Comparison of ASTM and ISO sound absorption test methods

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A series of planned experiments were conducted to investigate whether systematic differences may exist between ASTM C423 and ISO 354 measured sound absorption using the E-400 mm mounting condition for acoustical ceilings. These experiments focused on the differences in the two test methods, with the goal of identifying and understanding differences in the resulting test results. A variety of acoustical ceiling tile were tested, in a facility accredited (NVLAP) to perform both ASTM and ISO testing, generating data representing a broad range of acoustical performance. The factors examined were: the effect of sample size and calculation procedure on the measured absorption; and the differences between the SAA and α_w calculations derived from the two test methods. The results of these experiments will then be used to identify areas in which additional research is needed if harmonization of the two standards is to occur.

1 Introduction

As currently written, the ASTM and ISO test methods for measuring the sound absorption of acoustical ceiling tile have subtle but distinct differences. In an effort to understand the impact of these differences on the test results, a series of experiments have been conducted in which the same materials have been tested using both methods. By way of comparison, critical facility and testing properties for the two test methods are shown in Table 1 *(next page)*.

There are several important differences to note: the ISO standard requires larger sample sizes and larger minimum room volumes. The convention in Europe is to use an E-200 mounting for ceilings, while North America uses an E-400 mounting. The initialization of the decay slope calculation is time-based for the ASTM test, whereas the ISO test is based on dB level reduction. Additionally, the ISO α_w calculation is more complex, using a weighted average and a shape indicator curve (minimized deviations from a reference curve); the SAA calculation used in the ASTM method is a simple average.

There are also concerns with regards to sample size and edge diffraction for smaller or less square samples, as well as the impact of sample size on the sound diffusion within the test room and its impact on the validity of the sabine equation.

2 Experimental Results

2.1 Test methods and samples

A series of traditional acoustical ceiling tile were tested in a variety of configurations in the NVLAP accredited acoustics laboratory at Armstrong World Industries, Lancaster, PA *(NVLAP lab code 100228-0)*. As noted in Table 1, the reverberation room has a volume of 264.7 m^3. This facility is accredited to conduct absorption tests according to both the ASTM and ISO specifications. The standard sample sizes used are 62 ft^2 or 64 ft^2 for ASTM C423 (62 ft^2 for tiles having metric dimensions; 64 ft^2 for imperial dimensions), and 12 m^2 for ISO 354. The ASTM tests were run using an air gap dimension of 400 mm; the ISO test can be run using an air gap dimension of 200 mm or 400 mm. For these comparisons, a 400 mm gap was used for all samples. To eliminate the impact of sample variability, the same samples were tested in multiple configurations.

The reverberation room used to collect these data is shown in Fig. 1a and 1b.

Figure 1a: Reverberation Chamber

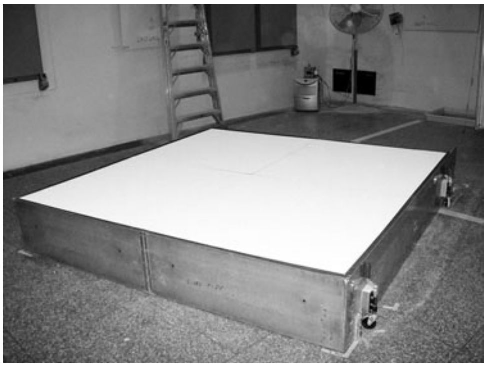

Figure 1b: Sample mounted in E-400 test fixture, 64 ft^2

Table 1: Comparison of ASTM and ISO Test Requirements and Facility Conditions

Property	**ASTM C423 [1]**	**ISO 354 [2]**
Minimum Room Volume	125 m^3 *≥ 200 m^3 recommended*	150 m^3 *≥ 200 m^3 recommended*
Maximum Room Volume	None given	500 m^3
Actual Room Volume	*264.7 m^3*	*264.7 m^3*
Temperature and Humidity	≥ 40% RH	30 % RH – 90% RH and ≥ 15 °C
Minimum Sample Size	5.57 m^2 (60 ft^2)	10 m^2
Upper Limit for Sample Size	None given	(1) 12 m^2 or (2) If room volume > 200 m^3, then the sample size will increase by $(V/200)^{2/3}$
Actual Sample Sizes used for testing	*62 ft^2 or 64 ft^2*	*12 m^2*
Recommended mounting air gap, E mounting	400 mm *others allowed as specified [1, 3, 5]*	• 400 mm recommended for NA • 200 mm recommended for Europe • 300 mm recommended for Japan [4]
Air Gap used for testing	*400 mm*	*400 mm*
Frequency Range Tested	100 - 5000 Hz	100 - 5000 Hz
Delay to start of calculation	100 – 300 ms after the signal is turned off	After a 5 dB drop in level
Range of calculations	25 dB level drop (Collect for 6 s)	20 dB level drop
Delay and range used for testing	*After 100 ms, 25 dB level drop*	*After 5 dB drop in level, 20 dB level drop*
Steady State noise level during collection	≥ 45 dB above background level	≥ 10 dB above background level
Noise level used for testing	93 – 94 dB; results in ≥ 48 dB above background level	93 – 94 dB; results in ≥ 48 dB above background level
Number sound sources	≥ 1	≥ 2
Number sound sources used	*2*	*2*
Placement of sample	Asymmetric; ≥ 0.75 m from a reflective surface	Asymmetric; ≥ 0.75 m from a reflective surface
Minimum number of microphones specified & placement	≥ 5 *(fixed)* ≥ 1.5 m apart, ≥ 0.75 m from sample surface	≥ 3 *(fixed)* ≥ 1.5 m apart, ≥ 2 m from sound source, ≥ 1 m from reflective surface and sample
Number microphones used for testing	*6*	*6*
Minimum number of decay curves collected	50 (≥ 10 per microphone)	≥ 12
Number of spectra collected during testing	*60 (10 for each microphone)*	*60 (10 for each microphone)*
Reported values	SAA: average for (12) ⅓ octave bands from 200 - 2500 Hz; round to 0.01 before averaging	α_w: calculation required

2.2 The effect of sample size on measured sound absorption

The consequences of sample size and shape on the edge diffraction effects have long been debated, but the resultant effects on the calculated absorption values have not been well characterized to date [1]. This may be due, in part, to the possible confounding effect that large sample sizes may have on sound field diffusion, which would impact the assumption of equal sound energy flow in all directions within the test room. Since the ISO sample size is twice that used for the ASTM test, we would expect to see a difference, if in fact sample size is significant.

To evaluate the effect of sample size on absorption, 12 samples were run following the ASTM C423 method using an E-400 mounting for both the ASTM and ISO sample sizes, as noted in Section 2.1. The ASTM 'SAA' values were calculated for both sizes; these are presented in Table 2. All samples were standard production materials covering a range of acoustical performance, as denoted by SAA, of 0.47 to 0.95.

Table 2: Effect of Surface Area on absorption, as measured by SAA (ASTM C423)

Substrate	Degree of texture	tile dimension	SAA, 62 ft^2	SAA, 12 m^2	% difference
Slag wool	Fissured, 2'x2' scoring	1200 x 600 x 19 mm	0.47	0.49	4.3
Slag wool	Sand-like, 2'x'2 scoring	1200 x 600 x 19 mm	0.51	0.52	2.0
Slag wool	Fissured	2' x 4' x 5/8"	*0.55**	0.57	3.6
Slag wool	Highly textured	1200 x 600 x 15 mm	0.56	0.55	-1.8
Ceramicized Slag wool	Fissured	1200 x 600 x 15 mm	0.62	0.61	-1.6
Slag wool	Painted veil, smooth	1200 x 600 x 19 mm	0.65	0.67	3.1
Slag wool	Fissured	1200 x 600 x 19 mm	0.69	0.69	0.0
Slag wool	Painted veil, smooth	2' x 4' x 3/4"	*0.70**	0.69	-1.4
Slag wool	Painted veil, smooth	2' x 2' x 3/4"	*0.70**	0.69	-1.4
Slag wool	Fissured	600 x 600 x 19 mm	0.72	0.72	0.0
Fiberglass	Painted veil, smooth	200 x 600 x 15 mm	0.90	0.87	-3.3
Fiberglass	Painted veil, smooth	2' x 4' x 1"	*0.95**	0.94	-1.1

** Sample size is 64 ft^2*

The % difference in SAA between the 12m^2 sample and the smaller ASTM sample ranges from -3.3 to +4.3%. The average % difference for the 12 samples is only 0.2% overall. Eight of the samples had absolute differences in SAA of 0.01 or less; 3 others had differences of 0.02. The largest absolute difference is 0.03, for the 15 mm fiberglass planks. ASTM C423 Section 13 Precision and Bias, Table 3 indicates the repeatability 'r' factor for this test method over the frequency range of 125 – 4000 Hz is ± 0.03 to 0.07 with 95% confidence [1]. Even without looking at the individual absorption values over frequency, for all of these samples, it is clear that the difference in SAA for the two sample sizes falls within these limits of variability. Therefore, it appears that sample size does not have a significant impact on the reported absorption results obtained using the ASTM C423 test method.

The absorption curves for a low performance (fissured slag wool) and a high performance (fiberglass) product are shown in Fig. 2 *(next page)*. There are minimal variations in the individual absorption coefficients across the entire frequency range. Looking at the entire data set, it appears that in general, above 2500 Hz, the absorption coefficient is slightly higher for the larger area sample; below 200 Hz, the absorption coefficient tends to be higher for the smaller area sample. However, there are no significant shifts in the absorption curves, again suggesting that the surface area effects are minimal.

2.3 Comparison of single number ratings for absorption: ASTM v. ISO test method

The methods for calculating the SAA and α_w ratings are quite different [1, 2, 4]. (*refer to the appropriate standards for details*). Fifteen 12 m^2 samples were tested according to both ASTM C423 and ISO 354, making it is possible to compare the reported absorption curves as well as the single number ratings prescribed by ASTM C423 and ISO 11654. A wide variety of textures and sample substrates was tested.

The sound absorption curves for the same materials can be compared if the absorption value α_s (ISO) and α (ASTM) values are overlaid for the E-400 mounting fixture. For example, Fig. 3 shows the absorption curves for two slag wool products and a fiberglass product: (a) a slag wool product with a sand-like texture; (b) a slag wool product finished with a painted fiberglass veil, or scrim; (c) a fiberglass product with a painted veil. The curves are representative of the data set. In addition, duplicate tests of the same material on the same or different days show no significant variations, suggesting that the repeatability of the data is good. In all cases, the α_s and α curves show very little difference, suggesting that the data collection methods for the two tests are comparable, despite the differences noted in Table 1.

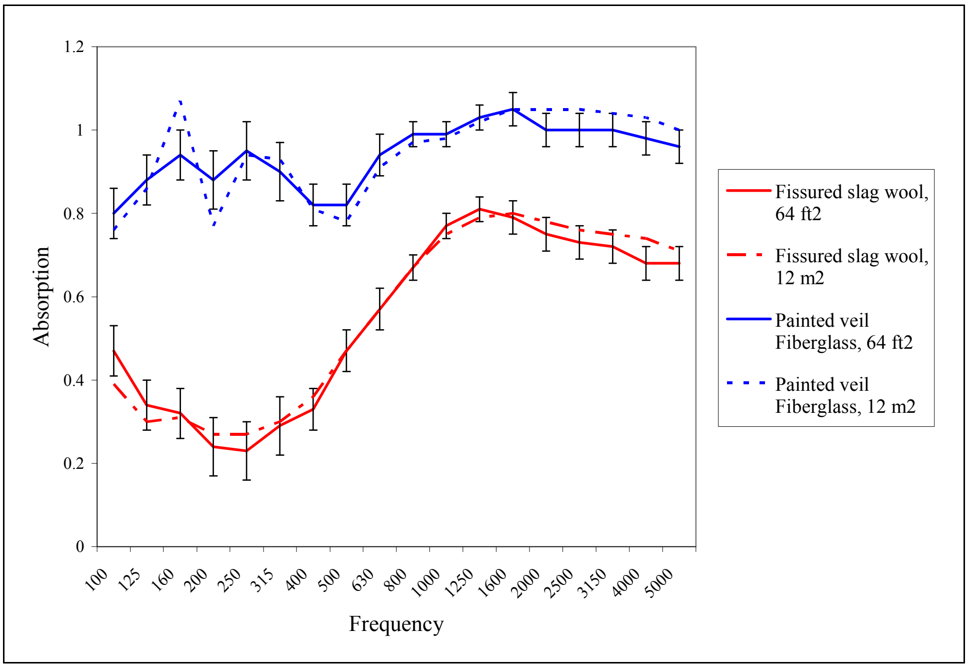

Figure 2: Sound Absorption as a function of Surface Area (ASTM C 423, E-400 mounting). The error bars denote 'r' values as given in ASTM 423.

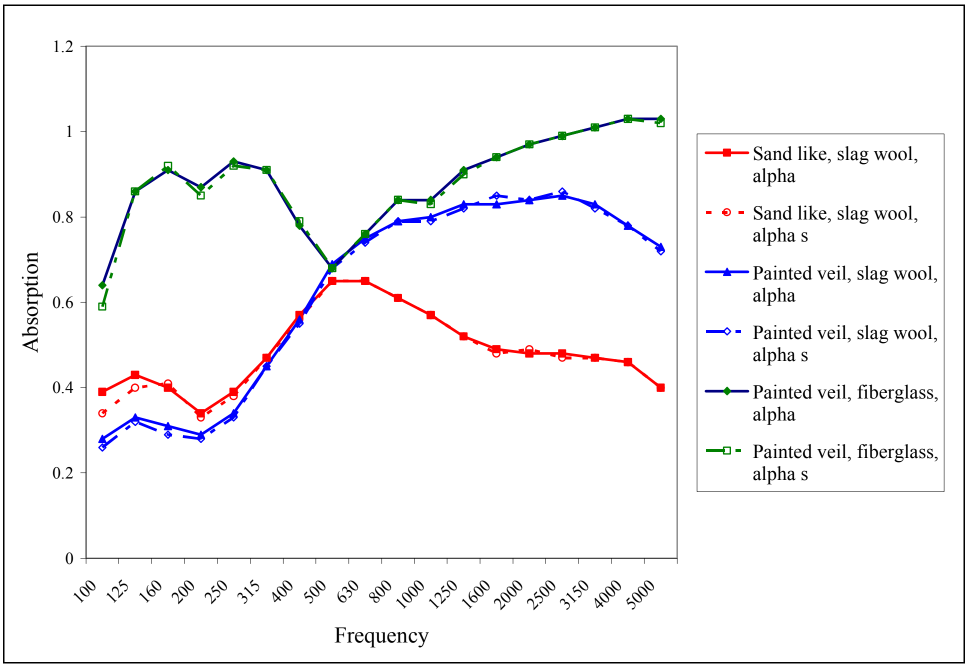

Figure 3: Comparison of α (ASTM C 423) and α_s (ISO 354) sound absorption (E-400 mounting)

Table 3 shows the calculated sound absorption ratings reported by the two methods. In general, the SAA absorption rating is the same as, or higher than, the corresponding α_w rating. To a specifier of ceilings, the same material could appear to be less effective when the sound absorption is reported using the ISO method. This apparent shift in performance is linked to the weighting curve used to calculate α_w [4]: the weighting curve has a positively sloped skirt in the low frequency range, is flat over the mid to high frequency range, and has a negatively sloped skirt in the high frequency range (as shown in Fig. 4); the need to limit deficiencies frequently lowers the α_w value for denser slag-wool products. The fact that many of these products are then designated with an MH or H suffix indicates that they have significantly higher mid or high frequency sound absorption than represented by the α_w rating alone. These results suggest that differences in the calculation methods can skew the perceived performance of the same material, and that the calculated absorption values may not strictly represent a material performance property.

Table 3: Absorption: α (ASTM C 423) v. α_w (ISO 354) ratings (400 mm air gap)

Substrate	Degree of Texture	SAA	α_w
Ceramicized slag wool	Fissured	0.61	0.55 MH
Slag wool	Embossed texture	0.74	0.65 MH
Slag wool	Embossed texture (duplicate)	0.77	0.70 MH
Slag wool	Sand-like, 2'x2' scoring	0.52	0.50
Rock wool	Painted veil, smooth	0.74	0.75 H
Rock wool	Painted veil, smooth (duplicate)	0.74	0.75 H
Rock wool	Painted veil, smooth (duplicate)	0.73	0.75 H
Slag wool	Fissured, 2'x2' scoring	0.49	0.45 H
Slag wool	Fissured	0.69	0.60 MH
Slag wool	Fissured	0.72	0.60 MH
Slag wool	Fissured		
Slag wool	Textured	0.55	0.55
Slag wool	Painted veil, smooth	0.70	0.65 H
Slag wool	Painted veil, smooth	0.67	0.65 H
Fiberglass	Painted veil, smooth	0.87	0.85 LH

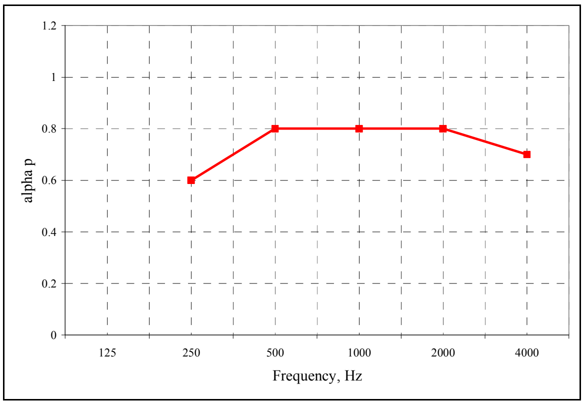

Figure 4: Reference Curve for evaluating a_w (after ISO 11654)

3 Conclusion

A series of tests has been conducted which compare various parameters of the ASTM 423 and ISO 354 tests for absorption of acoustical ceilings. The results suggest that sample size does not have a significant impact on the absorption performance. The absorption data, as represented by the α and α_s coefficients are virtually identical for the two methods. However, there can be significant differences between the reported SAA and α_w values that would appear to an uneducated specifier to reflect differences in the performance of the product.

Acknowledgments

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References

[1] ASTM C423, "Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method," 2002.

[2] ISO 354, "Acoustics – Measurement of sound absorption in a reverberation room," 2003.

[3] ASTM E1264, "Standard Classification for Acoustical Ceiling products," 1998.

[4] ISO 11654, "Acoustics – Sound absorbers for use in buildings – rating of sound absorption," 1997.

[5] ASTM E795, "Standard Practices for Mounting Test specimens during Sound Absorption Tests," 2005.