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ACOUSTICALLY EFFICIENT CONCRETE: ACOUSTIC ABSORPTION COEFFICIENT OF POROUS CONCRETE WITH DIFFERENT AGGREGATE SIZE

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ABSTRACT

Porous absorbers are the most widely used type of acoustically absorptive materials. The interest on their outdoor applications has put further attention on the use of porous concrete in the building industry. This work investigates the acoustic properties of porous concrete. The assessment of the sound absorbing performances has been conducted in the small-scale reverberation room at Politecnico di Torino (Italy), following the procedure indicated in the ISO 354:2003 Standard. Two different aggregate sizes have been considered. For each concrete type, three panel thicknesses, i.e. 20 mm, 40 mm, 60 mm were tested. Moreover, different mounting methods were tested, considering the presence of an airgap between the panel and the backing, and considering the introduction of rockwool in the airgap itself. The result show weighted absorption coefficients (a_w) in the range 0.30-0.75 depending on the thickness and mounting conditions. These encouraging values make these materials useful for practical applications in architecture and civil engineering.

1. INTRODUCTION

Recent studies have highlighted the importance of the architectural design and use of acoustic materials on urban noise mitigation in several urban environments [1-4]. Therefore, this work aims to investigate the sound absorbing properties of porous concrete as an appropriate material for outdoor applications. Compared to other porous sound absorbers, porous concrete is characterized by high resistance and high durability in outdoor conditions.

Porous concrete can be considered as granular absorber according to its microstructure [5]. In granular materials, pores are created by the presence solid aggregates which are bonded together by a binder. These materials are characterized by high porosity and an interconnected network of pores. Porous concrete mainly consists of normal Portland cement, coarse aggregates and water, while it typically has little or no fine aggregates. The void content of porous concrete generally ranges from 18% to 35% [6]. However, the sound absorbing properties of granular materials tend to be uneven in frequency and to be characterized by important peaks [6].

Different strategies have been suggested to enhance the rate and the evenness of the sound absorption provided, by altering the microstructural properties of concrete. As concerns the aggregates, several studies have investigated the effect of using aggregate material of various nature (cenospheres, crumb rubber, recycled aggregates, bottom ash, expanded perlite, plant particles, etc.) [7-10], and that of varying aggregate size or mixing different aggregates types [11]. However, there are no studies regarding the effects of the mounting conditions of porous concrete panels, which may result of great importance when considering façade claddings.

The present study aims to investigate through a systematic study the effects of two concrete aggregates with different dimensions, three different material thickness and two mounting conditions on the absorption properties of porous concrete. The measurements have been performed in a small-scale reverberation room (SSRR) at Politecnico di Torino [13]. Therefore, the main aim of this study is to define the sample configuration that could lead to an improvement of the sound absorption properties of concrete panels.

2. METHODOLOGY

Two different porous concrete typologies (T1 and T2) with different aggregate dimensions have been tested. Figure 1 shows T1 and T2, which are characterized by 2-4 mm and 0.5-1 mm lightweight aggregates, respectively. The measured samples are squared in plan (60 x 60 cm^2) with three different panel thicknesses, i.e. 20 mm, 40 mm, 60 mm. Different mounting methods were tested considering the presence of an airgap between the 20 mm panel and the room floor (Figure 1), and also considering the introduction of rockwool in the airgap itself (Figure 2) for T2 only.

The assessment of their sound absorbing performances has been conducted in the small-scale reverberation room (SSRR) of Politecnico di Torino (Italy), following the procedure indicated in the ISO 354:2003 Standard [12]. It has been extensively described in [13].

For each condition, three different samples of the same typology have been considered and measurements on each sample have been repeated three times. The arithmetic mean of the sound absorption coefficients has been used to describe the performances of each type. In this way repeatability and reproducibility issues have been controlled. The sound absorptive properties are expressed as 1/3 octave bands.

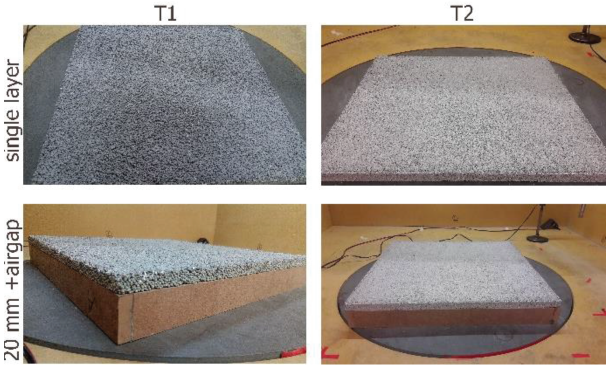

Figure 1. Sample T1 and T2 single layer and single layer of 20 mm combined with an airgap of 50 mm.

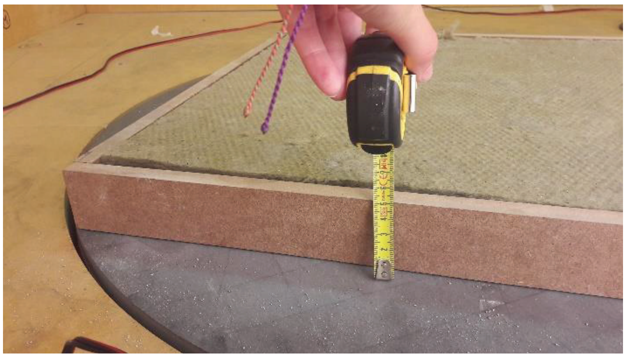

Figure 2. T2 single layer of 20 mm combined with an airgap of 50 mm filled with 50 mm rockwool.

3. RESULTS

3.1 Sample thickness

Figure 3 shows the results of the comparisons between different thicknesses. The absorption spectra of panels T1 is slightly uneven and tend to provide poor absorption (< 0.25) at frequencies lower than 630 Hz for panels with either 40 mm or 60 mm thicknesses, while at higher frequencies the absorption ranges between 0.40 and 0.80. The 20 mm thick panel feature an absorption peak between 4000 Hz, achieving a value of 0.90. The absorption coefficient for this thickness becomes lower than 0.25 at frequencies below 2000 Hz. As expected, the sound absorbing properties of the panel are extended toward the lower frequencies for thicker panels. The 60 mm sample reaches significant high values of absorption coefficient (> 0.40) at 800 Hz, while the 40 mm panel at 1250 Hz.

The absorption spectra of panels T2 is more even than the T1 and tend to provide slightly higher absorption coefficients below 630 Hz and for panels with either 40 mm or 60 mm thicknesses compared to T1. The absorption ranges between 0.40 and 1 at higher frequencies. The 20 mm thick panel feature an absorption peak between 2500 Hz and 4000 Hz, achieving 1.20; the peak is broader than those featured by 20 mm thick panel of T1.

As expected, the sound absorbing properties of the panel are extended toward the lower frequencies for thicker panels. This is evident below 1600 Hz. Indeed, for the thicker panels, the significant absorption range is extended in a similar way down to 630 Hz.

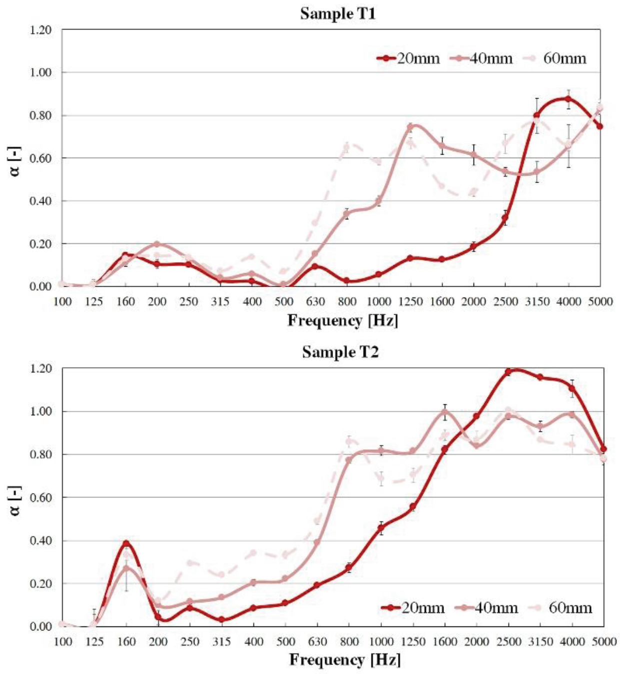

Figure 3. Sample T1 and T2 as single layer with different thicknesses (20, 40 and 60 mm).

3.2 Sample mounting on airgap

Figure 4 shows the comparison between T1 and T2 mounted over an airgap of 50 mm. It can be noticed that T1 shows a decrease of the absorption coefficient at high frequencies when an airgap is left between the panel and the backing. For the 20 mm panel this is significant above 2500 Hz. The performances are slightly enhanced at the lower frequencies, where a peak appears in the range 315-2500 Hz.

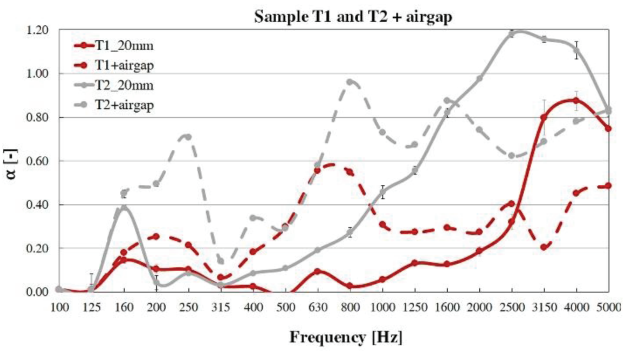

Figure 4. Sample T1 and T2 single layer of 20 mm combined with an airgap of 50 mm.

Sample T2 shows a decrease at high frequencies above 1600 Hz when an airgap is left between the panels and the backing. However, the sound absorption coefficients result above 0.55. The performances are enhanced at the lower frequencies, where a peak appears around 250 Hz. The absorption coefficient increases in the 160-630 Hz frequency range when the airgap is added.

By comparing the sound absorbing performances of the two different panel types measured, it emerges that the panel T2 outperforms T1. It presents a more uniform frequency-dependent sound absorption, and a broader frequency range of high values of absorption coefficients. Therefore, this sample performance has been further tested when coupled with an airgap filled with porous material.

3.3 Sample mounting on airgap filled with rockwool

As reported in the previous section, the most performative sample T2 has been further improved by combining it with an airgap in empty condition and filled completely with porous material. The introduction of rockwool layer of 50 mm in the airgap has been tested with the sample of 20 mm thickness. Figure 5 shows that the two conditions have a very similar trend above 800 Hz. Generally, the combination of an airgap with a porous material is shown to improve the acoustic performance down to 250 Hz. A peak value at 800 Hz is further increased when the airgap is filled with rockwool compared to the empty condition. Furthermore, a significant improvement is obtained in the 250-800 Hz frequency range reaching values of sound absorption coefficients of 0.60-0.90, which can be comparable to those of the most performative porous materials used for indoor applications (e.g. rock wool, glass wool, melamine foam) [5].

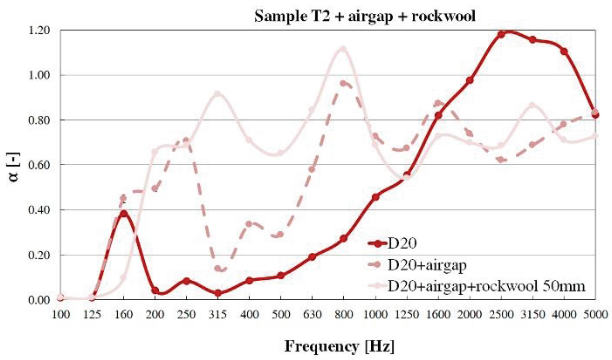

Figure 5. Sample T2 single layer of 20 mm combined with an airgap of 50 mm filled with a rockwool.

4. CONCLUSIONS

The sound absorption properties of porous concrete have been investigated through measurements in small-scale reverberation room. Two different aggregate sizes have been used to produce two different samples and investigate the effect of sample thickness and its mounting over an airgap. Furthermore, the effect of filling the airgap with porous material such as rockwool has been tested for one of the better performing porous concrete.

The results showed that the increase of sample thickness and strategies of mounting might have some beneficial effects on the sound absorption properties at a broader mid-high frequency range that extends at lower frequencies with single frequency peaks.

It emerges that the smaller aggregates in the range of 0.5-1 mm lead to better performing panels. It might be observed that in this formulation a more uniform porosity and higher tortuosity is expected due to the smaller dimensions of the aggregates, which allow to create smaller regular pores.

Future work will focus on other aggregate typologies and on the application sound absorption analytical models that could predict the acoustic behavior at the design phase of the material. In this way an easier optimization of the formulation can be reached.

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