ day wall in order to highlight where the unfavourable deviations are predominant (Unfavourable deviations occur when transmission losses are below the R_w reference curve).

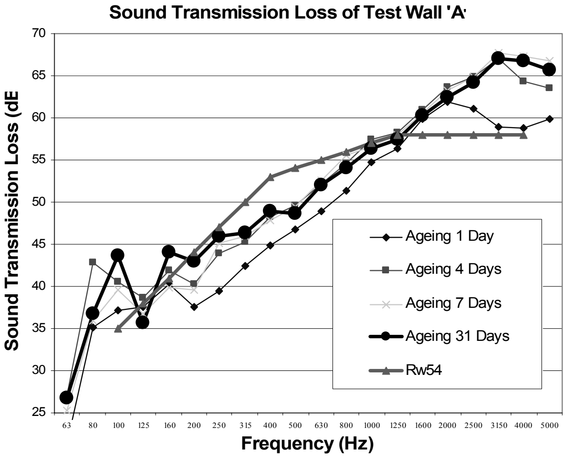

Figure 2 Sound Transmission Loss of Test Wall ‘A’.

Table 3 below shows the sound transmission loss data for Masonry Wall A tested at various time intervals. Figures in italics show where δ_{max} is exceeded.

Table 3. 95% Confidence Limits of the STL through Wall A.

Frequency, Hz	δ_{max}, dB	measured 95 % confidence interval, δ, dB		
		1 Day	4 Days	7 Days
100	3.7	*6.4*	3.1	*4.0*
125	3.5	1.9	3.0	1.1
160	3.3	*3.7*	2.1	*4.2*
200	3.0	*5.4*	2.7	*3.4*
250	2.5	*6.4*	2.0	0.8
315	2.0	*3.9*	1.1	0.4
400	1.6	*4.0*	0.7	1.0
500	1.3	*1.9*	0.9	0.7
630	1.1	*3.1*	0.2	0.6
800	1.1	*2.7*	0.6	*1.5*
1000	1.1	*1.7*	1.0	0.2
1250	1.1	1.1	0.9	0.6
1600	1.1	0.5	0.7	0.3
2000	1.1	0.6	*1.2*	0.7
2500	1.1	*3.1*	0.6	0.6
3150	1.1	*8.1*	0.0	0.7
4000	1.1	*8*	*2.5*	0.5
5000	1.1	*5.9*	*2.2*	1.1

The environment of the test laboratory during aging of Walls A and B did not change significantly. The wall test measurements were each carried out during the middle of the day over the 31 day period.

Wall B

Table 4 below shows the sound transmission loss for Wall B tested at four repeat test intervals within the aging period of 28+ days.

Figure 3 below graphs the sound transmission loss for Wall B at five repeat test intervals and shows the R_w 54 reference curve for the 28+ day wall in order to highlight where the unfavourable deviations are predominant (Unfavourable deviations occur when transmission losses are below the R_w reference curve).

Table 4. Sound Transmission Loss of Wall B.

Frequency, Hz	STL for each Aging Period, dB				
	2 Days	3 Days	4 Days	8 Days	44 Days
100	42	42	43	38	42
125	40	42	41	41	37
160	35	40	41	39	43
200	41	41	39	39	41
250	44	44	46	47	46
315	46	47	46	47	46
400	48	49	48	50	48
500	49	50	51	51	49
630	53	53	53	53	52
800	55	55	54	54	54
1000	56	56	56	57	55
1250	57	58	57	58	56
1600	59	61	60	58	60
2000	62	63	62	62	61
2500	64	64	64	64	62
3150	64	67	66	66	63
4000	64	67	66	66	64
5000	66	67	65	65	64
R_w	53	54	54	54	54
Unfavourable deviation	23	23	23	22	29

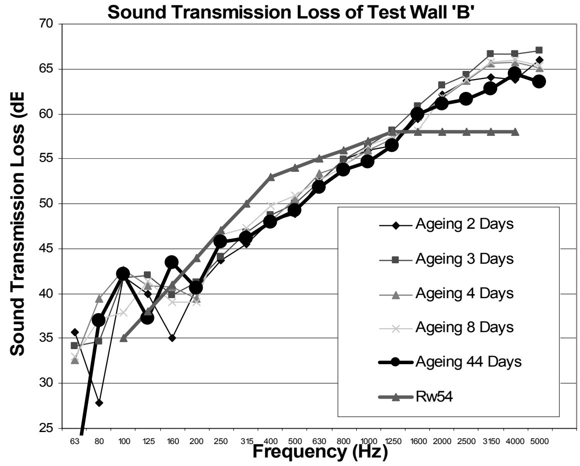

Figure 3 Sound Transmission Loss of Test Wall ‘B’

Table 5 below shows the sound transmission loss data for Masonry Wall B tested at various time intervals. Figures in italics show where δ_{max} is exceeded.

Table 6 below shows a summary of the R_w ($C;C_{tr}$) test results for both Wall A and B at different ages.

Table 5. 95% Confidence Limits of the STL through Wall B.

Frequency, Hz	δ_{max}, dB	measured 95 % confidence interval, δ, dB			
		2 Days	3 Days	4 Days	8 Days
100	3.7	0.2	0.3	0.6	*4.2*
125	3.5	2.7	*4.7*	*3.6*	*4.1*
160	3.3	*8.3*	*3.6*	2.7	*4.4*
200	3.0	0.0	0.6	1.2	1.6
250	2.5	2.0	1.6	0.1	0.8
315	2.0	0.6	0.7	0.3	1.2
400	1.6	0.2	0.8	0.2	*1.8*
500	1.3	0.4	0.8	1.3	*1.7*
630	1.1	0.7	0.7	*1.6*	0.8
800	1.1	1.1	1.1	0.5	0.3
1000	1.1	*1.3*	*1.8*	*1.4*	*1.9*
1250	1.1	0.1	*1.7*	0.8	1.1
1600	1.1	0.5	1.0	0.2	*1.7*
2000	1.1	1.0	*2.1*	0.6	0.8
2500	1.1	*2.1*	*2.7*	*2.1*	2.2

Table 6. Summary of the change in R_w over time

Aging Period, days	$R_w(C;C_{tr})$	
	Wall A	Wall B
1	51(-1;-5)	-
2	-	53(-1;-5)
3	-	54(-1;-4)
4	54(-1;-4)	54(-1;-4)
7	54(-1;-5)	-
8		54(-1;-5)
14	-	-
31	54(-1;-4)	-
44	-	54(-1;-4)

DISCUSSION

Theoretically, the factors controlling sound transmission loss are stiffness (low frequency, below 200 Hz), mass (mid frequencies, 200 to 2500 Hz) and self damping of a material (high frequency, above 2500 Hz).

The age of a wall is not normally considered as a factor in calculating the transmission loss of a wall. It is assumed that the material properties of the wall do not change and have already reached equilibrium.

Of these material properties the stiffness and self damping of masonry walls showed the most change during the curing process, which are displayed in the low and high frequency ranges. The mid frequency range is very stable, which is expected as the mass of the wall is fairly consistent with the exception of some water evaporation.

When a masonry wall is newly built, the structural strength of the cement mortar is low and the wall is not stiff. The resonant frequency of the test wall is not very prominent in the first 2 days of curing as shown in Figures 2 and 3.

As the masonry walls age, they stiffen and the transmission loss at the resonant frequency degrades. This is clearly demonstrated in both Walls A and B in the 125 to 160 Hz region in Figures 2 and 3.

During the same time period, the self damping property of the wall reduces when the strength of the cement mortar increases. This is displayed in the settling of the STL in the high frequency region as the test walls aged.

The loss in sound transmission at the fundamental frequency of the masonry wall is offset by the overall improvement in sound transmission. In fact the overall sound transmission loss of the tested masonry walls improve by 3 dB after just 3 days of aging.

The time required for a stable sound transmission loss was found to occur within three days of building a masonry wall. A stable sound transmission loss result can be described when the overall R_w result of a wall is within 1 dB of the "fully cured" R_w result achieved after 28 days of curing.

Although the results show that the overall R_w stabilises after 3 days, it is likely that change is still occurring in the STL after 28 days, especially in the lower frequency region.

The reliability of the results was assessed against the recommended upper limits for 95% confidence intervals in AS1191-2002. It was found that the upper limits were exceeded in both the low and high frequency ranges for all tests within the 28+ day aging period. This suggests that the STL of the walls did not completely stabilise during the period.

This tends to give support to the ASTM 28 day rule required for laboratory tests as the individual third octave sound transmission loss results were outside the recommended 95% confidence intervals during the first 7 to 8 days of curing.

However, further testing of masonry walls over several months may be required to confirm that the "28 days" result has achieved the recommended 95 % confidence interval at all frequencies especially for the low and high frequency ranges. This would be most applicable in an acoustical laboratory, where a material's acoustical properties are being tested and the sound transmission loss at each frequency is important.

The R_w on the other hand, did not vary after the fourth day in Wall 'A' or the third day in Wall 'B', and appears to have reached equilibrium relatively quickly. On closer examination, the unfavourable deviations in Tables 2 and 4 vary by 3 dB for Wall A and by 7 dB for Wall B during the 28+ day testing period.

If the unfavourable deviations are high (above 30) in the first three days of the aging process, then, it is possible that as the wall continues to age, the R_w will decrease by 1 dB due to the unfavourable deviations exceeding 32 and "clocking over" the R_w, thus seeing a change of up to 1 dB in the R_w. However this was not the case for both test walls.

It would seem that the measurement of the overall R_w may be carried out after 4 days with a high probability of measuring a stable result.

CONCLUSION

The sound transmission loss of two masonry walls was measured at different time intervals in order to establish that the overall weighted sound reduction index (R_w) stabilises before the recommended 28 days.

The overall sound transmission loss tests results as shown in Table 2 and 4 indicate that 3 or 4 days of aging will produce a relatively stable overall R_w result (within 1 dB).

The R_w was shown to increase by 3 points between one and three days of curing.

Specific frequencies (namely the lower frequencies such as 125 to 160 Hz) may require at least 28 days before the sound transmission loss stabilises as the fundamental frequency of the masonry wall appears to be more sensitive to the masonry wall stiffness.

An unusual increase in the sound transmission loss occurs at the higher frequencies of 2500 to 5000 Hz in test Wall A when comparing the sound transmission loss after 1 day of curing and 31 days of curing. This may be due to vibration occurring between individual bricks before the mortar in the wall binds together the bricks in the test wall.

To achieve equilibrium at all frequencies, the full 28 days aging is required. This would be most applicable in an acoustical laboratory, where a material's acoustical properties are being tested and the sound transmission loss at each frequency is important.

It would be reasonable to apply the conclusions drawn in this paper to all cement mortar based block walls as the mortar would be the changing variable in any block work wall.

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