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Indoor Environment Impact Noise Attenuation with Use of Polyethylene Polymer

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ABSTRACT: *The acoutisc comfort and noise attenuation between floors in vertical housing is an engineering challenge. In this work the noise attenuation promoted by a floating floor system with expanded polyethylene sheet was studied. For that purpose, three built prototypes were constructed, the Prototype 1 was constructed without use of polyethylene sheet. In the Prototype 2, a 5mm layer of the blanket was used and in Prototype 3, a 10mm layer. The sound intensity levels within the prototypes after impact of a metal ball released at different heights of 10, 20 and 30cm were measured. The results showed lower sound levels in Prototypes 2 and 3 compared with Prototype 1, indicating that the use of an expanded polyethylene sheet attenuated the sound. However, there were no differences between the use of a 5 and 10mm blankets, no statistically significant difference were found in the Prototypes 2 and 3 sound levels (p>0.05ANOVA,Tukey).*
Keywords: *Expanded-polyethylene. Acoustic comfort.Noise.Environmental.Buildings.*

I. INTRODUCTION

Environmental noise can occur due to fall of a glass or walking from one person[1]. For construction engineering such discomfort has not been characterized as a priority, because there are no guidelines indicating safe alternatives for solutions.

In Brazil, there is the implementation of the NBR 15575-3 2008, which establishes a maximum noise level in housing units[2]. This leads to the study of acoustic treatment options.

Despite the wide variety of materials available on the market, the knowledge of them is scarce, and scientific studies proving their effectiveness are rare[3].

The low density polyethylene (LDPE) has firmness, high impact resistance, high flexibility and stability as characteristics although even proving to be highly resistant to water, it is slowly attacked by oxidizing agents. The manufacture of the low density polyethylene occurs at pressure between 1000 and 3000 atm and temperatures between 100 and 300°C[4]. Currently, its combination with other materials to compose low density polyethylene blends has been studied in order to make this a biodegradable material[5].

The expanded polyethylene sheet used in this present work has a structure similar to a honeycomb and is intended to provide sound insulation. Other characteristics are low density and low cost, making it more accessible than other insulation materials available[3].

The conventional method to evaluate impact noise is through a Tapping machine[6-7]. However, according to Shi et al. (1997), this noise machine does not really simulate the walk of a person[8]. Therefore, they changed the sound source to a sand ball. The system drops the sand ball onto floor from a certain height, causing noise on impact. In this work, a similar system was used but the sand ball was replaced by a metal ball intended to better simulate sound impact caused by the walking in the apartment overhead, especially those sounds caused by shoes with thin heels. The aim of this study is to test the performance of flexible expanded polyethylene sheet in reducing environmental impact noise, using a steel ball for noise simulation.

II. MATERIALS AND METHODS

1.1. Prototypes

Three prototypes that mimic a closed environment were built, using conventional construction materials.

Initially three walls were raised, 1.0m wide by 0.8m high using ceramic brick (8 hole brick (9x19x19cm) provided by Cerâmica São Benedito, Brazil). At the end of this stage, a frame for the construction of a reinforced concrete slab with thickness of 5cm was installed.

The slabs for the 3 prototypes were concreted on the same day, always following the same process. All were 5cm thick containing a 5mm diameter steel mesh with 10cm spacing in the middle of each slab. The mixture was standardized a ratio of 1:2:3 (cement: coarse sand: stone). Subsequently subfloors, 3 cm thick were formed.

In the first prototype, white glue was dissolved in the subfloor mass for a better grip for the slab that was directly applied and leveled.

In the second prototype the same steps were performed but with addition of a 0.2mm thick black polyester fabric (Tegape®, Brazil) on the subfloor and an expanded polyethylene sheet layer, 5mm thick (Cell-Aire®), white, density 26kg/m³) (Figure 1 and 2). Figure 2 shows photomicrography of transversal section of expanded polyethylene sheet demonstrating the honeycomb structure with holes of approximately 1mm diameter. As already mentioned, the sheet was installed between the slab and the subfloor (Figure 3).

The third prototype followed the same procedure as with Prototype 2, but with placing another expanded polyethylene sheet superimposed on the first, composing a dual5mm layer between the slab and the subfloor (Figure 3).

The finishing step of the prototypes was laying of a ceramic coating (45x45x1 cm), which was conducted in the same way for all the prototypes. It was carried out with water and a mass for ceramic coating (mixed according to manufacturer's specification).

For the experiments the prototypes that simulate a closed room were sealed by a plate, made with a double layer of wooden board (5cm thick), having a foam layer of 8cm thickness and polystyrene, 10cm thickness suitable for insulating sound.

Fig.1 - Polyethylene-expanded blanket

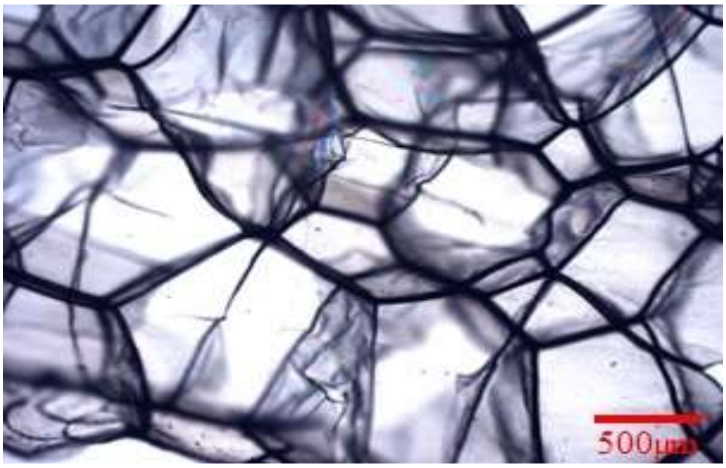

Fig.2 - Photomicrography of transversal section of expanded-polyethylene blanket

1.2. Measurement the loudness level

The impact noise was generated by a steel ball weighing 67.4g dropped on the surface of the prototypes from different heights (10, 20 and 30cm) to differentiate the magnitude of the impact. Three launches were performed for each height and each prototype. This experiment was repeated 3 times, on different days, resulting a total of 9 releases for each height.

The sound intensity levels (L_I) were measured with mini sound level meter properly calibrated (Instruterm, DEC-300, Brazil). The value was converted into sound intensity (I) according to the equation:

$$L_I = 10.\log\left(\frac{I}{I_0}\right) \qquad (1)$$

Where the reference I0 is 1.10^{-12}W/m^2.

The values of sound intensity for each height and each prototype were statistically analyzed by ANOVA test followed by Tukey post hoc with level $\alpha = 5\%$ significance.

III. RESULTS AND DISCUSSIONS

Before the experiments, loudness measurements were performed in the prototype sealed with the aid of an acoustic seal cap, to determine interference in the data due to external noise near the laboratory. These interference levels, averaging 34.17 ± 2.23dB, are lower than the values obtained after the release of the ball under all conditions and prototypes.

In order to compare the performance of the flexible expanded polyethylene sheet, the mean and standard deviation of loudness levels for each release height were calculed. Figure 4 shows loudness levels results for each prototype and the release at 10cm, 20cm and 30cm of height.

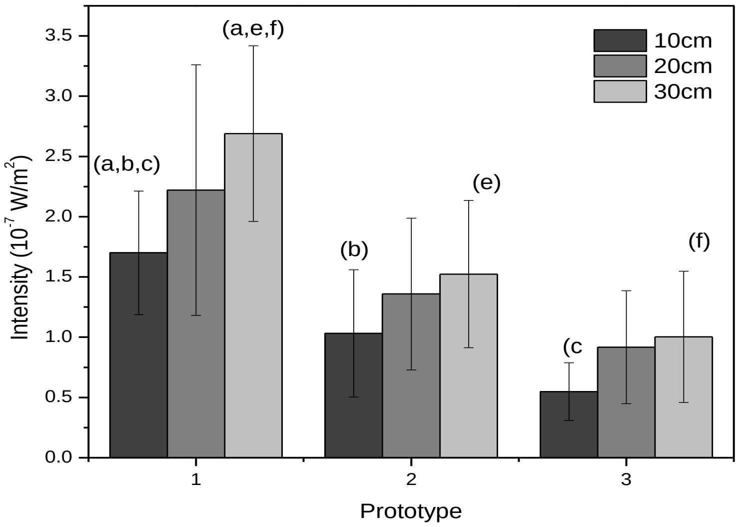

Fig.3 - Sound Intensity measured within the Prototypes after launching of metal ball at height of 10, 20 and 30 cm. The expanded polyethylene sheet was used in the Prototypes 2 and 3. The same letter indicates the condition where the difference in sound intensity is statistically significant ($p<0.05$, ANOVA, Tukey)

The acoustic performance results obtained in tests of Prototype 1 represent a conventional slab with a thickness of 5cm, without any acoustic treatment. When comparing the noise intensities obtained at different ball release heights, we noticed that at 10cm they were lower compared to release at 30cm. This difference is statistically significant ($p <0.05$ ANOVA, Tukey) which validates the evaluation method of different levels of impact at 10 and 30cm.

The results of Prototype 2 represent a conventional slab 5cm thick, having acoustic treatment with an expanded polyethylene blanket 5mm thick. Results indicate that there is a reduction in the noise level compared to Prototype 1 without a sheet at releases of 10cm and 30cm. Similarly, Prototype 3, with acoustic treatment with two 5mm layers of expanded polyethylene produced the same performance results as Prototype 2. However there is no significant difference between the performances of Prototypes 2 and 3, indicating that one layer of the sheet is enough to produce noise attenuation at the level tested in this work ($p <0.01$ ANOVA, Tukey).

The impact noise may be defined as the sound transmitted withing a solid medium which is generated by a mechanical stimulation of short duration, giving rise to a wave, causing discomfort. This type of noise can be transmitted through solid and liquid media and partly by air[9-10]. In porous solids with internal air pockets, sound waves reflections are partially converted into heat energy. Plastic materials have the ability to store energy, significantly attenuating the sound intensity[8]. Therefore resilient materials, such as some polymers, possess the ability to cushion the impact without deforming and are useful in reducing the impact of noise.

The literature reports some previous work regarding the use of resilient polymers. Brondani (1999)[11] demonstrated that the thickness increase of the resilient layer and the increase in slab thickness influence the sound attenuation of the impact noise and decrease the resonant frequency. The type of resilient material influences the sound wave damping performance. Among the materials studied, authors concluded that glass wool is the material that provides the greatest attenuation of acoustic noise[10-11].

The expanded polyethylene sheet used in this work presents firmness, high impact resistance, high flexibility and stability and is considered a low cost material. It also contains air bubbles, which can further contribute to sound attenuation. According to Brondani (1999)[11] it presents similar performance on sound attenuation produced by glass wool.

In similar work, Machado (2003)[12] has tested several polyethylene blanket thicknesses applied with wooden slim floor. In this situation, the authors found no differences in sound attenuation by using a layer of 10mm, but was noticed from the thickness of 20mm. Our results indicate a reduction of impact noise with the layer of 5mm on ceramic floors.

IV. CONCLUSIONS

Despite the prototypes were not built with the same characteristics of the floors in real buildings, the model was useful for testing the effectiveness of the expanded polyethylene sheet in impact noise attenuation in ceramic floors. The thickness of 5mm of polyethyelene was enough to promote sound attenuation.

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