ISSN 2347 - 3983
Volume 10. No.6, June 2022
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter031062022.pdf
https://doi.org/10.30534/ijeter/2022/031062022

Reducible Experimental Deviations between ISO 354 and ASTM C- 423

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Received Date : May 3 , 2022 Accepted Date : May 29, 2022 Published Date : June 07, 2022

ABSTRACT

The main standards used to determine the sound absorption coefficient (α) of materials in the reverberation room are ISO 354 and ASTM C- 423. Really there is a difference between the two standards. The materials with the highest sound absorption determined by ASTM C423 standards (α_{TM}) increases more than that determined by ISO 354 standards (α_{IS}) and decreases as the ability of the material decrease to absorb sound, as in the case of wood. The number of source locations has no effect on the sound absorption of materials. To reduce the difference between ISO (α_{IS}) and ASTM (α_{TM}) methods for sound absorption measurements, a new idea of a sample area was proposed with 9.36m^2 and only two locations for sample placement in the reverberation room.
The sound absorption coefficient (α_{NA}) of (9.36m^2) approximates the findings of the sound absorption coefficient in highly absorbent materials with ISO standards method, and vice versa for low absorption materials, when the sound absorption coefficient results converge with ASTM standards. For all situations of source locations (2, 3, 4), the sound absorption average (SAA) established by ASTM standards is greater than that determined by ISO standards for high sound-absorbing materials (rockwool (k), polyurethane sponge (s)), and vice versa for weakly absorbing materials (wood (w)). In the reverberation room, the relative standard deviation ranged from 0.01 to 0.04.

Key words : reverberation room, sample placement, sound absorption, sample area, ISO 354 and ASTM C- 423

1. INTRODUCTION

To investigate the influence of different settings of a reverberation room on the standard deviation of the reverberation time, measurements are performed, compared to the theoretical standard deviation. The diffusion in reverberation chambers needs to be clarified to reduce differences between laboratories. Although there are practical ways to accomplish this, it is critical to note that the ISO 354 standard has specification points regarding sound field quality diffusion. noted that one option is to use the standard deviation of reverberation time in conjunction with the number of microphone and sound source positions in the reverberation chamber for distinct groups [1]. The sound field inside the reverberation room must have a high degree of propagation in order to be achieved Accurate measurement of different sound quantities. Usually, the diffusers are either suspended or movable, and panels are installed in the chamber in an attempt to achieve this diffusion [2]. The last suggestion to review ISO R354 recommends the use of diffusers when The decaying sound field is insufficiently diffuse, without exactly explaining the meaning of this assertion or the differences between the use and non-use of posting devices in Absorption measurements on materials of different types [3]. The synthesized diffuse sound field can be used to measure a tiny region of a specimen in the laboratory [4]. knowing the difference between the two measurement methods in ISO and ASTM in order to describe and clarify the difference between them by measuring the different ceiling tiles. And the absorption coefficient data for the two methods are identical for α and αs. But there is a clear difference between αw and SAA [5]. Insufficient diffusion of sound in the reverberation room is
the main reason for the difference in the results of acoustic measurements with frequency in the reverberation chamber. This is because the current approaches under ISO and ASTM standards produce erroneous findings. The best correlation was found in the low-frequency region when the placements of the diffusers changed [6]. The difference between rectangular and spherical diffusers as well as the two together and their effect according to the measurement procedures mentioned in ISO 354 and also calculate the total equivalent absorption area from the Sabine equation in a reverberation room of 243 m2 as well as calculating the diffuse field factor {7]. there are many reasons for the difference in the results of sound absorption performance between the laboratories and also the studies showed that the size and shape of the reverberation chamber, the type and area of the test sample, the effect of the edge, and the placement of the sample are the main factors affecting the results [8]. there are differences in the inter-laboratory of measurements in the reverberation chamber according to Standard 354. The differences are

greater than acceptable. The main factors affecting the results include the shape of the room, the position of the diffusers in the reverberation room, as well as the area of the sample to be measured [9].

the comparisons between ISO and ASTM standards regarding the factors required to know the ability of the material to absorb and the extent of the need for all existing calculations and curves required in them [10]. the basic and main lines of the supposed modification of the iso 354 standard, the main change is the use of a reference sorbent to improve the values of the reproducibility standard deviation [11]. experiments using fiberglass plates of different sizes and shapes in order to try to correlate the measurements of the absorption coefficient of the material according to the specifications of ASTM-C423, ISO-354, and ISO-17497-1 standards. But note that there is a discrepancy in the results of the measurements for the absorption coefficient of the material between the three standards. A fixed area of 8.22 m^2 with changes in shape and volume was studied, as well as a constant perimeter of 10.17 m, and a change in shape and volume [12].

2. EXPERIMENTAL

2.1 Reverberation Room Method

Measurements were conducted in the reverberation chamber at NIS. The reverberation room of total size of 160m^3 and a total surface area of 178m^2, a non-parallel surfaces, and non-equalized dimensions, with a height, ranging from 4.18m to 4.27m with a room floor of length dimensions ranging from 6.10 to 6.3m and width ranged from 5.8 to 6m. The reverberant room follows the standard ISO 354 and ASTM C423. The standard also recommends that the reverberation room should be contained diffusers, which should be randomly oriented and positioned throughout the chamber. Thus, to meet those criteria, the diffuseness of the reverberation chamber was increased using 10 diffusers. The hanging diffusers used in this research are metal panels with different areas ranging from 1.8m^2 to 2.08 m^2. The diffusers hung at varying heights from the room floor.

2.2 Instrumentation and Measurement Setup

The reverberation time from 125Hz to 6300Hz of the room with an acoustic diffuser was measured according to standard ISO 354:2003 [13] and ASTM C423 [14]. Measurements were carried out using sound source type 4296 B&K, precession sound level meter type 2260B&K with software 7204, and power amplifier of type B&K 2716. Instruments adjusted before starting measurements using sound level calibrator type B&K 4231. According to ISO 354 requirements, the sound source height from the room floor 1.5m, Five microphone positions in the room with a minimum distance from room walls 1m, the spacing between any two microphone positions 1.8m, and source microphone distance 1.8m. The sample location is spaced far from walls by 0.8m, and sound source spacing 2m. A sound source emitted a white noise signal was used to create diffuse field conditions in the room. Each specimen was sited on the room floor. Its perimeter was sealed with wood framing. Ten sound decay rates were measured in the empty room and in the presence of the specimen. The empty reverberation times T1 and T samples were deduced from these decay rates and used to calculate the sound absorption coefficient in the third-octave frequency bands following equation (1).

With the qualification of the reverberation room, Averaging Reverberation time T_E measurements of the empty reverberation room without diffusers were carried out when using four locations for sound source at four room corners and when the room contained the diffusers the Reverberation time represented by (T_1,T_2,T_3 and T_4).

3. ISO 354 AND ASTM C423 COMPARED WITH THE PROPOSED AREA (NA) XPERIMENTAL

Measurements conducted in the reverberation room, for four source locations at the room corners, was accompanied by 5 microphone positions for each source location to measure the reverberation time. The distance between sample locations and room walls was not lower than 0.8m.

General procedures in the reverberation room for the tested materials; samples inserted with a wooden frame of height 6cm with 2.5cm thickness, for a number of needed sound sources with a proposed area compared with ISO and ASTM areas, this article recorded calculated and experimental results on the estimation of the sound absorption coefficient of three different materials in a diffuse acoustic field excitation in a reverberation room.

ISO 354 stated the area; 12m^2 (3*4) represented by (α_{IS}), with one location for the sample nearer to the center of the room

ASTM C423 stated the area; 6.24m^2 (2.6*2.4) represented by (α_{TM}), with three locations (1,2&3) for samples with samples position overlaps by 26 and 26.5%.

New Proposed area (NA); 9.36m^2 (2.6*3.6) represented by (α_{NA}) with two locations (Y& Z) for sample, with samples position overlapping 23 %.

4. ABSORPTION CALCULATION AND REPEATABILITY

Three materials were taken considered in this work: rockwool(k), polyurethane sponge(S), and wood (w).

Table 1: Materials specifications

Material	Area m^2	Thicknes s (m)	Density kg/m^3	Air-Permability $cm^3/cm^2.s$
Rockwool	13.	0.054	120.35	85
Polyurethane sponge	11.5	0.047	19.5	148
Wood	10.5	0.016	582	0.0

4.1 Sound Absorption Coefficient Calculation

Using sabine formula (1), with Figure 1, which represents the reverberation time (T) values obtained by the various procedures described above, and the variation in the reverberation time (T) of the reverberation room when empty Using reverberation times T1 and T2

$$A_T = A_2 - A_1 = 55.3V\left[\frac{1}{C_2T_2} - \frac{1}{C_1T_1}\right] - 4V(m_2 - m_1) \qquad (1)$$

for constant temperature t, c1=c2=c so,

C = (331+0.6 t) m/s

Where c; speed of sound at constant temperature t

T1:reverberation time of the room without sample

T2:reverberation time of the room with sample

Power attenuation coefficient m1 and m2, can be calculated from the attenuation coefficient

$$A = \left[\frac{55.3V}{c}\right]\left[\frac{1}{T_2} - \frac{1}{T_1}\right] \qquad (2)$$

$$A = \alpha s = \alpha_1 s_1 + \alpha_2 s_2 \qquad (3)$$

$$\alpha_2 = \frac{\alpha s - \alpha_1 s_1 \alpha_1}{S_T}$$

Where: α, total absorption coefficient α, total absorption coefficient of the room surfaces and material inside the rooms, A, total surface area of the room surfaces and material inside the room, S1, is the surface area of the room, α1, the absorption coefficient of the room surfaces, and S2, the area of the absorbent material and α2, the absorption coefficient of the material.

4.2 Repeatability of reverberation time

The relative standard deviation of the reverberation time T20, can be estimated by the following formula:

$$\frac{\varepsilon(T_{20})}{T} = \sqrt{\frac{2.42+3.59/N}{f \cdot T}}$$

(4)

ε(T20), is the standard deviation of the reverberation time, T: is the reverberation time measured, f; is the centre frequency of the one-third-octave band, N; is the number of decay curves evaluated and ε(T20)/T; is the relative standard deviation.

5.RESULTS AND DISCUSSIONS

5.1 Effect of the Number of Source Locations on The Reverberation Time

The reverberation time of reverberation room without (Tref) and with diffusers for four sound source locations (T2,T3 and T4) were measured. Figure 1, illustrates four curves, including the highest curve, to represent the average reverberation time of the reverberation chamber without diffusers with using four positions for sound source. The following three curves are combined into a single curve object, which depicts the reverberation time of an empty room without samples in the presence of diffusers for four sound source positions. The reverberation time of the room with diffusers for the four positions of the sound source was shown on the curve, suggesting that the diffusers were distributed evenly across the space.

5.2 Effect of Source Locations on The SAA of ISO 354 and ASTM C- 423

The sound absorption average (SAA) according to the ASTM method is calculated by averaging the sound absorption coefficient from 200Hz to 2500Hz on 12 third-octave bands. The difference in SAA between the ISO ($12m^2$) samples and the ASTM ($6.24m^2$) appears in table 2. It discusses the averaging sound absorption for Rockwool (k), polyurethane sponge (S), and wood (w). The difference in SAA between the ISO ($12m^2$) samples and the ASTM ($6.24m^2$) appears in table 2. It discusses the SAA difference between the two measurement standards for Rockwool (k), polyurethane sponge (S), and wood (w). The SAA values were tabulated in table 2. The SAA was calculated as averaging of sound absorption coefficient from 200Hz to 2500Hz. The contains date discusses that the values of SAA (TM) are greater than SAA (IS) for all cases of source positions (2, 3 and 4) for high sound-absorbing materials (Rockwool, polyurethane sponge) and vice versa for weakly absorbing materials (wood). Table 2, contained a comparison for SAA calculations for using 2,3 and 4 locations of sound sources for ISO as; SAA(IS)2, SAA(IS)3, SAA(IS)4 and for ASTM as; SAA(TM)2, SAA(TM)3, SAA(TM)4 for tested three materials.

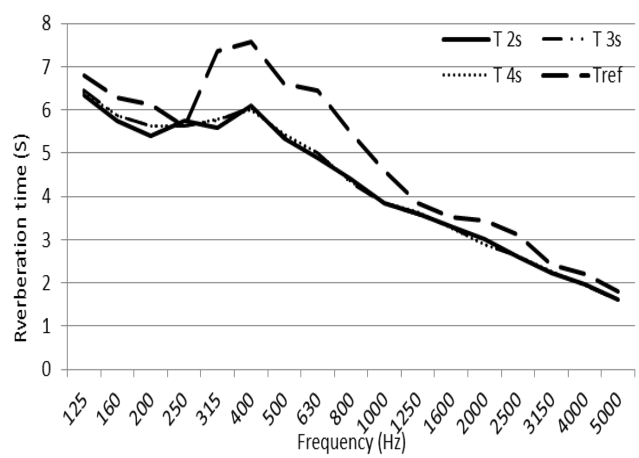

Figure 1: Reverberation time of the reverberation room with a number of a sources

Table 2: The obtained SAA by ASTM and ISO standards

Mat.	SAA (TM)2	SAA (IS)2	SAA (TM)3	SAA (IS)3	SAA (TM)4	SAA (IS)4
K	0.9	0.87	0.9	0.87	0.91	0.87
S	0.68	.63	0.67	0.62	0.67	0.63
W	0.08	0.1	0.08	0.09	0.08	0.08

5.3 Effect of Source Locations on The Absorption of ISO 354 and ASTM C- 423

The values of sound absorption by ISO method (α_{IS}) and the values of sound absorption by ASTM method (α_{TM}) for all cases of source positions (2, 3 and 4) for different materials (rockwool, polyurethane sponge and wood), represented in figure's 2,3.4

Figures 2,3.4; appear that the effect of two locations of the source on the absorption of rockwool materials α_{k2IS}& α_{k2TM}, for polyurethane sponge α_{s2IS} & α_{s2TM} and for wood α_{w2IS}& α_{w2TM}. Figure 3, appears that the effect of three locations of the source on the absorption of rockwool materials α_{k3IS}& α_{k3TM}, for polyurethane sponge α_{s3IS}& α_{s3TM} and for wood α_{w3IS}& α_{w3TM}. Figure 4, appears that the effect of two locations of the sound source on the absorption of rockwool materials α_{k4IS}& α_{k4TM}, for polyurethane sponge α_{s4IS}& α_{s4TM} and for wood α_{w4IS}& α_{w4TM}. Until 2500Hz, the α_{kTM} is higher than the α_{kIS}, except between 200 and 250Hz, where the α_{kTM} values decline lower than the α_{kIS}. Above 2500Hz, the α_{kTM} values decrease lower than the α_{kIS}. While the α_{sTM} increases throughout the frequency range of 125Hz to 1600Hz, the α_{sTM} decreases and the α_{sIS} increases above 1600Hz. The α_{wIS} appears to exceed the α_{wTM} in all frequency ranges in the sound absorption curve of wood, except at frequencies 1250Hz and 1600Hz.

As a result of these figures (2,3 & 4), it appears that the α_{TM} is greater than the α_{IS} in materials with the best sound absorption and decreases as the material's ability to absorb sound decreases, as in the case of wood. The number of sound source positions appears to have no influence on the sound absorption of the three materials, and the behavior of the sound absorption coefficient and its value is nearly constant as the number of sound source positions changes. This is most likely owing to the room's diffusivity spread of sound.

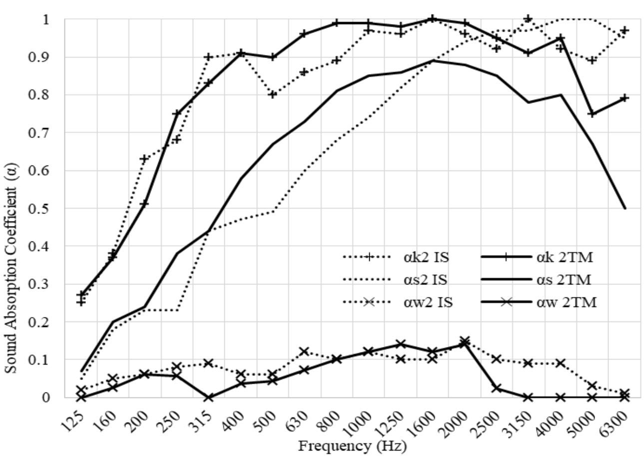

Figure 2: Comparison between sound absorption for α_{IS}& α_{TM} with 2 source locations

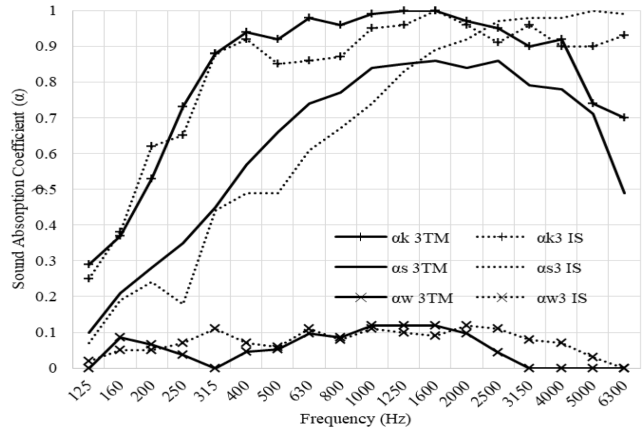

Figure 3; Comparison between sound absorption for α_{IS}& α_{TM} with 3 source locations

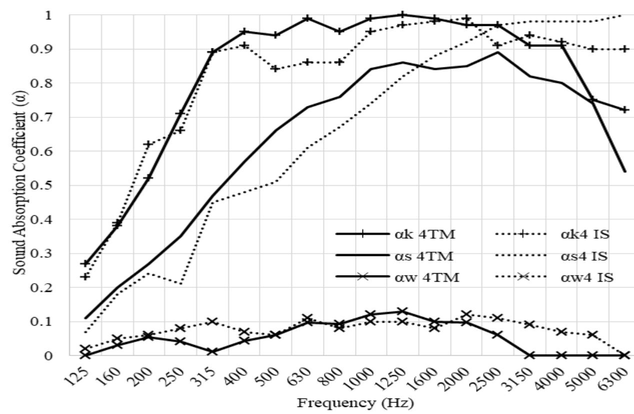

Figure 4; Comparison between sound absorption for αIS& αTM with 4 source locations

5.4 Effect of Sample Area on The Absorption of *ISO 354,* ASTM C- 423 and New Area (NA)

At the frequency range from 125 to 1600Hz, in Figure 5, the value of α_{sNA} sits between the values of α_{sIS} and α_{sTM}, and the curve α_{sNA} behavior is similar to that of α_{sTM}. Nonetheless, at 1600Hz, both α_{sIS} and α_{sTM} decreased, with s_{TM} having the largest decrease, so its values in this range were smaller than α_{sIS} and α_{sTM}; however, we did not scatter values between the values of α_{sIS}, and it continued to increase with frequency except at 6300Hz.

In the frequency band-limited between 400 and 2000 Hz in figure 6, there appears to be a convergence between the three names α_{wNA}, α_{wIS}, and α_{wTM} of wood sound absorption coefficient, with values of the absorption coefficient ranging between 10 and 15%. However, the value of α_{wIS} is the largest in all frequency ranges, and it was found in the range of 125 to 400Hz. The α_{wNA} and α_{wTM} values show a slight discrepancy. And there was the most convergence between the values and behavior of α_{wNA}, α_{wTM} over the entire frequency range of 125 to 6300Hz, with an absorption coefficient of 15%.

Figure 7, appears that the behavior and values close to each of α_{kNA} with values of α_{kIS} during all frequency range from 125 to 6300Hz better than the convergence of α_{kTM} with values of α_{kIS}.

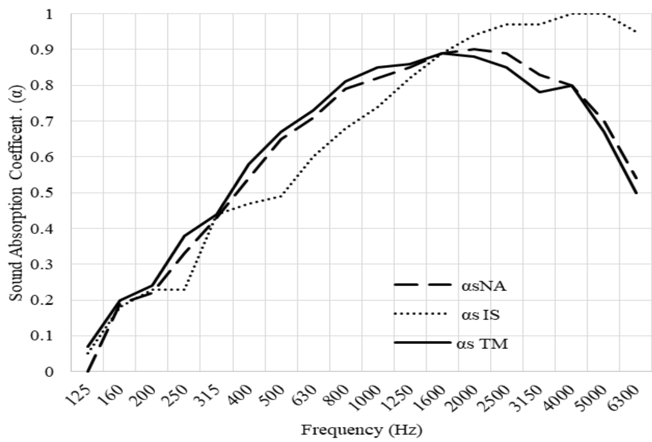

Figure 5; comparison of α_{sNA}, α_{sIS}& α_{sTM} for sound absorption

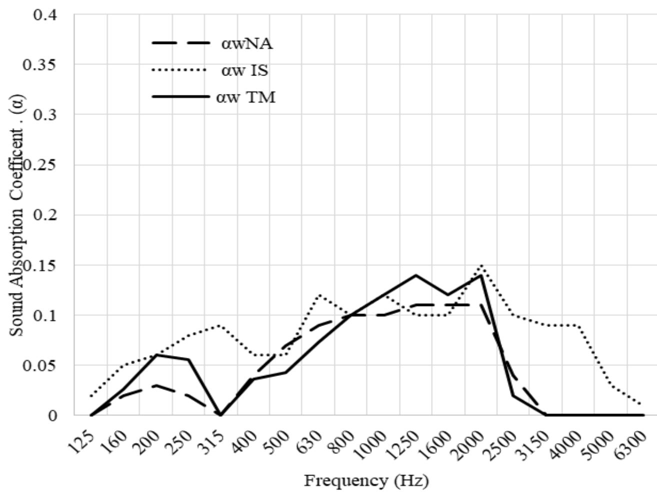

Figure 6; comparison of α_{wNA}, α_{wIS}& α_{wTM} for sound absorption

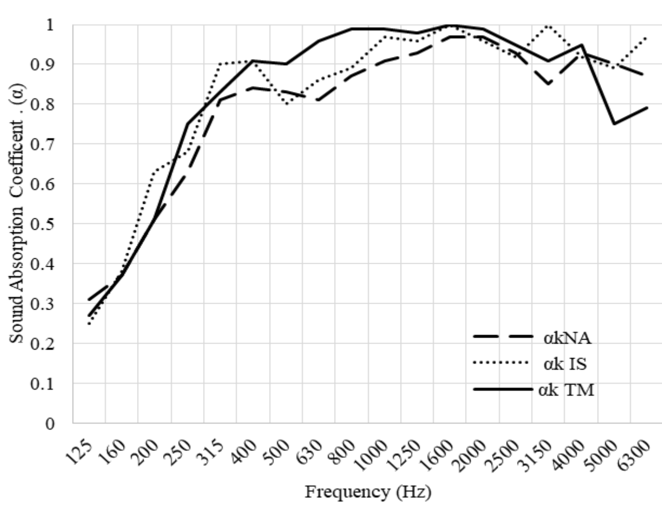

Figure 7; comparison of α_{kNA}, α_{kIS}& α_{kTM} for sound absorption

5.5 Effect of Sample Locations on The Absorption of ASTM C- 423 and New Area (NA)

Figure 8 depicts the values and behavior of the absorption coefficient of rock wool for an area of 6.24 m^2 when placed in three positions 1, 2, and 3, and for an area of 9.36 m^2 when placed in two positions y & z inside the room, as well as the effect of these positions on the values of the absorption coefficient. According to the new area, the difference in sound absorption values of highly absorbent (rockwool) materials for the three places described in the American standard and the two specified positions Y and Z, and the difference in values between them, is roughly 0.15.

Figure 9 depicts the values and behavior of the absorption coefficient of wood for an area of 6.24 m^2 when placed in three positions 1, 2, and 3, and for an area of 9.36 m^2 when placed in two positions y & z inside the room, as well as the effect of these positions on the values of the absorption coefficient. The sound absorption values for weakly absorbing materials (wood) for the three positions defined in the American measurement and the two specified positions Y and Z according to the new area are convergent, with a difference of around 0.03 between them.

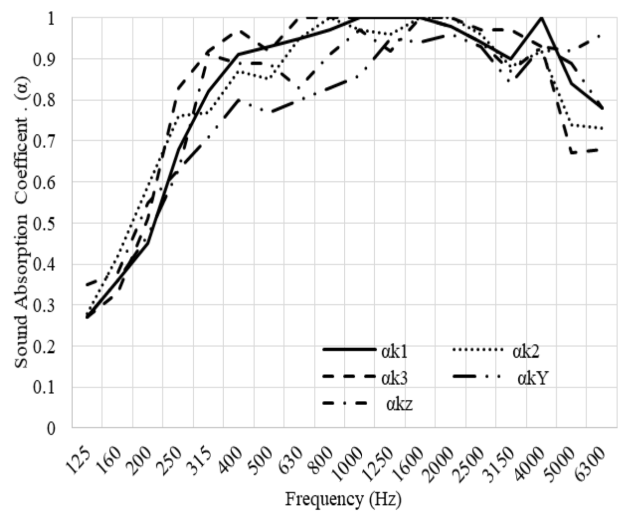

Figure 8; comparison of rock wool absorption for (6.24 and 9.36m^2) at locations (1,2,3,Y and Z).

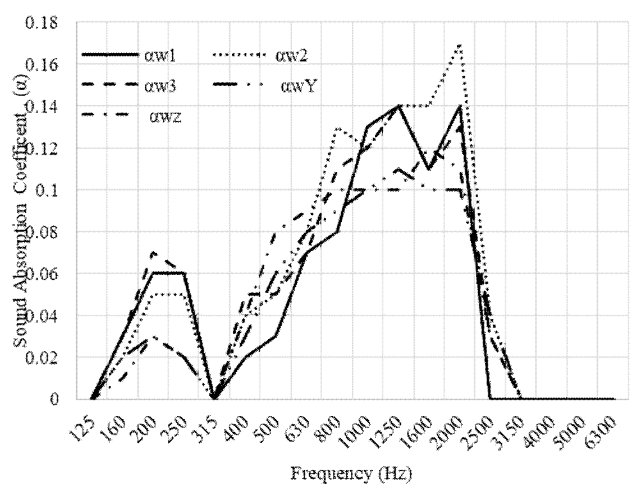

Figure 9; comparison of wood absorption for (6.24 and 9.36m2) at locations (1,2,3,Y and Z).

The highest curve in figure 10, is the relative standard deviation of Rockwool reverberation time $\mathcal{E}/T_k$. The region between frequencies 125Hz and 400Hz, respectively for empty room and boor sound-absorbing materials represented by low relative standard deviation values 0.01to 0.015 of reverberation time measurements of empty and wood $\mathcal{E}/T_E$, and $\mathcal{E}/T_w$. The relative standard deviation of reverberation time measurements of polyurethane sponge Ɛ/Ts is in the range from 0.01 to 0.03.

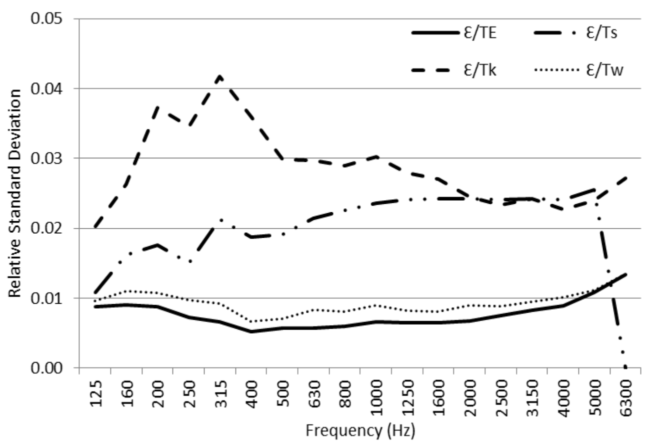

Figure 10: the Relative standard deviation of reverberation time for different Materials

6. CONCLUSION

To minimize the errors in sound absorption coefficient, diffusers are essential to improve the reverberation time measurements in the reverberation room [13]. For all cases of source positions (2, 3, and 4) affecting the values of SAA, in high sound-absorbing materials (Rockwool, polyurethane sponge), the values of SAA (TM) are greater than SAA (IS), and vice versa for weakly absorbing materials (wood).

Sound absorption coefficients calculated according to ASTM standards are higher than those measured according to ISO standards in materials with the highest sound absorption and decrease when the material's ability to absorb sound decreases, as in the case of wood. The number of sound source positions appears to have a little influence on the three materials' sound absorption. According to the new area, the difference in the values between the three positions specified in the ASTM standard and the two assumed specified positions Y and Z are about 0.15 due to the sampling placement effect on the sound absorption values of highly absorbent (Rockwool) materials for the three positions specified in the ASTM standard and the two assumed specified positions Y and Z. The difference in readings between them is also roughly 0.03 for poorly absorbing materials (wood). In the reverberation chamber, the sound absorption measurement exhibited an unusually low relative standard deviation, ranging from 0.01 to 0.04.

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