COMPARATIVE ANALYSIS OF MEASUREMENT TECHNIQUES OF THE SOUND ABSORPTION COEFFICIENT OF A MATERIAL

ANÁLISIS COMPARATIVO DE LAS TÉCNICAS DE MEDIDA DEL COEFICIENTE DE ABSORCIÓN SONORA DE UN MATERIAL

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RESUMEN

Las tendencias actuales apuntan al desarrollo de nuevos materiales económicos y ecológicos con óptimas propiedades mecánicas, acústicas y térmicas. En la caracterización acústica del material es habitual medir su coeficiente de absorción sonora. Las dos técnicas usuales de medida de este parámetro son en cámara reverberante y en tubo de Kundt. No obstante, existen técnicas de medida “in situ” del coeficiente de absorción que permiten una comprobación del comportamiento real en la forma definitiva de colocación del material. En este trabajo se presenta un estudio comparativo del coeficiente de absorción sonora medido en un material usando distintas técnicas de medida.

ABSTRACT

The actual tendencies point to the development of new economical and ecological materials with optimal mechanical, acoustical and thermal properties. In the acoustical characterization of a material is very usual the measurement of the sound absorption coefficient. The Kundt tube method and the reverberant room method are the most commonly used techniques for the measurement of this parameter. Nevertheless, there are “in situ” measurement techniques what allow a verification of the real sound absorption behaviour after installation of the material. In this work, a comparative study of the sound absorption coefficient measured by means these techniques are presented.

1. INTRODUCTION

For optimal material selection the performance of acoustic samples should be known. There are many methods to measure the acoustic absorption of samples. These techniques all have their specific strengths and weaknesses. The Kundt tube method and the reverberant room method are the most commonly used techniques and they are standardized.

The impedance tube is one of the oldest and most well-know instruments to measure impedance, reflection, absorption and transmission of a sample at normal incidence. In ISO 10534-2:1998 [1] the use of the transfer function method as developed by Chung&Blaer in 1980 is specified [2]. This method is easy to use, and because the tube is closed the influence of the background noise is low. However, sound absorption properties can only be determined at normal incidence. There are sample installation problems: air gaps behind the sample and at the specimen side are difficult to avoid. Also, sample size is restricted by the tube´s inner diameter and depending on the sample properties the measured absorption can be different to that of a large sample.

On the other hand, absorption measurements in a reverberant room are based on the principle that an acoustic absorbing sample reduces the sound pressure over time. The sound field in a reverberant room is supposed perfectly diffuse, to achieve this, random sound is generated inside a room that has strongly reflecting walls, with preferable are shaped irregularly to avoid standing waves [3]. The reverberant room method is standardised in ISO 354: 2003 [4]. Large facilities and large samples are required for this standardised method.

Nevertheless, the main shortcoming of the aforementioned laboratory methods is that they do not represent the sample after installation. When samples are mounted they can be deformed which can change acoustic properties, but also nearby structures can influence the behaviour.

Since 1997, Microflown Technologies commercialises a sensor which can directly measure sound pressure and particle velocity in a small spot (approximately 3 mm x 1 mm x 0.5 mm). Compared to laboratory techniques, in situ methods are more influenced by external disturbances such as background noise and reflections from nearby objects. For a rock wool we present a comparative study of the sound absorption coefficient measured by means a PU probe, by the Kundt tube method and the reverberant room method. The novelty of this work is that the values assigned by means these two last techniques have been extracted from intercomparison exercises organized by Laboratory Society Acustilab under EUROLAB-Spain.

2. MÉTHODS AND MATERIALS

Although the in situ measurement technique based on the PU probe is commercial we consider appropriated a detailed description of the assembly used. The sound is generated by a small loudspeaker of 11 cm diameter, broadband and easy to power. During the measurement the loudspeaker has been fixed on a tripod as it has been shown in Figure 1 and the distance to the sample surface (hs) has been kept constant and equal to 27 cm.

The frequency range is limited from 200 to 10000 Hz by the loudspeaker performances and the impedance phase estimation. The PU probe is calibrated when it is fabricated and it should be recalibrated on per two years. However, each time a measurement is performed in a different ambience a “measurement calibration” should be performed to take into account the effect of the room. To perform this calibration the impedance gun must be placed pointing to the best free field conditions possible, meaning to the ceiling or other far surface from the measurement position. The measurement signals from the data acquisition module were acquired with the software: the Plane Wave model, the Mirror Source model and the Q-term model have been implemented [5].

Figure 1. Picture of the assembly used for the PU probe for the measurements.

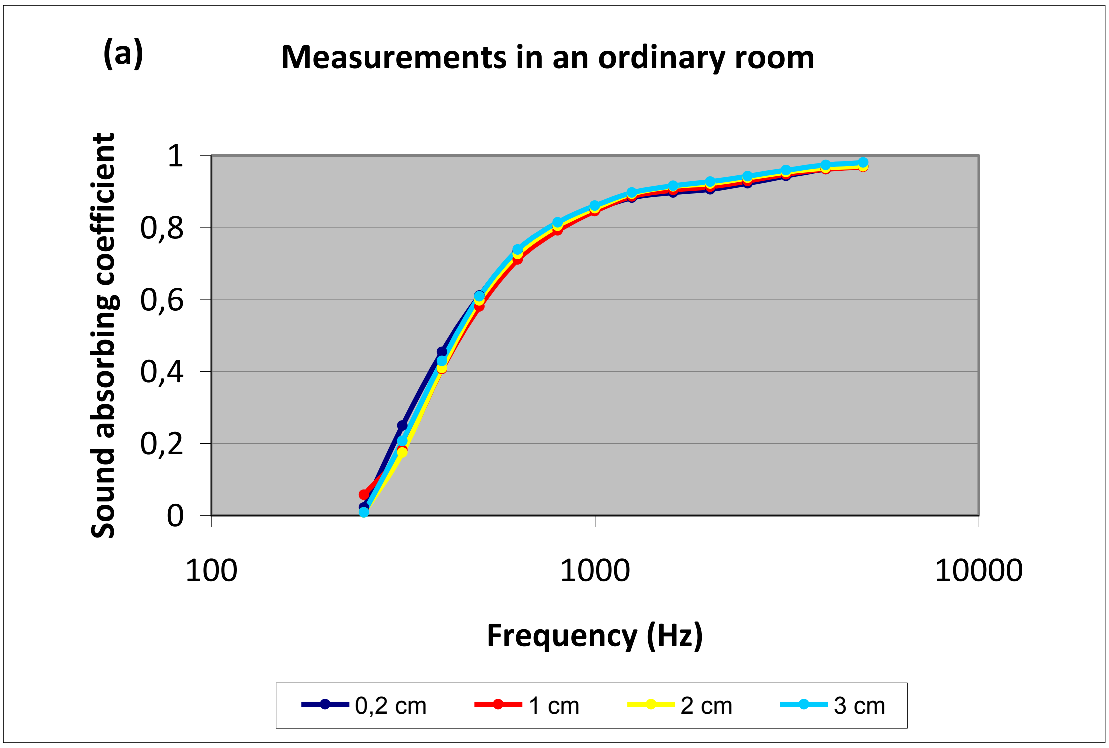
The Plane Wave model is the simplest model and it assumes that the material under test is exposed to a plane wave of normal incidence which gives rise to a reflected plane wave. In the Mirror Source model, the reflected sound wave from the surface is represented as a “mirror source” below the impedance boundary. It accounts for the propagation of spherical sound waves above the sample, but it does not account for propagation of spherical waves inside the sample. The Q-term solution describes the sound field as the sum of the direct wave and a wave originating from a mirror source using a spherical reflection coefficient Q. On the other hand, reflections from surfaces other than the sample can affect the measurements. In order to reduce noise from the measuring system and unwanted reflected waves, two techniques are used in the software to approach the anechoic response: moving average in the frequency domain and impulse windowing. The moving average principle is based on that a value at a certain frequency point is the average value of a certain amount of frequency points. Two options can be used in the software: linear and logarithmic scaling of the frequency bands. The impulse windowing method is based on the room reflections are later in time than the primary response and can be removed mathematically by setting the impulse response to zero by a window.

The material used for the measurements is a 5 cm thick rock wool, model 231.652 fabricated by Rockwool Company and a density of 70 kg/m^3. A single measurement of the acoustic surface impedance has been carried in the configuration illustrated in Figure 1: the loudspeaker normal to the sample surface and the PU probe positioned parallel to the surface.

3. RESULTS AND DISCUSSION

For the calculus of the absorption coefficient the Plane Wave model is discarded. There is insufficient space to the assumption of plane waves because the sound source is positioned near the sample. The Mirror Source model and Q-term model are in good agreement if the distance between the probe and the sample is kept small. But in general, there is similarity between the results obtained with these two models in high frequencies and they differ in low frequency range. Although Q-term model can be supposed theoretically more precise because spatial interferences effects are included, sometimes the simpler Mirror Source model is preferred, as it appears to be more robust. The Q-term model is based on involved integrals and an iterative procedure, which are sensitive to measurement inaccuracies as negative values of the sound absorption coefficient at low frequencies. A detailed comparative studied of these two models will be published elsewhere. In summary, the Mirror Source model was used to calculate the sound absorption coefficient and the measured impedance was smoothened with a moving logarithmic average in the frequency domain.

The distance between the probe and the sample surface (z) have been varied during the experiment between 0.2 and 3 cm while the loudspeaker height to the sample surface has been kept constant and equal to 27 cm. The sound absorption coefficient is calculated in third octave bands for a frequency range between 250 and 5000 Hz. The measurements have been performed on a rock wool sample of a rectangular area of 1.2 x 0.6 m^2. In Figure 2 for four different distances of the PU probe to the sample surface ranging between 0.2 and 3 cm the sound absorption coefficient for the rock wool sample placed in three different environments is shown: in an ordinary room with an office background noise, a reverberant room and a room with sound insulation materials on the walls which approximates the condition of a semi-anechoic room….. in all the cases the sample has been placed in horizontal position on a rigid surface. Each of the curves shown is the average of five measurements carried out under repeatability conditions. The results shown in Figure 2 point to that for this measurement configuration only a level influence of the distance PU-sample surface is observed, the higher differences has been measured for the semi-anechoic room. In Figure 3 the sound absorption coefficient measured for the sample in horizontal and in vertical position with the PU probe placed at 30 and 60 cm from the floor have been plotted together. The measurement has been carried out in the reverberant room. In the vertical configuration, the sound field is clearly influenced by reflections from the floor. The higher discrepancies are going to be found at frequencies where the direct sound waves and the waves that have reflected against these surfaces strongly interfere. Since the absorption coefficient of a fibrous material at low frequencies has small values, the normal component of the particle velocity close to the material becomes very small at those frequencies. The problem is that in situ measurements the surface distributions near the surface measured is unknown.



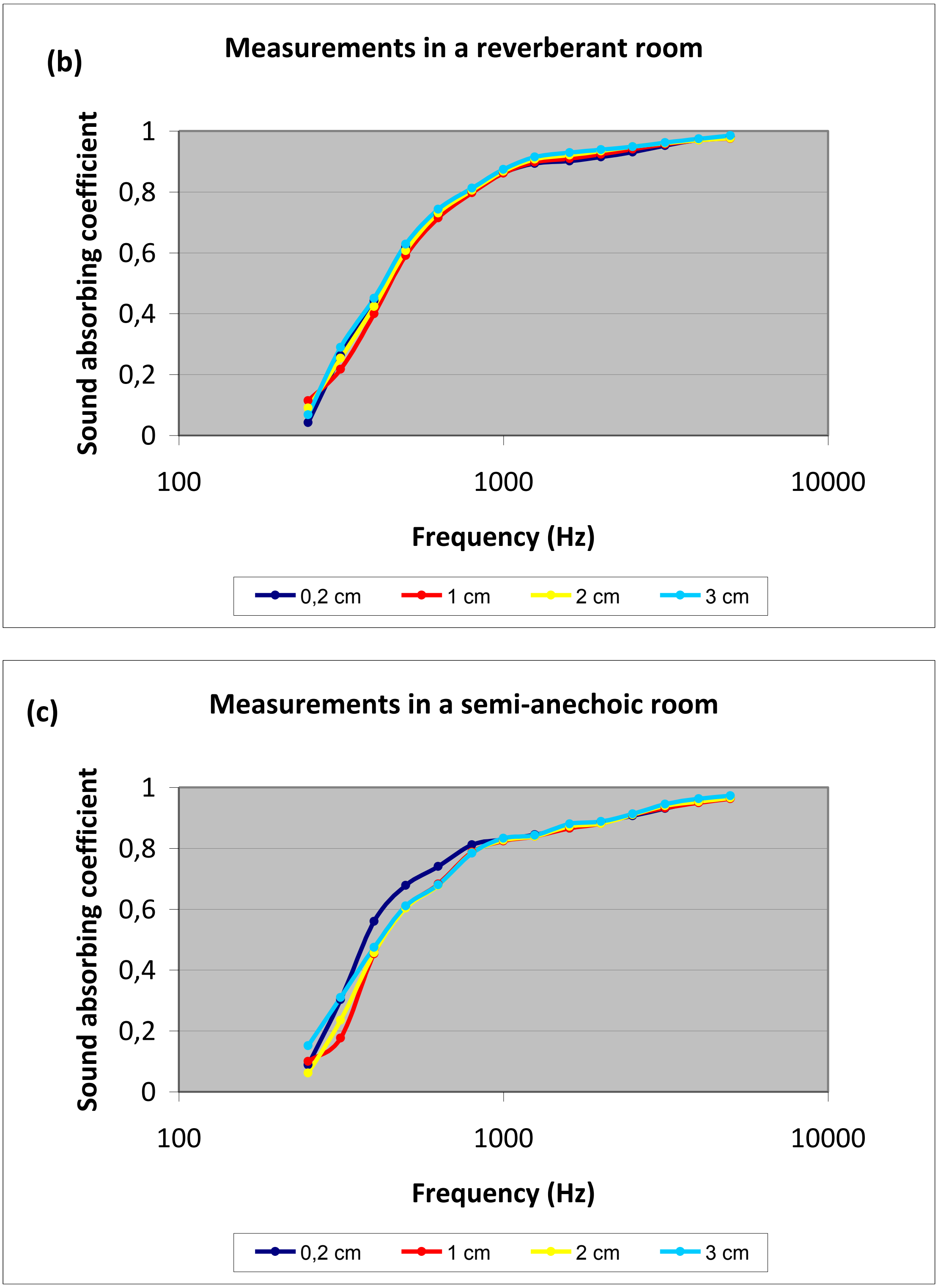


Figure 2. Sound absorption coefficient measurement at three different environments: (a) an ordinary room, (b) a reverberant room and (c) a semi-anechoic room. The sound absorption coefficient is plotted for four distances PU probe-sample surface.

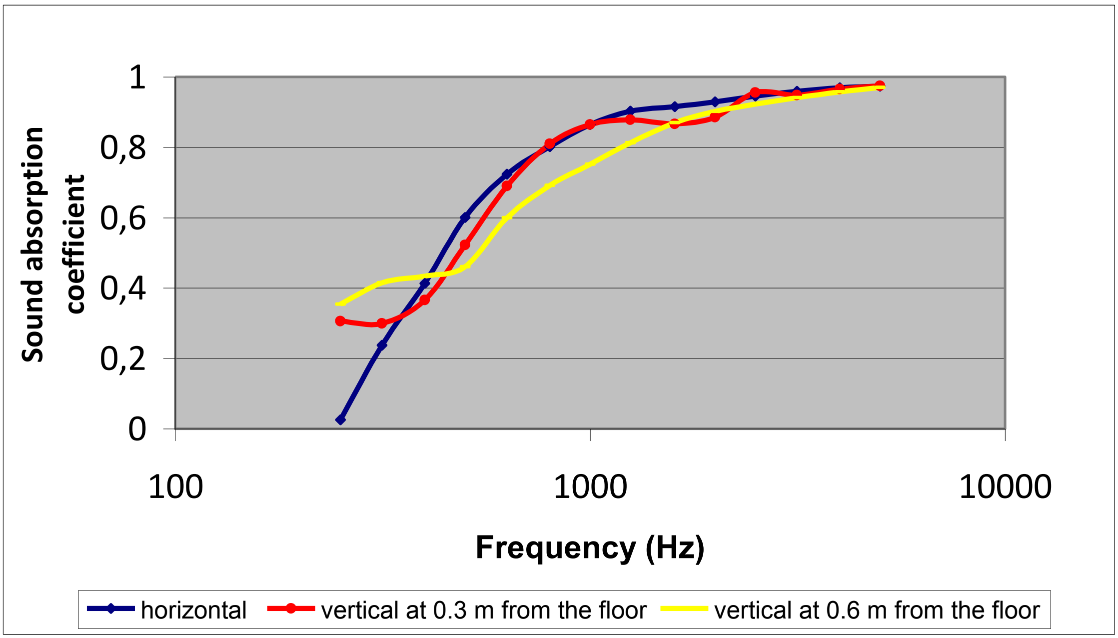


Figure 3. Sound absorption coefficient measurement in the reverberant room with the sample placed in horizontal on a rigid surface and in vertical position. In the last case the PU probe has been placed at two different distances from the floor. The distance PU probe-sample surface was 1.5 cm.

At this point a comparison with the other techniques of measurement of the absorption coefficient is necessary, the Kundt tube and the reverberant camera methods. The values assigned to the sound absorption coefficient measured by means these two techniques has been extracted from intercomparison exercises. These intercomparison exercises have been organized by the Laboratory Society ACUSTILAB under EUROLAB-Spain. This Kundt tube intercomparison exercise is focus on measurements of acoustic absorption according to standard ISO 10534-2:1998 [1]**.** The intercomparison involved a total of 9 Spanish laboratories participants. The reverberant room intercomparison exercise is focus on measurements of acoustic absorption according to ISO 354:2003 [4] The intercomparison exercise involved a total of 14 laboratories participants members of EU. All laboratories participants have reverberant chamber and/or alpha cabine. In both intercomparison exercises the sound absorption coefficients are calculated in octaves and single weighted evaluation index retrieved according to the standard EN ISO 11654:1998 [6]. In Figure 4 the sound absorption coefficient resulting from intercomparison exercises and measured by the PU probe for different sample configurations have been shown. The values obtained with the reverberant room method were significantly higher at low frequencies, and for some bands exceed unity. This behaviour has been discussed in many studies and has e.g. been attributed to finite sample size and to edge diffraction. Although some discrepancies exist at frequencies of 300-1000 Hz the results obtained with the rectangular sample in horizontal position placed on a rigid surface are closed to the values measured in the tube. Some authors claim that for some kind of materials the values measured by means the Kundt tube method are reproduced with the PU probe if a similar collocation for the sample is used [5]. However in our case, a similar assembly to the Kundt tube does not give better results as it has been shown in Figure 5. A circular sample of 10 cm of diameter was cut from the material. The sound absorption coefficient has been measured placing the sample on a rigid surface and mounted in the Kundt tube. The discrepancies observed at 2000 Hz are related to the interference between direct waves and diffracted waves from the edges around the specimen.

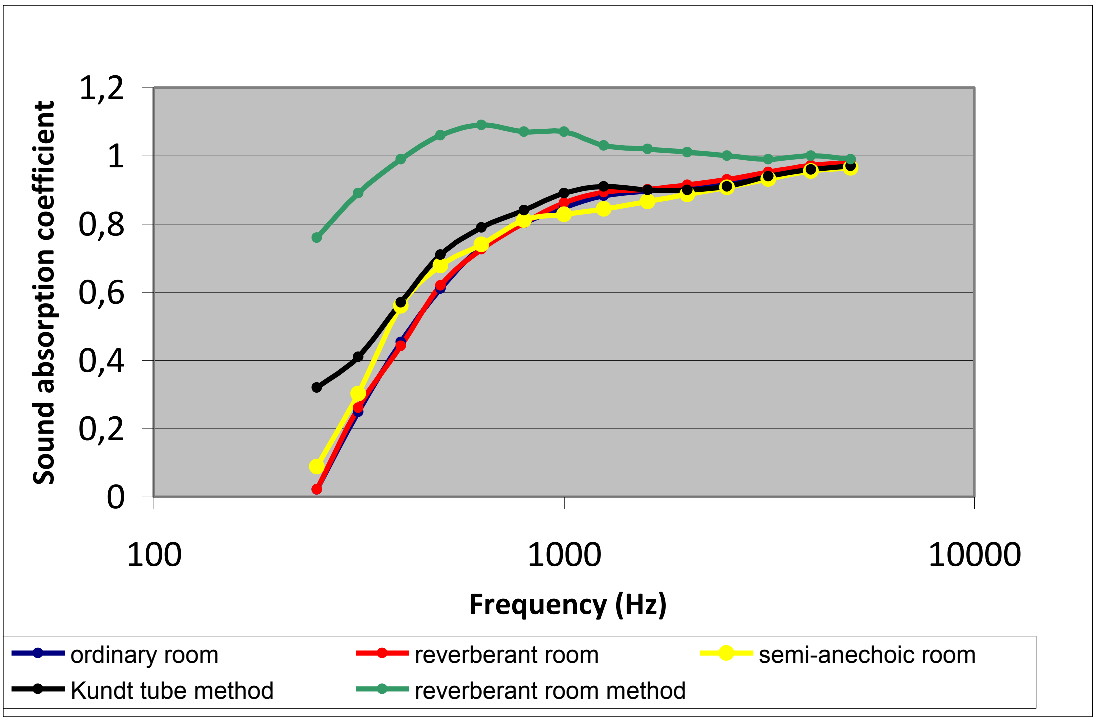


Figure 4. Sound absorption coefficient measured for the rock wool sample by means three different techniques. The sound absorption coefficient measured in different environments by the PU probe has been included in the figure.

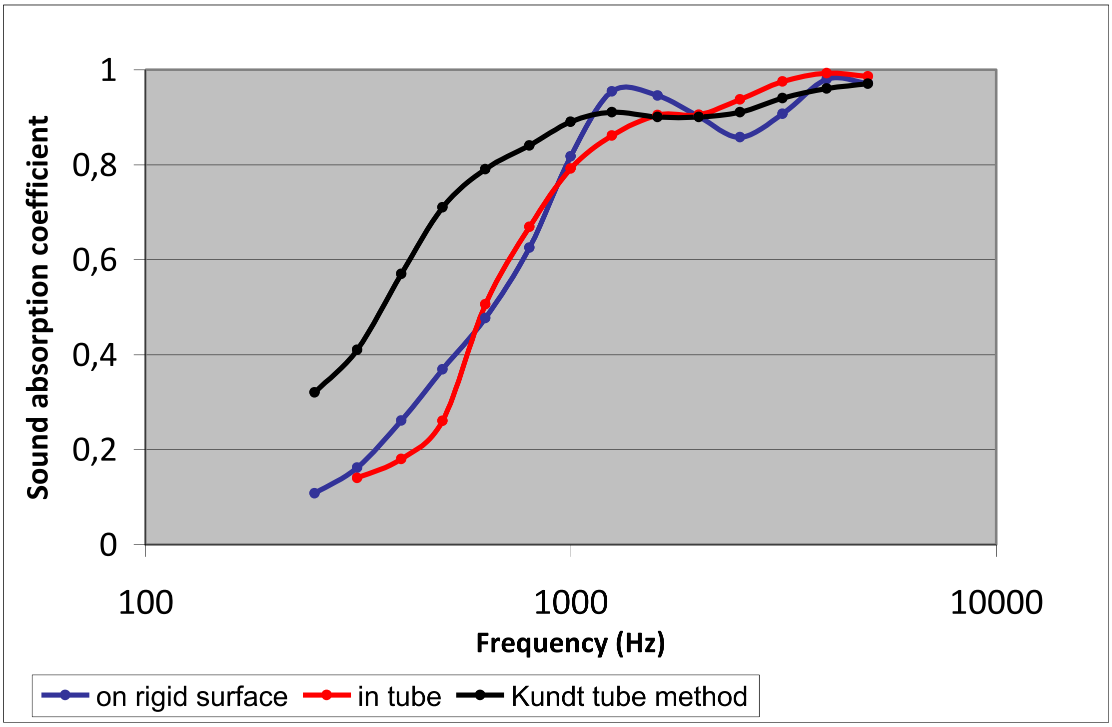


Figure 5. Sound absorption measured in the Kundt tube and with a 10 cm diameter circular sample placed on a rigid surface (with borders) and inside the Kundt tube surrounded of rigid material.

5. CONCLUSIONS

The sound absorption coefficient of a rock wool has been measured by means the Kundt tube method, the reverberant method and by means a PU probe. The results derived by the two first methods have been extracted from intercomparison exercises organized by the Laboratory Society ACUSTILAB under EUROLAB-Spain. Concerning the kind of material chosen, comparable results to the Kundt tube method are obtained if a large dimensions sample on a rigid surface and far away of reflecting surfaces is used. The problem is that in situ measurements the surface distributions near the surface measured and the size of the sample can be unknown and variable. The higher discrepancies seem to be found at frequencies where the direct sound waves and the waves that have reflected against other surfaces, or the direct waves and diffracted waves from the edges around the specimen strongly interfere. Due to these factors affecting the in situ measurements based on PU technique a quantitative analysis in terms of precision of this in-situ measurement method will be published elsewhere.

6. REFERENCES

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