SOUND INSULATION OF THE POLYMERIC LIGHTWEIGHT CONCRETE CHARGED WITH THERMOSETTING UNSATURATED POLYESTER (TUP) BY ISO 140-5

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Abstract. *The Lightweight Concrete has been widely used by civil construction for structural and fencing purposes. This work addresses the production of Polymeric Lightweight Concrete by means of the joint use of industrial waste of thermosetting unsaturated polyesters and biodegradable foaming agent, which presents special properties such low density, good strength, absorption, impermeability, durability, thermal and acoustic insulation and low cost, when compared to conventional masonry. Thus, this article presents comparative sound insulation results of new Polymeric Lightweight Concrete and conventional fencing materials, using ISO 140-5, which standardizes the measurement of sound insulation level of buildings.*

Keywords*: lightweight concrete, polymeric, sound insulation*

1. INTRODUCTION

Noise pollution is one of the most common types of pollution in urban areas. (Zannin et al, 2003). Thus, the city is considered a noisy environment. The urban noise pollution is characterized by environmental noise, which is very complex to be composed by several kinds of secondary noises coming from different sources and activities. Therefore, one of the solutions to provide greater acoustic comfort for the population on interior homes is to isolate the noise, reducing their entry into the buildings (Ferreira et al, 2009). It can be obtained by new and specials materials with better resistance and soundproof properties.

Lightweight and Cellular concrete are different from conventional concrete by presenting reduction in density and changes in thermal and acoustic properties. However, these are not the only important features that warrant special attention to cellular concrete. The use of lightweight aggregates also causes significant changes in other important properties of concrete such as workability, mechanical strength, modulus of elasticity, shrinkage and creep, and reduces the thickness of the transition zone between the aggregate and cement matrix (Melo, 2009).

A German standard DIN 4109 (1999) provides values for facade sound insulation, connecting external noise levels and the type of environment assessed. In this case insulation is related to the external wall, window size and the environment studied. For living rooms and bedrooms the considered index varies by the external noise levels. If the external noise is up to 60dB (A), the insulation should be at least 30dB, reaching a minimum isolation of 35dB when the external noise is from 65dB (A) (Ferreira et al, 2009).

Second Ferreira (2009), the properties of a façade element are defined primarily due to climatic conditions in the region where the housing will be built, especially considering the temperature. Thus, a major component to consider is the thermal insulation. In northeast the numbers of openings (windows, doors, etc.) for ventilation is considerable, which greatly reduces noise insulation level.

Only in Rio Grande do Norte, about 20 tons of polyester waste is discarded per month, which represents 55% loss of raw material during the production process. This waste must be transported to a landfill, creating a diversity of problems and costs (Melo, 2009).

Therefore, this article aims to evaluate the soundproof of a new Polymeric Lightweight Concrete button industry TUP waste. The soundproof evaluation was obtained comparing the sound level reduction for both materials: Lightweight concrete and conventional brickwork by Standard ISO 140-5. It is expected verify the sound insulation quality of materials conventionally used nowadays in construction and the improvement on building acoustic comfort by the new structural material TUP waste charged.

2. BREAF REVIEW

2.1 – Polymeric lightweight concrete

The study of concrete is made in two lines of research: "High Perfomance Concrete - HPC" – which compression resistance may overcome 100 Mpa in 28 days - and "Structural Lightweight Concrete - SLC". Merging advantages of both concretes, it brings a new subject of study, the "High Performance Lightweight Concrete - HPLC". According to Alduaij et al. (1999) and Haque and Al-khaiat (1999) there is a world trend based in economic and technical criteria, favorable to use of HPLC to structural and fencing purposes in construction industry, specially using pre-fabricated technology.

Among the concretes with density between 400 and 1800 kg /m³, stands out in the context of this study the "Foamy Lightweight Concrete - FLC", a lightweight concrete obtained by addition of an air entrained agent (foam) to cement mortar. FLC allows the reduction of the concrete density keeping the mechanical strength and providing weight reduction from itself and from the loads acting on the foundation, with consequent reduction of the work final cost (Berner, 1991; Zhang and Gjörv, 1991a; Bremmer and Holm, 1994; Vieira and Gonçalves, 2000; Rossignol et al, 2001). Concrete is widely researched, and were found some studies of thermoplastic polymer in conventional and lightweight concrete. However, thermosetting polymer in the cellular concrete had not been explored.

The major problem of modern society is the rapid growth of industrial products consumption, generating an excessive increase of waste and its disposal in inappropriate places. This is the case of button industry: only in Rio Grande do Norte, about 20 tons of polyester waste is discarded per month, representing 55% raw material loss on production process. This waste must be transported to a landfill, creating a diversity of problems and costs (Melo, 2009).

The button industry thermosetting unsaturated polyesters waste as load for composite material is an alternative to its reuse as raw material for superior properties constructive elements. Melo (2009) proposed the reuse of waste as raw material to construction industry, as an original and viable material under technical, environmental and economic approaches, creating the "Polymeric Lightweight Concrete - PLC", Fig. (1).

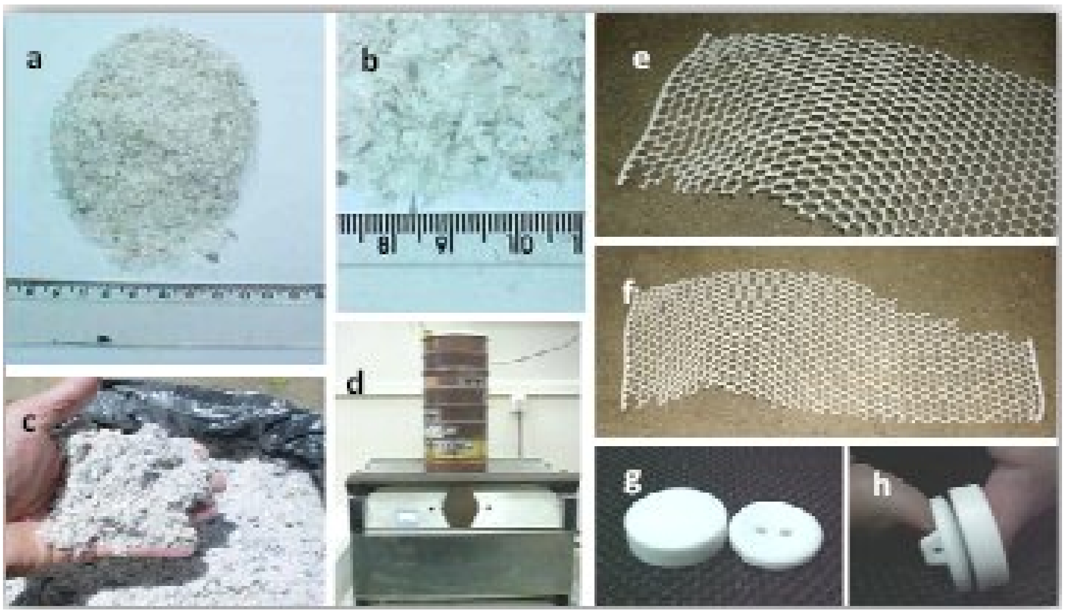


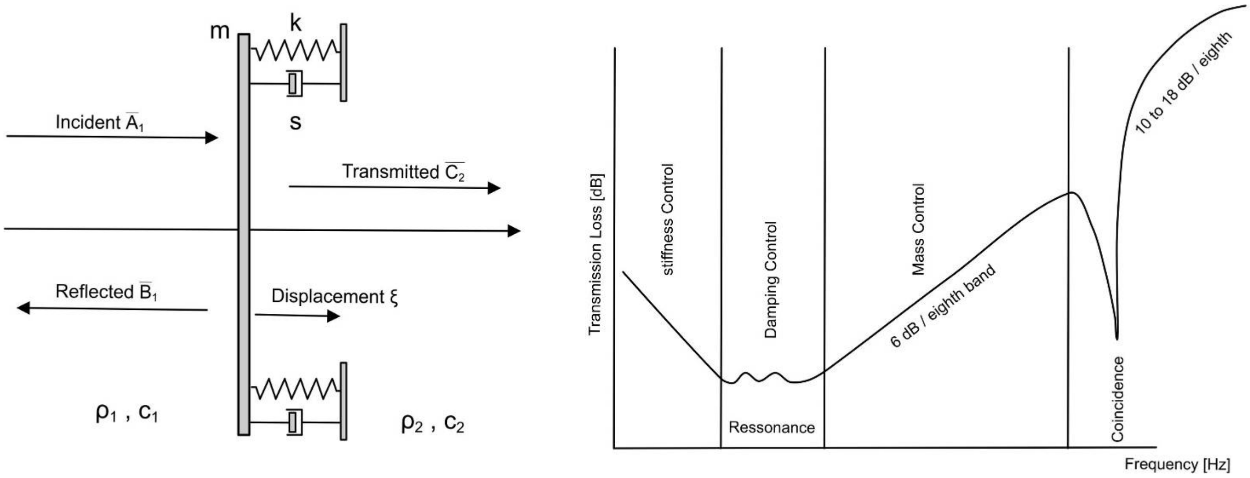
Figure 1: TUP waste. (a) and (b) granulometric feeling. (c) and (d) residue crushed. (e) and (f) PIT net before crushed. (g) and (h) Button (Melo, 2009).

2.2 – Sound Insulation

This work focused the acoustic isolation of Polymeric Lightweight Concrete as fencing part. The sound insulation prevents that the sound escapes to another environment, usually by heavy and dense materials such as concrete, bricks, flat stones, wood and lead.

The properties of materials or devices (enclosure, partitions, etc.) for acoustic insulation can be established by Transmission Loss (TL) and/or level difference (L).

A wall can be represented by a mass system (m), a spring (k) and a damper (s) as illustrated in Fig. (2a) and dampers and springs are distributed per unit area and having a mass per unit area (m) (Fahy and Gardonio, 2007).



(a) (b)

Figure 2: (a) Model of normal incidence sound transmission through a single-leaf partition (Fahy & Gardonio, 2007). (b) Transmission loss curve for a single-leaf partition. (Gerges, 2005).

The equation of motion for this system is given by Eq. (1) (Fahy & Gardonio, 2007).

$$m\frac{\partial^2 \xi}{\partial t^2} + s\frac{\partial \xi}{\partial t} + k\xi = \left(\overline{A}_1 + \overline{C}_2 - \overline{B}_1\right)_{x=0} \quad \text{Eq. 1}$$

The transmission loss relates logarithmically the sound energy transmitted with the sound energy incident on a wall, and can be expressed mathematically by Eq. (2) (Fahy & Gardonio, 2007).

$$PT = 10\log\frac{1}{\alpha_t} \quad \text{Eq. 2}$$

where

$$\alpha_t = \frac{transmitted\ energy}{incident\ energy} \quad \text{Eq. 3}$$

High transmission loss has a physical meaning: low transmission of acoustic energy. Fig. (2b) illustrates the behavior of the transmission loss for three different frequency bands. The first region of the curve (low frequency) is controlled by stiffness. Observe that the second region corresponds to the resonance frequency of the wall, and in this case for values of mechanical damping (s = 0) there is no net reflection and the wave passes through the wall as if it did not exist. At high frequencies the transmission loss control is given by mass, an increase in transmission loss of 6 dB doubling the frequency or the surface density (m) (Gerges, 2005).

Figure (2b) shows that the insulation of a wall is lowest when the noise resonant frequency approaches to the resonant frequency of the wall (coincidence frequency). The resonant frequency is given by Eq.(4) for a flat wall of rectangular homogeneous material fixed on four sides.

$$f_{n,m} = \frac{35{,}99}{2\pi a^2}\sqrt{\frac{D}{\rho_m . h}} \quad \text{Eq. 4}$$

$$D = \frac{Eh^3}{12} \quad \text{Eq. 5}$$

(h) is the wall thickness, (a) is the wall width or length, (ρ) is the density and E is the Young Modulus of the material.

2.3 – ISO 140-5

The ISO140-5 specifies two series of methods (element methods and global methods) for measurement of the airborne sound insulation of façade elements and whole façades. The element methods aim to estimate the sound reduction index of a façade element, for example a window. The element method uses a loudspeaker or available traffic noise as an artificial sound source. The global methods, on the other hand, aim to estimate the outdoor/indoor sound level difference under traffic conditions. The global methods use the actual traffic as sound source, and a loudspeaker may be used as an artificial sound source.

The element loudspeaker method estimates the apparent sound reduction index, and can be compared under specified circumstances, with the sound reduction index obtained in laboratories for the corresponding façade elements. The global loudspeaker method quantifies the airborne sound insulation of a whole façade or even a whole building in a specified situation and this result cannot be compared with laboratory measurements.

With a loudspeaker, directivity in a free field shall be such that the local differences in the sound pressure level in each frequency band of interest are less than 5 dB, measured on an imaginary surface of the same size and orientation as the test specimen. Figure (3) suggested the loudspeaker (4) placed in one or more positions outside the building at a distance *d* from the façade, and angle of sound incidence equal to 45° ± 5°. The average sound pressure level is determined either directly on the test specimen (the element method) or 2 m in front of the façade (the global method), as well as in the receiving room.

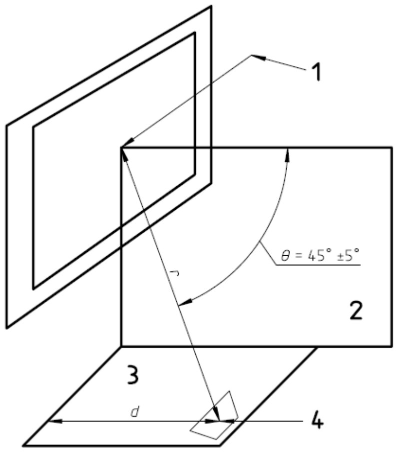


Figure 3. Suggested position of the loudspeaker, point (4).

The generated sound field shall be steady and have a continuous spectrum in the considered frequency range. The standard specifies the measurements frequency ranges. In all relevant frequency bands, the sound source power level shall be high enough to give a sound pressure level in the receiving room that exceeds the background noise level by at least 6 dB.

Following, the measurement of the average sound pressure level in the receiving room may be done by using a single microphone moved position to position or by an array of fixed microphones or by a continuously movement of oscillating microphone. The sound pressure levels at the different microphone positions were averaged on an energy basis for all sound source positions. Five microphone positions shall be used, as a minimum, distributed within the maximum permitted space throughout each room, spaced uniformly to obtain the average sound pressure level of each sound field. If a moving microphone is used, the sweep radius is specified to be at least 0,7 m.

In order to ensure that the observations in the receiving room are not affected by extraneous sound, such as outside noise, electrical noise in the receiving system, or electrical cross-talk between the source and receiving systems, background noise levels shall be measured.

3. MATERIALS AND METHODS

This research performed the sound insulation measurements of two different façade elements. The conventional masonry wall (ceramic blocks, stucco) and the TUP waste Polymeric Lightweight Concrete.

The conventional masonry ceramic brickwork was built according to the traditional technique. The bricks being laid (standing up) with mortar joints of cement and sand. The cement was CP II - Z - SR 32 attends NBR 11578 and 5737 (sulphate-resistant Portland cement). The blocks were ceramic brick type with eight holes, 9 cm thick and added to stucco 10 cm thick wall.

The slab of TUP waste foamy process added in the standard mixer: sand, cement, lime and TUP according to the required density. TUP was wet to avoid absorb the mixing water from PLC. The same cement was used. The foaming agent was Neopor® 600 an organic biodegradable liquid agent based on a protein of hydrolyzed animal keratin, non-toxic, pH = 6.9.

The water was added and blended by 5 to 8 minutes until obtaining a homogeneous mixture. Finally, added the Neopor ® 600 foam by 3 to 5 minutes. The solution made of 40 (forty) parts of water to 1 (one) part of the Neopor® 600 transformed in a stable and homogeneous foam. The blisters size varies between 0.1 and 0.5 mm. These small blisters when mixed to the PLC cause an expansion in the concrete dough reducing its density.

The mechanical mixer, vertical axis, 15 liters capacity, metallic spade, planetary movement spin around the tank axis was used to produce PLC.

The slab of TUP waste foamy had a density of 1400 kg/m³, measuring: 1.5 m, 3 m and 0.1 m thick.

The equipment used to register/measure the sound pressure was the Sound Level Measurer brand 01dB Fig.(4a), sound pressure level measurer Solo SLM, Type 2.

The loudspeaker, or amplified speaker, CSR 5500XA model Fig. (4b) was:

- 2-way Bass-Reflex System
- 15” Woofer
- Cornet with a 1” titanium drive
- 200W RMS power
- Frequency divider: cut at 3.5 KHz
- Frequency response: 40 Hz – 20 KHz
- Dimensions: W 43 cm – H 68 cm – D 45 cm
- Mass: 21kg

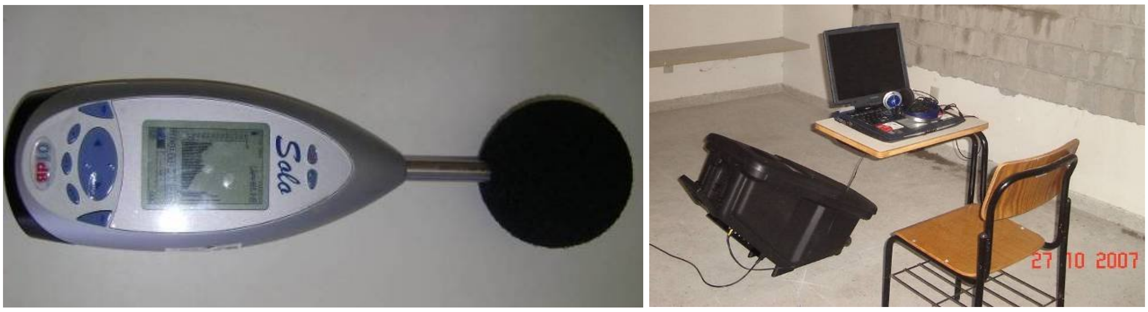


Figure 4: (a) Sound Pressure measurer SOLO SLM 01dB. (b) Loudspeaker model CSR 5500XA and White Noise sound source generator.

The acoustic insulation measurement attended the standard ISO 140-5. For measuring the indoor sound pressure level (inside the room) three measurements in different positions were performed. The outdoor sound pressure level was obtained through a single measurement and the microphone positioned 2m from the center of the fencing element. The loudspeaker was positioned 4,5m away the wall and facing the center of the fencing element. Fig.(5).

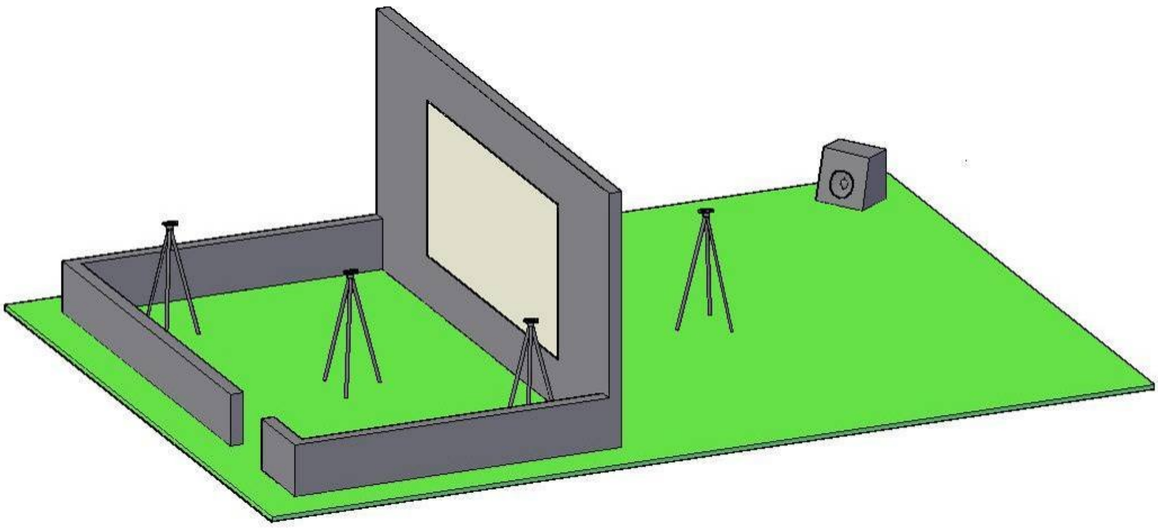
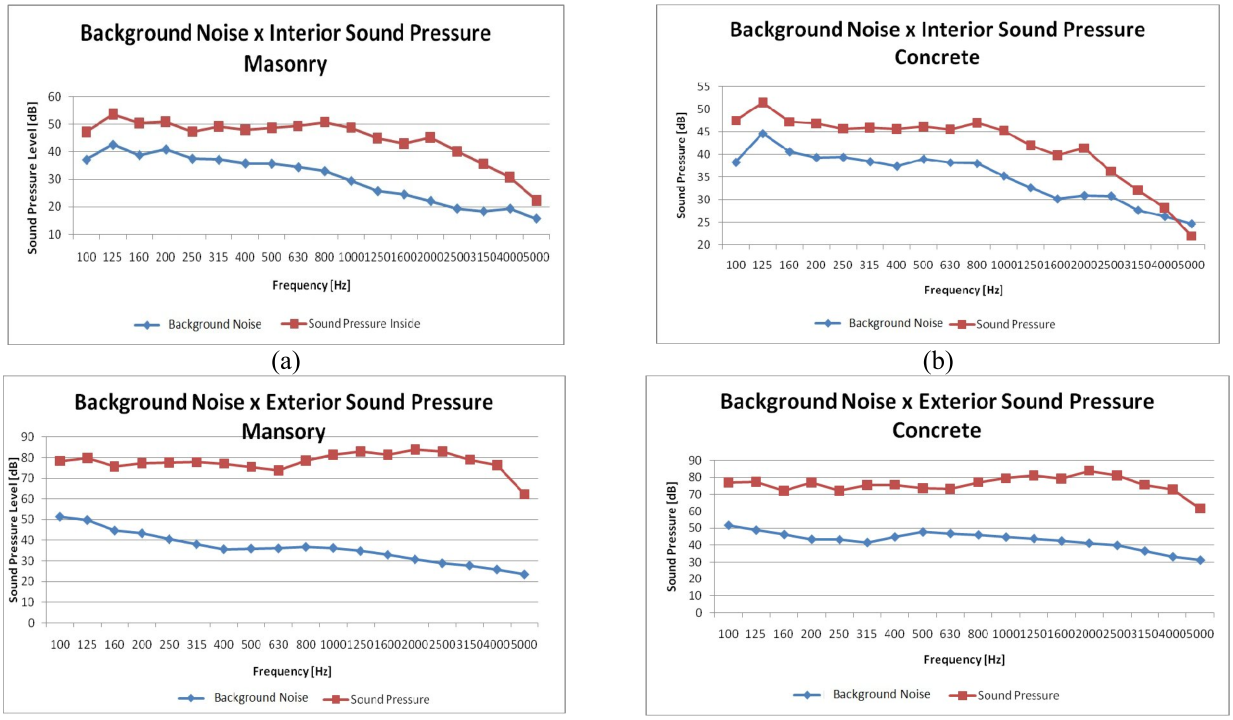


Figure 5: Sound Insulation measurement setup.

4. RESULT ANALYSIS

Figure (6) presents the indoor and outdoor background noise curves. The sound pressure levels are according to ISO 140-5, background noise level at least 6 dB below of sound pressure level.



(a) (b)

(c) (d)

Figure 6: Curves of Background noise vs. Interior and Exterior Sound Pressure. (a) and (c) for mansory and (b) and (d) for Concrete.

Figure (7) shows the comparison of sound pressure level difference between mansory and Polymeric Lightweight Concrete.

The soundproof of concrete is better than the mansory because the cellular concrete is denser and more rigid than conventional masonry and these properties control the transmission loss at low and high frequencies.

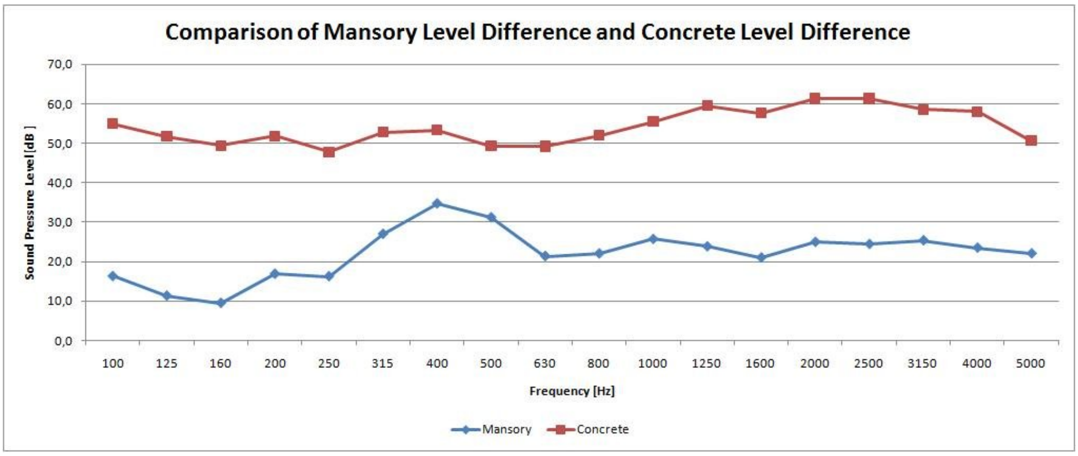


Figure 7: Comparison of Mansory and Concrete Sound Pressure Level Difference.

5. CONCLUSIONS

All difference level of background noise and generated Sound Pressure stay up to 6dB, according to the Standard ISO 140-5, ensuring soundproof results to both masonry and PLC.

The obtained soundproof results of PLC were satisfactory, since for the examined frequency range the isolation rates were higher than 45dB. According to DIN4109 (1999) is considered an excellent sound insulation material.

Analyzing the results for the conventional masonry is observed a sound insulation about 25dB for most of frequency bands and a peak of 35 dB at 400Hz that do not respect the European standard DIN 4109 (1999), that determines a minimum isolation of 30dB. Thus, the sound quality of these façade elements are minimal and do not improve a good interior noise.

Thus, the PLC improves a better acoustic comfort than conventional masonry

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8. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.