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Research Article

DETERMINATION OF SOUND TRANSMISSION COEFFICIENT OF GYPSUM PARTITION WALLS INSULATED BY CELLUBOR™

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ABSTRACT

One of the biggest problems of using public spaces for constructions, such as high-rise buildings, offices, hospitals, and hotels, is noise caused by sound transmission through the lightweight partition walls used to divide volumes. In this study, experiments were carried out to determine the sound transmission coefficient of lightweight gypsum partition walls insulated by CelluBor. Experiments were performed in an anechoic test chamber consists of two separate cells. One cell was used as the sound source, and the other one was used as the receiver cell. A total of 12 samples were used in the experimental studies, which were categorized into four separate groups. The main features that distinguished these groups from each other were the profile height used in the samples and the number of gypsum board layers used on each side of the profiles. In addition, one blank (no insulation) sample, one half filled, and one fully filled with insulation material were used for each test group. The test samples were placed between two cells. The sound volume of the sound source was measured separately in dB in both cells, and the sound transmission coefficients of 12 different samples were determined. It was observed that the most efficient results were obtained only when half of the profile height was filled with the CelluBor material. The use of a composite material consists of boron and waste materials such as CelluBor as sound insulation material in lightweight partition walls can affect the sound transmission coefficient greatly.

Keywords: *Gypsum Partition Walls, CelluBor, Sound, Transmission Coefficient, Structural Acoustic*

1. INTRODUCTION

In recent years, population is rapidly increasing, especially in cities. Big problems on residential areas are growing as well. One of the most practical solutions to these problems is to build multi-story structures in narrow spaces. Thus, high-rise buildings are built. Many people are allowed to live and work together. However, some problems still exist, which are caused by these common living spaces. One of them is the emergence of sound that is defined as disturbing noise. Different kinds of noise have many negative impacts on human health and performance (Ilgun *et al*., 2010). People living in common areas need to be protected from these adverse effects. One of the most basic solutions in solving this issue is to prevent sound transitions among volumes. According to the law of mass, partition walls must be rigid and heavy, causing undesired loads in addition to the loads of barrier elements of structures. Because the interactions of buildings from earthquake loads are directly proportional to their weight, buildings having heavy weight are impacted greatly by earthquake loads.

There are many valuable academic researches which investigates the sound transmission issue of lightweight partition walls. Researchers worked on both numerical and experimental solutions to solve the noise problem. One of the noteworthy works is to use the finite layer method as a numerical technique for modeling the acoustic behavior of walls (Díaz-Cereceda *et al*., 2012). Researchers also pointed out that, in addition to the mass and sound frequencies, some other parameters can affect acoustic insulation as well, such as the arrival angle of sound waves, weak points in insulation, hardness, and damping properties of the element (Tadeu and Santos, 2003). Moreover, investigations have also been done on the use of lightweight materials in different engineering fields because of their acoustic properties (Tadeu *et al*., 2004).

Experimental studies can be reviewed in different categories. Some researchers carried out experimental work on lightweight partition walls made of gypsum and some new materials, including mixtures of mushrooms, corn cobs, coconut shells, and cellulose with mineral additives. Meanwhile, researchers have also worked on the sound transmission of gypsum walls themselves (Senthilkumar, 2012; Hernández-Olivares *et al*., 1999; Carvalho, 1995; Faustino *et al*., 2012; Karaağaçlioğlu, 2012; Warnock and Quirt, 1997).

Other noteworthy works include determinations of the influence of slit size on sound transmission through a lightweight partition wall, measurements of the plumbing appliance noise using ISO 3822-(1999) test procedures, and determination of the sound insulation performance of suspended ceilings (Başbuğ, 2005; Uris *et al*., 2004; Thomalla, 2003). In addition, some researchers focus on issues such as experimental determination of the accuracy of methods that are used to approximately calculate the loss in sound transmission among walls and floors, analysis for noise control of conservatory buildings, comparison of computer programs used to design acoustic rooms, and noise problems of a building built of tunnel formwork systems (Cambridge, 2006; Çoşgun *et al*., 2008; Özkan, 2001; Ballagh, 2004).

In this study, an experimental work was carried out to find the sound transmission coefficient of CelluBor, which is used as a sound insulation material inside lightweight partition walls to solve the noise problem and to reduce unnecessary loads of these walls to a building. CelluBor is a material obtained from cellulose-based materials and contains boron salts, which is mostly used as the heat and fire insulation material. Because CelluBor can be produced directly from cellulose, it can be produced using recycled paper as well. In addition, the experiment also investigated the optimum thickness for both the partition wall and the insulation inside it.

2. EXPERIMENTAL STUDY

2.1. Materials

To produce the test specimens, 75 × 30 × 0.5 mm and 50 × 30 × 0.5 mm (height, width and thickness) U aluminum profiles, 1200 × 2500 × 12.5 mm (width, height and thickness) gypsum boards and CelluBor were used.

2.2. Preparation of Test Specimens

A total of 12 test specimens were produced in four groups having dimensions of 1500 × 1500 mm^2 to find the sound transmission coefficient of the lightweight gypsum partition walls insulated with CelluBor. As shown in Fig 1, the main structure of all 12 test specimens consisted of an aluminum U profile skeleton frame, gypsum boards at each side of the frame and CelluBor sprayed inside as sound insulation material. The test specimens were constructed according to infrastructures of lightweight partition walls that are very commonly used in Turkey.

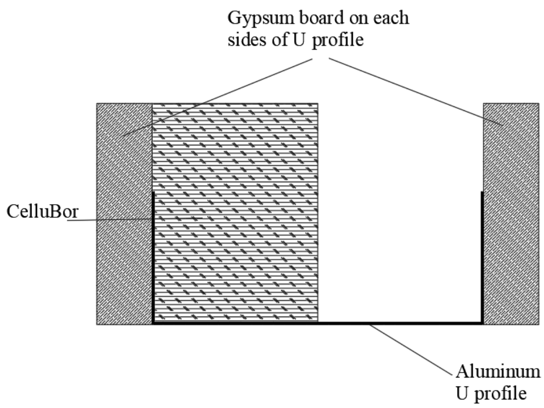
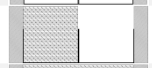
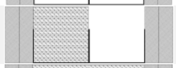


Fig. 1. Main structure of test specimens (The number of profiles, gypsum boards and the thickness of CelluBor differs in all test specimens).

The first group P[75]GB[I] was constructed using a 75 mm aluminum and one gypsum board attached on each side of the profile. Three different specimens were used in this group. One of them had no CelluBor insulation. The second one had half filled (37 mm) CelluBor insulation, and the third one had fully filled (75 mm) insulation. The three specimens in the second group P[75]GB[II] had the same insulation and aluminum profile. The two gypsum boards were placed on each side of the profile. The third and fourth groups had two 50 mm aluminum profiles attached with each other, with a total height of 100 mm, and the insulation materials (0, 50, and 100 mm) were placed inside the profiles.

Table 1. Materials used in all test specimens and cross section for every single test specimen.

No	Specimens	U Profile	Gypsum Board (Number)	CelluBor (Thickness)	U profile (Number)	Specimens Cross Section
1	P[75]GB[I]-00	42x74x42 mm	1	-	1	
2	P[75]GB[I]-37	42x74x42 mm	1	37 mm	1	
3	P[75]GB[I]-75	42x74x42 mm	1	75 mm	1	
4	P[75]GB[II]-00	42x74x42 mm	2	-	1	
5	P[75]GB[II]-37	42x74x42 mm	2	37 mm	1	
6	P[75]GB[II]-75	42x74x42 mm	2	75 mm	1	
7	P[100]GB[I]-00	2x42x49x42 mm	1	-	2	
8	P[100]GB[I]-50	2x42x49x42 mm	1	50 mm	2	
9	P[100]GB[I]-100	2x42x49x42 mm	1	100 mm	2	
10	P[100]GB[II]-00	2x42x49x42 mm	2	-	2	
11	P[100]GB[II]-50	2x42x49x42 mm	2	50 mm	2	
12	P[100]GB[II]-100	2x42x49x42 mm	2	100 mm	2	

The third and fourth groups had two 50 mm aluminum profiles attached with each other, with a total height of 100 mm, and the insulation materials (0, 50, and 100 mm) were placed inside the profiles. The only difference between the third and fourth groups is the number of gypsum boards attached on each side of the profiles, i.e., the third group P[100]GB[I] had one gypsum board, and the fourth group P[100]GB[II] had two. A summary of the materials used in all test specimens and the cross section for each single test specimen are listed in Table 1.

3. METHODOLOGY

To conduct transmission loss testing according to standardized method is to use two adjacent reverberant room with a gap between to put test specimen in (Phillips, 2014). Due to constraints, experiments were performed in an anechoic chamber built at the Construction Laboratory of KTO Karatay University in Konya, Turkey.

This anechoic chamber was constructed with almost same properties used by (Ilgun *et al*., 2010). The chamber consists of two adjacent rooms. Each room has a net volume of 2.28 m^3 and a surface area of 8.71 m^2. The interior dimension of each chamber was 1.35 × 1.3 × 1.33 m^3. A 0.15 × 1.50 × 1.50 m^3 gap between two chambers was designed for test specimens to be placed. This anechoic chamber with two cells was made in a suitable section of the laboratory. Rubber wedges were placed underneath the anechoic chamber to dampen possible vibrations from the ground.

The plan view and A-A section with all dimensions of this chamber is shown in Fig. 2. For entrance and exit purposes, two 70 × 70 cm^2 windows insulated with two layers of rock wool were constructed on both sides of the anechoic chamber.

In addition, the entire inner surface of the cells was also covered by two layers of rock wool having a thickness of 5 cm and a density of 150 kg/m^3. The aim was to prevent possible external noises and to prevent reflections in the cells where noise was produced and transmitted.

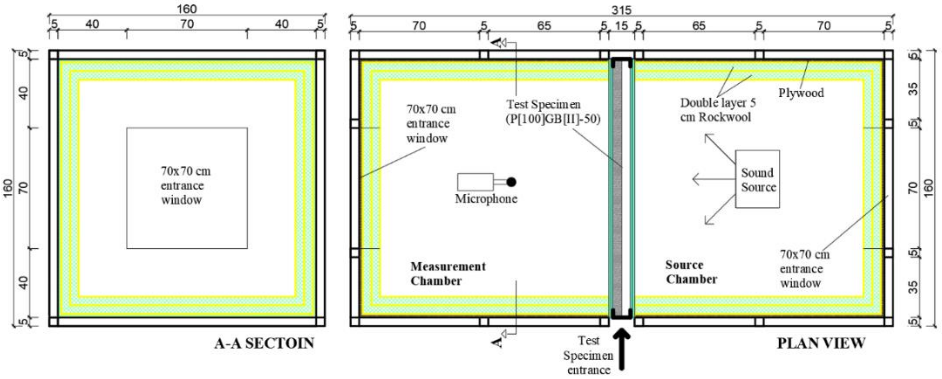
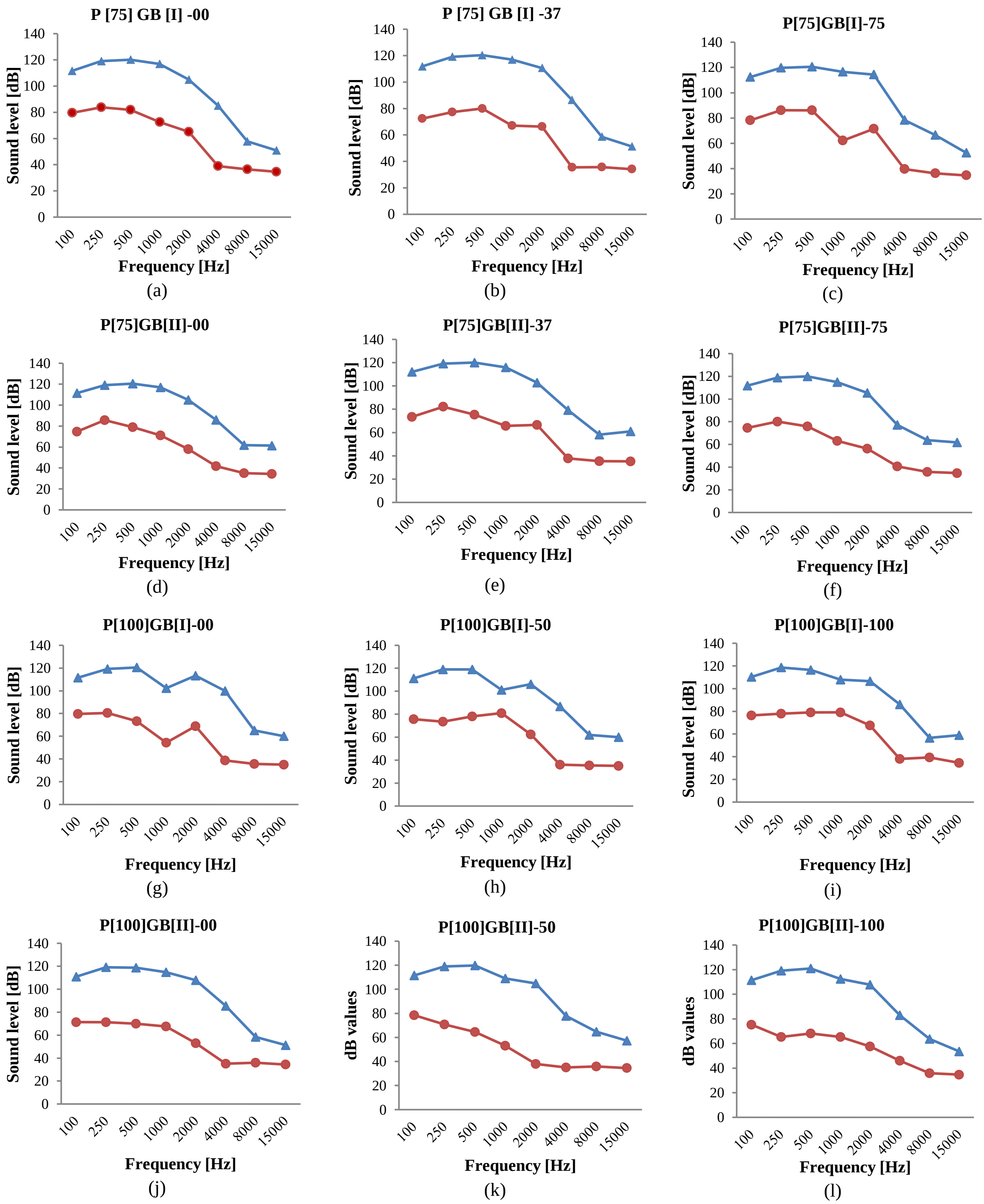


Fig. 2. The plan view and A-A section of anechoic.



▲ Represent the source chamber's sound level as dB.
● Represent the transmitted sound level as dB measured in the receiver chamber.

Fig. 3. The transmission losses (TL) for all 12 test specimens (a-l).

Different frequencies were produced inside one of the cells at very high decibels using Tone Generator 100-15k Hz (*http://www.ringbell.co.uk/software/audio.htm accessed date: August 10, 2018*) and an amplifier loudspeaker. The generated frequencies are the central frequencies which human ears can hear at middle and high levels of noises, including 100, 250, 500, 1000, 2000, 4000, 8000, and 15000 Hz. After placing the test specimen between two chambers, any gaps between test specimens remained open, and the chambers were filled and closed with rook wool.

Different frequencies were generated in the source chamber (Ilgun *et al*., 2010). The generated sound level was first measured in the source room before the same sound level was measured in the receiver room. The measurements were done on both rooms using an Extech HD600 sound meter.

The TL and α values of the test specimens were calculated using eq. (1) and (2) (Ilgun *et al*., 2010).

$$TL = IS - (RS + TR) \tag{1}$$

$$\boldsymbol{\alpha} = \frac{\boldsymbol{TL}}{\boldsymbol{IS}} \tag{2}$$

Where TL stands for sound transmission, IS incoming sound, RS reflected sound and TR transmitted sound

4. EXPERIMENTAL RESULTS AND ANALYSIS

The transmission losses (TL) for all 12 test specimens are given between [a-l] in Fig. 3. In addition, Fig. 4 shows the incoming sound, reflected and observed sounds, and the transmitted one. The reflected sound was neglected because of the double layers of rook wool.

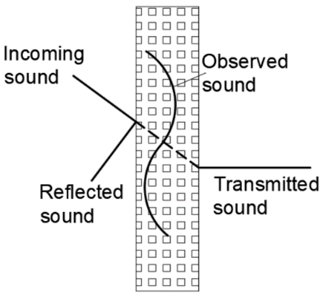


Fig. 4. Transmission losses (TL) for all 12 test specimens

12 different test specimens were divided into groups according to their size and types of insulation. According to their dimensions, the test specimens were divided into

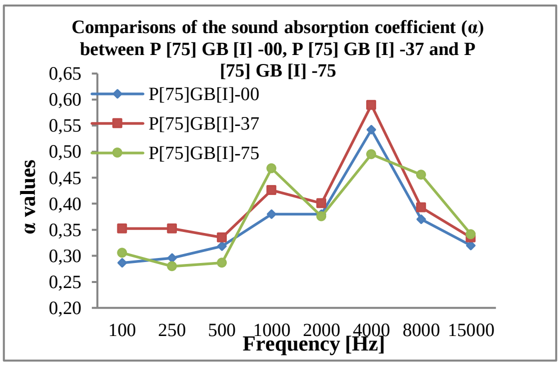


Fig. 5. Comparison of test specimens in group P[75]GB[I].

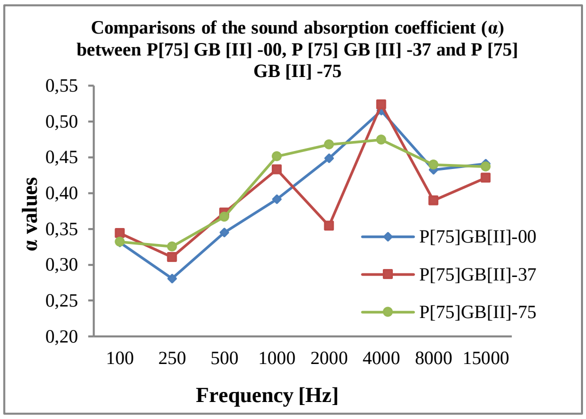


Fig. 6. Comparison of test specimens in group P[75]GB[II].

4 groups, i.e., P [75] GB [I], P [75] GB [II], P [100] GB [I] and P [100] GB [II]. According to the insulation types, each group above (P[75]GB[I], P[75]GB[II], P[100]GB[I], and P[100]GB[II]) was further divided into three different subgroups. These subgroups which contained 12 test specimens in total were examined with five different insulation thicknesses, i.e., uninsulated, 37 mm, 50 mm, 75 mm and 100 mm. First, the comparison among the three test specimens of each group is graphically represented. Then, the comparison among the best four test specimens in each group is demonstrated.

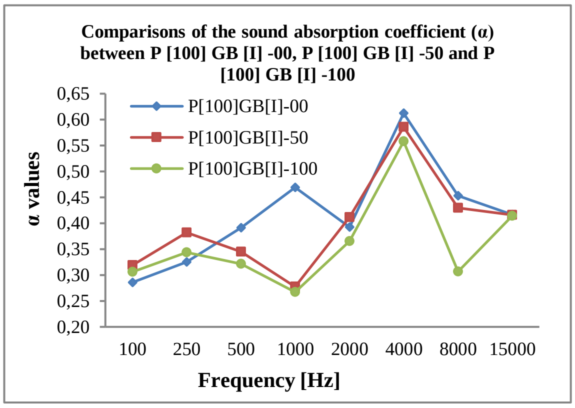


Fig. 7. Comparison of test specimens in group P[100]GB[I].

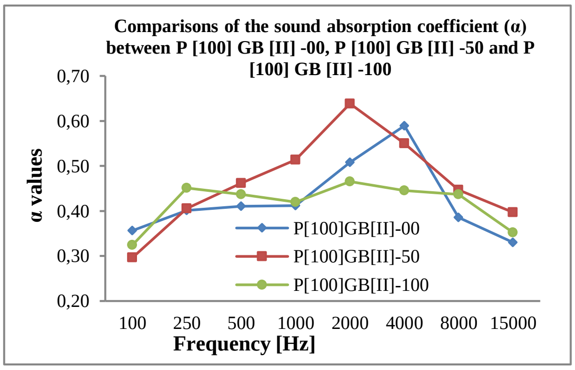


Fig. 8. Comparison of test specimens in group P[100]GB[II].

The comparisons of the test specimens in the four groups are shown in Fig. 5 to Fig. 8.

As shown in Fig. 5, the comparison of the three test specimens in the P[75]GB[I] group shows that the α values were between 0.28 and 0.58. The first reduction in α values occurred at 500 Hz. After an increase, the second reduction occurred at 2000 Hz. The maximum α values were at 4000 Hz, after which it decreased steadily. Fig. 6 shows the comparison of the three specimens in the P[75]GB[II] group. The first reduction in α values was at 250 Hz. Then, the α values increased until 4000 Hz. P[75]GB[II]-37, however, decreased at 2000 Hz. After a rapid reduction, the α value of P[75]GB[II]-37 was the highest at 4000 Hz. After that, the α values of all three specimens decreased.

As shown in Fig. 7 and Fig. 8, the α values of the P[100]GB[I] and P[100]GB[II] groups were between 0.26 and 0.62 and between 0.29 and 0.64 respectively. In the P[100]GB[I] group at 1000 Hz, the α values of all specimens decreased, except for P[100]GB[I]-00, which had a higher α value. The same specimen also had the highest α value at 4000 Hz. In the P[100]GB[II] group, the P[100]GB[II]-50 specimen had the best performance over the other specimens.

The best four test specimens in their groups can be easily observed, i.e., P[75]GB[I]-37, P[100]GB[I]-00, P[75]GB[II]-37, and P[100]GB[I]-50. Fig. 9 shows the four test specimens that had the highest α value at their own groups. The sound absorption performance of P[100]GB[II]-50 was much better than the other specimens till 2000 Hz. After a reduction, its performance was still at average.

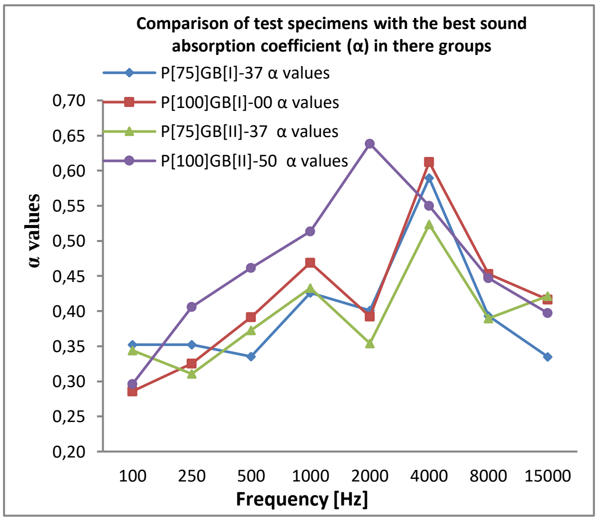


Fig. 9. Comparison of 4 different test specimens according to their α values.

5. CONCLUSION

The first aim of this study was to find out the sound transmission loss of lightweight partition walls insulated by CelluBor. The second aim was to find the optimum thickness of lightweight partition walls and the insulator inside them. To reach the goal, an experimental work carried out on lightweight partition walls with different sizes and insulated by CelluBor.

The results showed that the fully filled profile height with insulation did not give the best sound transmission loss. Half filling the profile would be the optimum choice because air can also work as a sound insulator. The number of gypsum boards on each side of the profile had a positive impact on the sound transmission coefficient.

It was understood from the results of this study that insulation should be made to reduce sound transmission when constructing lightweight partition walls. However, it is more economical and efficient to manufacture gypsum panels having insulation materials by half. As a result, it is recommended that the extension of such works and the development of lightweight partition walls insulated with different materials are noteworthy in terms of scarce resources.

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