DOI: 10.61782/fa.2025.0862

FORUM ACUSTICUM EURONOISE 2025

THE EFFECTIVENESS OF PLENUMS IN ROOM ACOUSTIC CONDITIONING

Espinel Valdivieso, Ana Esther[1*] **Arenaz Gombau, Angel**[1] **Riesco García, Jose Ignacio**[1]
Mena Moreno, Andrea[1] **Gonzalez Nieto, Jairo**[1] **Cambor Iglesias, Pablo**[1]
[1] Audiotec Ingeniería Acústica S.A. C/ Juanelo Turriano, 4. 47151 Boecillo. Valladolid. Spain

ABSTRACT

The same absorbent material behaves differently depending on whether it is installed directly on a surface or if there is a plenum - an air chamber - between the supporting surface and the material.

This fact is particularly relevant in cases where these materials are used with or without a plenum in the acoustic conditioning of rooms, as the acoustic quality of a room can vary considerably depending on this factor.

AUDIOTEC has developed a study in which, in a first phase, was characterized in a reverberation chamber the variation of the sound absorption coefficient of different materials as a function of the plenum used in the tests.

Based on this information, simulations were carried out using ODEON Room Acoustic Software to calculate various room acoustic quality parameters (reverberation time, definition, clarity, STI) as a function of the plenum used.

This study concludes that in the project phase of room acoustic conditioning, the correct definition of the plenum to be used is fundamental, as depending on it, the acoustic quality of these rooms can be significantly improved.

Keywords: *acoustic absorption, reverberation time, inteligibility*

[*] ***Corresponding author***: *ana.espinel@audiotec.es*

1. INTRODUCTION

The purpose of this study is to evaluate, by means of acoustic modelling, the improvement obtained by the use of plenums in the acoustic conditioning of rooms.
For this purpose, test results of the acoustic absorption of materials with and without plenums, obtained in standardised test chambers, are used, as well as the room acoustic simulation software Odeon © room acoustics simulation software.

2. SOUND ABSORPTION TESTS

As a starting point for carrying out the study, we have used the results of sound absorption tests on materials with and without a plenum, carried out in Audiotec's standardised reverberation chamber at its facilities in the Boecillo Technological Park in Valladolid. These tests were carried out in accordance with the ISO 354 standard.

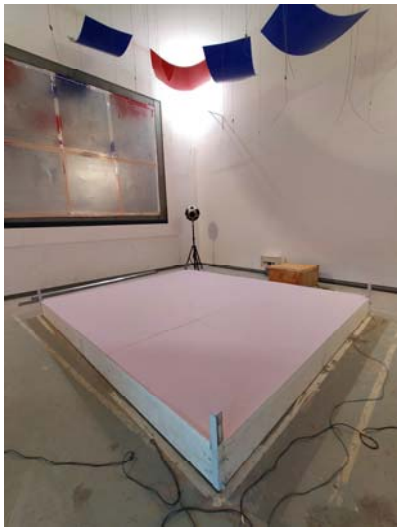

Figure 1. Plenum in reverberation chamber

2.1 TEST RESULTS USED IN THE STUDY

This study used the results of the absorption coefficient of different sound absorbing materials, including PET panels and mineral wool panels.
Firstly, the behaviour of sound-absorbing PET panels was analysed by varying the plenum.
The results obtained for the same material using different plenums

Frec Hz	α 0 mm plenum	α 50 mm plenum	α 200 mm plenum	α 400 mm plenum
125	0,05	0,15	0,35	0,40
250	0,05	0,40	0,65	0,75
500	0,25	0,85	0,85	0,80
1000	0,55	0,80	0,80	0,80
2000	0,85	0,95	0,85	0,85
4000	0,95	0,90	0,85	0,90

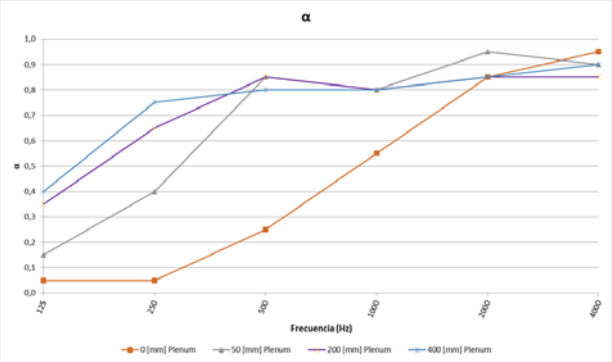

Figure 2. Sound Absorption Coefficient

3. ACOUSTIC CONDITIONING SIMULATION

3.1 The enclosure

In order to carry out the simulations, a multi-purpose enclosure was considered, with the following dimensions Floor area: 56 m2; height: 3 m; volume: 168 m3.

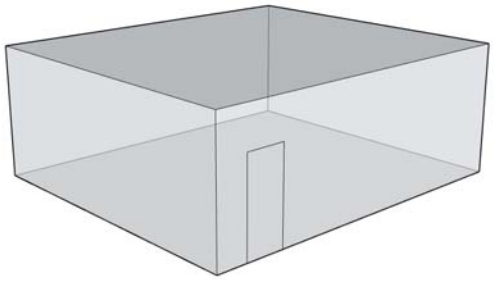

Figure 3. 3D Room Model.

The surfaces of the room are highly reflective: Ceramic tiled floor, smooth concrete walls and ceiling with plaster finish and a wooden door.
For the purposes of the simulation, only the ceiling is modified, leaving the other surfaces unchanged

3.2 Acoustic parameter recommended

Taking into account the intended use of our theoretical The recommended values to be obtained, taking into account the intended use of our theoretical enclosure as a multiple room, are as follows:

Parameter	Value
T20	0,80[s] – 1[s]
STI	≥ 0,65

3.3 Acoustic simulation

The simulations were carried out using the Odeon © acoustic prediction software. This software can be used to characterise various acoustic parameters, the results of which will vary according to the different materials present on the surfaces of the room.

The following parameters were analysed for this study:

- Reveberation timeT20 [s]
- Speech intelligibility STI

3.4 Initial acoustic characterization of the enclosure

As a starting point, we took the 3D model that had been generated to carry out a study of the most important acoustic parameters.

3.4.1 Reverberation time

The average reverberation time obtained (500 Hz, 1000 Hz and 2000 Hz) is 5.48 s, although there are reverberation times of the order of 10 s at low frequencies.
At medium frequencies, the reverberation times are also high, in the order of 6 s, which has a direct impact on speech intelligibility.
Finally, the high frequencies show values in the order of 3 and 4 s.

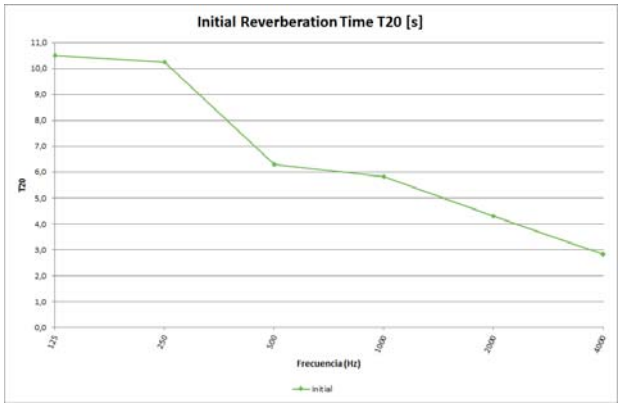

Figure 4. Initial reverberation time.

3.4.2 Speech intelligibility

Another parameter calculated is the speech intelligibility STI, which evaluates the quality of the perception of the spoken word, the initial value obtained is poor, which is consistent with what was observed in the reverberation time:

Parameter	Value
STI	0.30

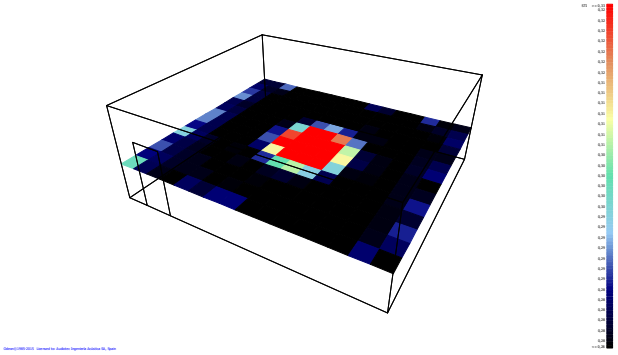

Figure 5. Initial speech intelligibility.

3.5 Acoustic characterisation of the enclosure with the sound-absorbing material installed without a plenum

3.5.1 Reverberation time

The simple application of the material to the ceiling reduces the reverberation time at low frequencies by almost half, with values around 5 [s].
At medium frequencies, the reverberation time is reduced to values around 1.6 [s].
The reverberation time at high frequencies shows a significant reduction with values around 1 second.

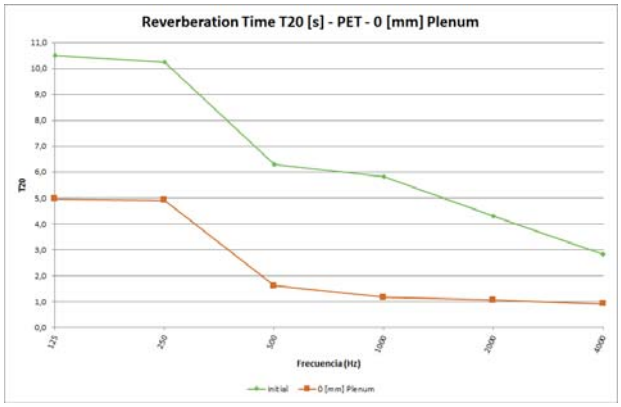

Figure 6. Reverberation time – 0 [mm] plenum

The application of the sound-absorbing material in the enclosure is effective at medium and high frequencies, although its behaviour is not so effective at low frequencies, since the reverberation time, although reduced, is still high for this type of enclosure.

Parameter	Value
T20 mid	1,17 s
T20 125 Hz	5 s
T20 250 Hz	5 s

3.5.2 Speech intelligibility

The impact of installing a non-plenum sound-absorbing material in the enclosure is positive, and speech intelligibility values have improved significantly, although they are still not good.

Parameter	Value
STI	0.55

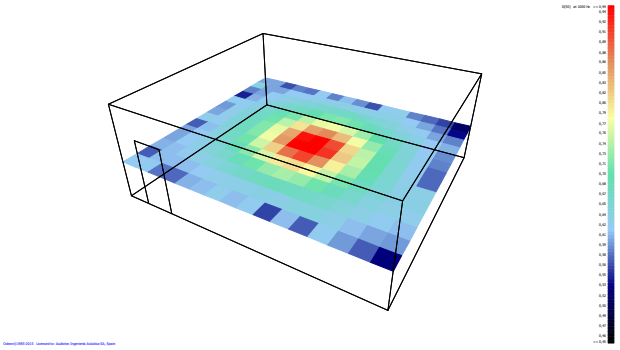

Figure 7. Speech intelligibility STI – 0 [mm] plenum.

3.6 Acoustic characterization of the enclosure with the material installed with 50 mm, 200 mm and 400 mm plenums

In this section we analyse the effectiveness and the improvement offered by the plenum in the acoustic conditioning of the enclosure.

For this purpose, a new simulation was carried out using plenums of 50 mm. 200 mm. and 400 mm. with the same material.

3.6.1 Reverberation time

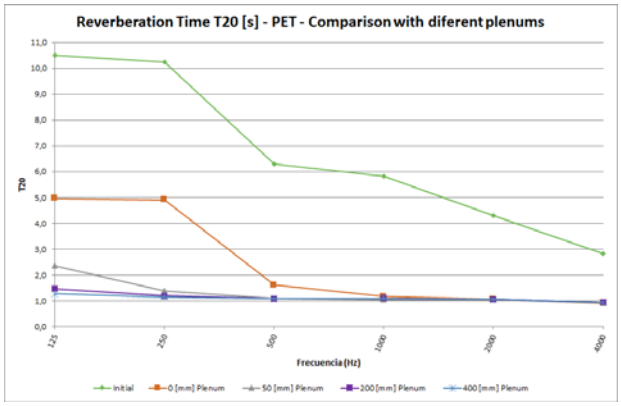

Figure 8. Reverberation time - Comparison according to the use of plenums.

As can be seen, the introduction of plenums with an air chamber improves the reduction of the reverberation time in the low frequency bands. This improvement is progressive as the air space (plenum) behind the material is increased, although there is hardly any difference between the 200 mm and 400 mm plenum.

The mid-frequencies also show a significant improvement with the introduction of an air gap. However, the improvement becomes less noticeable as the air gap increases.

Finally, it is observed that the high frequency is hardly affected by the introduction of the air gap. In other words, the improvement in this range is determined by the surface properties of the material.

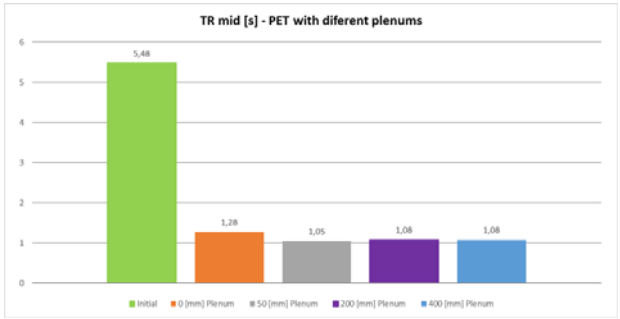

Figure 9. TRmid comparison

When the sound absorbing material is placed in the room without the air chamber, the average reverberation time shows a noticeable improvement.

It should be noted that the TR mid only considers the 500, 1000 and 2000 Hz bands.

mm, we have a decrease in the average reverberation time with respect to the material installed directly, but when the chamber is increased to 200 mm, we have a slight increase and a stagnation for the 400 mm chamber, proving that when the air chamber is increased, the medium and high frequencies are hardly affected, in this case, although an improvement is observed in the low frequencies.

3.6.2 Speech intelligibility STI

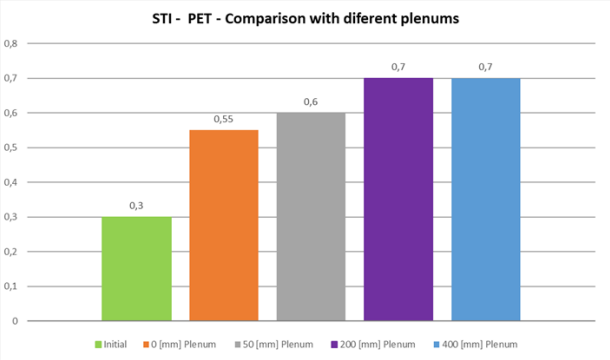

Figure 10. Speech intelligibility STI comparison

Speech intelligibility shows a significant improvement when the material is placed directly without an air chamber, going from a "very poor" value of 0.30 to a "fair" value of 0.55, meaning that the material alone has a positive effect on speech intelligibility.

With the addition of a 50 mm air chamber, the improvement is notable, with values classified as "good" of 0.65, indicating that this configuration provides better control of sound energy in the speech frequency range.

With 200 mm and 400 mm plenums, the values are 0.7 and are considered "very good".

Increasing the size of the air chamber shows little significant improvement, keeping the speech intelligibility values in the "very good" range.

4. COMPLEMENTARY STUDY

4.1 Test results used in the complementary study

A complementary study was conducted with a different material type (mineral wool) to verify the influence of material type on plenum performance.

The absorption coefficient of the material tested with different configurations is as follows:

F Hz	α 0 mm plenum	α 400 mm plenum
125	0,15	0,40
250	0,60	0,70
500	1,00	0,80
1000	0,95	0,90
2000	0,90	0,90
4000	0,90	0,90

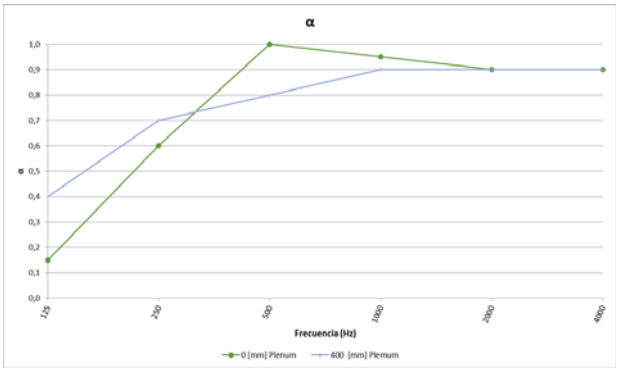

Figure 11. Sound Absorption Coefficient.

4.2 Acoustic characterisation of the enclosure with the sound-absorbing material 2 installed without a plenum

4.2.1 Reverberation time

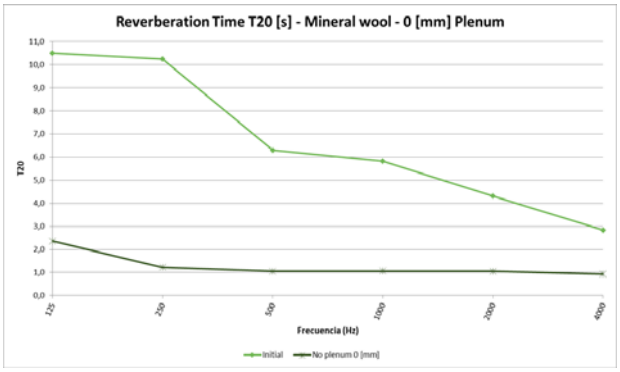

Figure 12. Reverberation time – 0 [mm] plenum.

The effect of using Material 2 in the enclosure without a plenum shows a reverberation curve with adequate values at medium and high frequencies.

The performance of material 2 at low frequencies without enclosure is better than that of material 1, reducing the reverberation time from around 10 [s] to values of 2.3 [s] for 125 Hz and 1.2 [s] for 250 Hz, reaching values of around 1.2 seconds, although still high.

At medium and high frequencies, the improvement in relation to material 1 is not so significant.

The average reverberation time obtained is slightly longer than recommended for this type of enclosure, although this difference is hardly noticeable at practical levels.

Parameter	Value
T20 mid	1,06 s
T20 125 Hz	2,3 s
T20 250 Hz	1,2 s

4.2.2 Speech intelligibility

The average speech intelligibility is rated "good". This indicates that the material has good control of the sound energy in the voice range.

Parameter	Value
STI	0.65

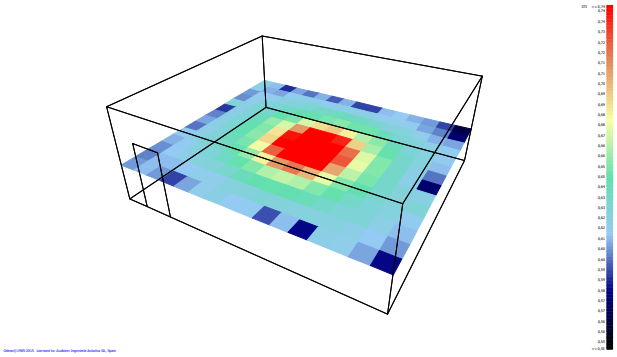

Figure 13. Speech intelligibility STI – 0 [mm] plenum.

4.3 Caracterización acústica del recinto con el material 2 instalado con plenum de 400 mm

4.3.1 Reverberation time

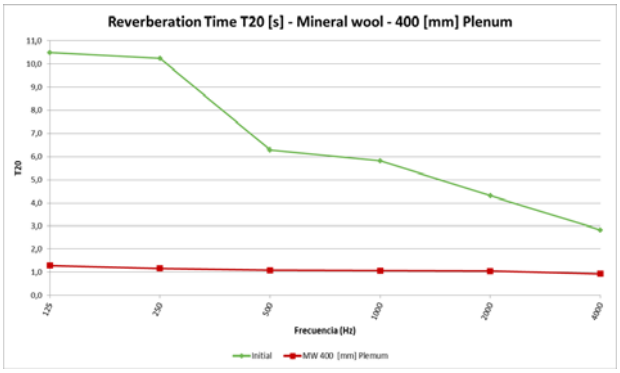

Figure 14. Reverberation time – 400 [mm] plenum.

As in the case of material 1, the reverberation time curve with a 400 mm air chamber stabilises at values close to 1 s over the whole frequency range studied, although a significant improvement can be observed in the 125 Hz band for this material.

4.3.2 Inteligibilidad de la palabra

In terms of speech intelligibility, the results are "very good".

Parameter	Value
STI	0.70

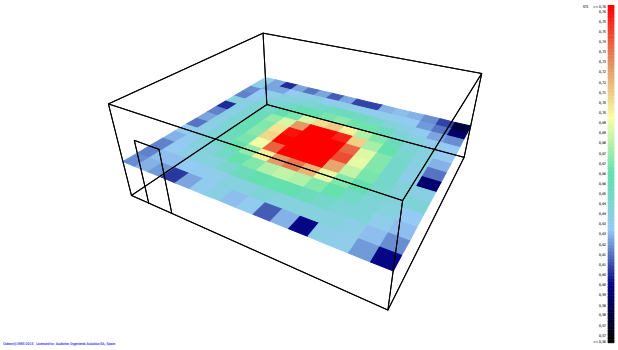

Figure 15. Speech intelligibility STI – 400 [mm] plenum.

5. COMPARATIVE ANALYSIS

5.1 Reverberation time

5.1.1 Materials installed without a plenum

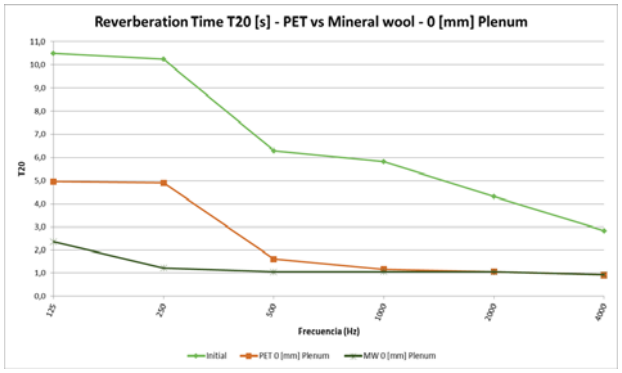

Figure 26. Reverberation time – 0 [mm] plenum comparison.

Material 2 has a better performance in the low frequency range compared to material 1 and controls the low frequency range more efficiently.

There is a slight increase in reverberation time in the 500 Hz band for material 1 at mid frequencies,

Both materials show similar behavior at high frequency, with material 2 being slightly better.

5.1.2 Materials installed with 400 mm plenum

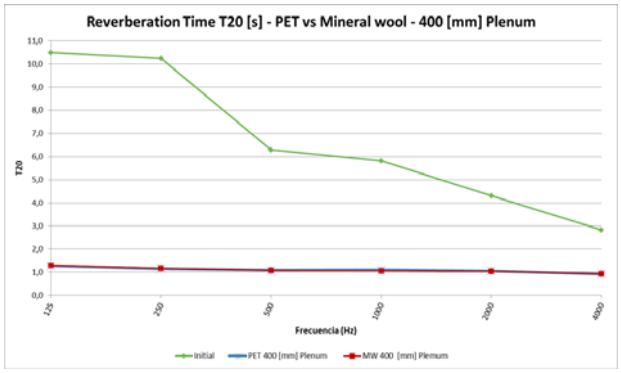

Figure 37. Reverberation time – 400 [mm] plenum comparison

The performance of the two materials with a 400 mm chamber is very similar, and in both cases the control of the low frequencies is significantly improved, while the performance in the mid and high frequencies remains stable.

5.1.3 TR mid comparison

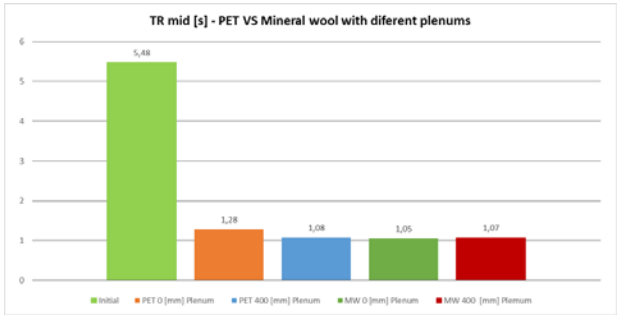

Figure 48. Trmid comparison.

As far as the average reverberation time is concerned, the placement of any sound-absorbing material improves the conditions, with material 2 showing the best performance

without an air chamber, with the most significant improvement at 125 and 250 Hz.

The reverberation time values obtained with a 400mm air chamber show hardly any perceptible differences between the different materials under consideration.

5.2 Speech intelligibility comparison

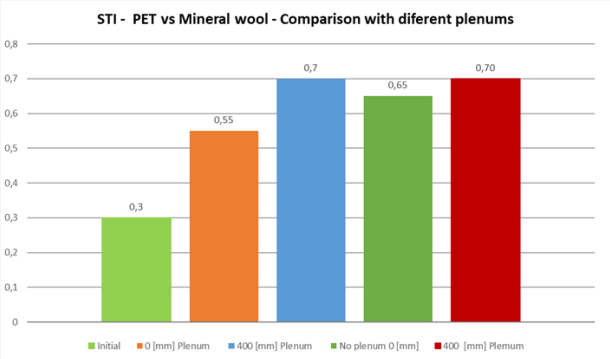

Figure 19. Speech intelligibility STI comparison

In terms of speech intelligibility, when placing the materials without air chamber, we have an improvement but insufficient with material 1.

Under the same conditions, material 2 without air chamber performs better than material 1.

The performance of both materials with 400 mm air chamber is similar, obtaining a "very good" performance.

6. CONCLUSIONS

The air chamber (plenum) is very effective in reducing low frequency reverberation (125Hz and 250Hz) for both materials, although its effect is less at medium and high frequencies than not using a plenum.

Material 2 without plenum shows a better performance at low frequencies than material 1, although this fact does not significantly affect the TRmid value, since it is calculated considering the 500 Hz, 1000 Hz and 2000 Hz bands.

The improvement in speech intelligibility without plenum is more significant with material 2, which has higher absorption results, especially at low frequencies, although the installation of a 400 mm air chamber tends to compensate for the improvement in room intelligibility.

The fact of inserting a plenum improves the speech intelligibility compared to not inserting it, although this improvement is hardly noticeable between the use of a 200 mm plenum and a 400 mm plenum.

7. REFERENCES

[1] Beranek, L.L., Acoustics, 5th edition, Acoustical Society of America, New York, (1954).

[2] Marshall, Long, Architectural Acoustics, Elseiver, California (2006)

[3] Blauert, Jens, Xiang, Ning, Acoustics for Engineers, Troy Lectures, Springer-Verlag, Berlin (2008)

[4] Everest, F. Alton, Pholman Ken c. Master Handbook of Acoustics, fifth edition, Mc Graw Hill (2009)