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ACOUSTIC PROPERTIES OF BIOMASS BOTTOM ASH IN DIFFERENT TYPES OF RECYCLED CONCRETE

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ABSTRACT

In Andalusia, the second-largest autonomous community in Spain, energy production through biomass combustion is emerging as one of the most promising alternatives to fossil fuels. This biomass can be incorporated into construction materials. Analyzing the acoustic properties of these new, more sustainable materials is essential. It could contribute to the search for quieter spaces, as noise reduction is key to enhancing comfort in buildings. A wide range of thermal insulating materials, such as rock wool boards, cellulose boards, and wood fibers, are commonly used for acoustic insulation in walls, floors, doors, ceilings, ducts, enclosures, and building installations. Currently, conventional insulating materials dominate the market, while innovative natural and recycled insulating materials are either minimally marketed or not yet commercially available. However, materials like rock wool and glass wool, derived from natural processes, are highly energy-intensive to produce. Additionally, porous materials made from synthetic petrochemicals are widely used as acoustic insulation but pose potential risks to human health and the environment. As a result, there is an increasing demand for environmentally friendly insulation materials to meet noise reduction needs. This study focuses on analyzing the potential of innovative construction materials to enhance sound quality and acoustic insulation.

Keywords: *biomass bottom ash, lightweight concrete, self-compacting concrete, acoustic insulation*

1. INTRODUCTION

Nowadays, there is an increasing demand for quieter spaces in workplaces and residential areas. Reducing noise levels helps improve people's quality of life and comfort [1]. The WHO published a guideline on noise exposure in Europe. This guideline reviews studies that provide evidence on noise exposure, particularly night noise exposure, and its consequences for human health. For night noise exposure caused by road traffic, 45 dB is set as the reference level to avoid health effects. However, noise levels in Europe are well above this value. The health consequences of this night noise exposure range from cardiovascular disorders to menta health problems [2]. For these reasons, soundproofing in construction materiales is increasing being considered. A wide variety of thermal insulating materials, such as rock wool boards, cellulose boards, and wood fibers, are also used for acoustic insulation in walls, floors, doors, ceilings, duct, enclosures, and building installations. Today, insulating materials (e.g. rock wool, polystyrene) are commercially available and more commonly used compared to innovative natural and recicled insulating materials (e.g., rice, cotton, palm oil fiber, glass foam, plastics, recycled textile fibers), which are either barely marketed or not yet available [3]. However, rock and glass wool, derived from natural processes, are energy-intensive building insulation materials during manufacturing. Although porous materials derived from synthetic petrochemicals (e.g., rock wool, glass wool, polyurethane, polyester) are used as acoustic insulationmaterials, they can cause adverse effects on human health and the environment. Consequently, there is a growing demand for environmentally friendly insulation materials [4]

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for noise reduction. It is important to distinguish between sound absorption and sound insulation. The firth refers to a material's ability to absorb sound anergy, thereby preventing echoes and improving indoor quality. In contrast, sound insulation or soundproofing materials pevent sound waves from entering or leaving a space, acting as a barrier to sound. This study will analyze the potential of new construction materials to improve sound quality and acoustic insulation.

2. MATERIALS AND METHODS

The conventional raw materials used were:
Portland cement from Cementos Portland Valderrivas S.A, Alcalá de Guadaíra, Seville, Spain: type I of medium-high strength 42.5 MPa at 28 days with high initial strength R (CEM I 42.5-R). This type of cement is recommended for the production of normal high-performance concrete, very suitable for the industrial manufacture of prefabricated structural elements requiring maximum strength.
For this study a by-product was used as an alternative material replacing natural sand and expanded clay in each type of manufactured concrete. Biomass bottom ash (BBA) is composed of unburned coarse particles produced in the primary combustion chamber during the biomass energy production process [5,6]. In this study the BBA used comes from the biomass power plant located in Linares of the company Sacyr Industrial. The biomass used as fuel supply for electricity generation is composed of 60% wood from pruning almond and olive trees, and 40% olive cake. A pre-processing of the BBA was carried out in the laboratory to obtain different materials for making concrete:
- BBA-D: Oven-dried at 60ºC to constant mass.
- BBA-C: Oven-dried at 60ºC to constant mass and crushed and sieved to obtain a grain size between 0 and 4 mm.

A study was carried out in two separate series. The first series, called SCC, produced self-compacting concrete with partial substitution of sand and limestone filler; the second series, called LC, produced lightweight concrete with partial substitution of sand and expanded clay.
It is essential to evaluate the properties of density, absorption and porosity in order to select the type of concrete for a specific use, as these characteristics affect the long-term performance and durability of the structures. Table 1 shows the results obtained for all the mixes studied.

Table 1. Density, absorption and open porosity of hardened concrete.

	Density (kg/dm3)	Absorption(%)	Open porosity (%)
SCC-CR	2.37	3.16%	7.48%
SCC-15NS	2.33	4.77%	9.68%
SCC-30NS	2.30	5.25%	11.23%
SCC-15NS/30LF	2.32	4.98%	10.66%
SCC-30NS/60LF	2.29	5.80%	12.15%
LC-CR	1.88	6.96%	14.26%
LC/BBA-25NS	1.65	7.45%	15.12%
LC/BBA-50NS	1.52	9.21%	16.15%
LC/BBA-25EC/25NS	1.89	7.16%	8.92%
LC/BBA-50EC/50NS	1.73	9.84%	8.05%

All tests were carried out in a reverberation chamber, following the guidelines of the UNE-EN ISO 10140-2:2022 standard, which establishes a laboratory method for measuring airborne sound insulation in construction materials.
The measurement equipment used complies with the specifications set forth in ISO 10140-5:2022. This includes class 1 sound level meters, as per the IEC 61672-1 standard, and an acoustic calibrator meeting class 1 requirements in accordance with the IEC 60942:2017 standard.
The sound generated in the emitting room must remain stable. In line with standard recommendations, white noise was used during testing, produced by a standardized white noise generator.
According to ISO 10140-4:2022, when performing measurements with fixed-position microphones and a single sound source, at least five microphone positions must be used in each room (both emitting and receiving) for every speaker placement. Additionally, the sound source must be positioned in at least two different locations within the emitting room.
Sound quality refers to how a listener perceives and evaluates a sound. Unlike objective properties such as loudness or frequency, sound quality is inherently subjective and shaped by human perception.
Loudness, a fundamental component of sound perception, describes the perceived intensity or strength of a sound.
To assess sound quality, a Mikado Gfai acoustic camera was used, equipped with 96 MEMS microphones operating within a frequency range of 10 Hz to 24 kHz.

3. RESULTS

Analysing the attenuation efficiency of the concrete plates by frequency, Table 2 shows the acoustic attenuation produced by each concrete plate during the tests.

Table 2. Acoustic attenuation for each concrete plate.

	L_{Aeq} 125Hz	L_{Aeq} 250Hz	L_{Aeq} 500Hz	L_{Aeq} 1000Hz	L_{Aeq} 2000Hz	L_{Aeq} 4000Hz	L_{Aeq} 8000Hz
SCC-CR	36.5	40.0	42.9	40.2	39.3	43.9	44.1
SCC-30NS	38.0	40.8	46.1	47.5	47.5	49.6	51.7
SCC-30NS/60LF	37.8	40.7	45.6	46.1	47.0	46.3	49.2
LC-CR	38.1	40.4	47.7	47.0	49.5	53.4	58.2
LC/BBA-25EC/25NS	38.3	40.6	47.5	47.4	50.3	53.4	57.7
LC/BBA-50EC/50NS	38.2	40.5	47.1	48.5	51.7	54.0	58.0

As can be seen, the main insulation efficiency occurs at high frequencies, 4000Hz and 8000Hz, with LC/BBA-50EC/50NS being more effective and SCC-CR less effective.

Obtaining the average values for each mix concrete, the attenuation values achieved are collected in Table 2.

In Figure 1, it can be seen that the highest loudness corresponds to the concrete (SCC-CR). It is observed that the LC compounds have lower loudness than the SCCs. This may be due to the fact that the LCs have greater absorption and open porosity compared to the SCCs. Open porosity is the ratio of the total volume of open pores to the total volume of the material. High open porosity values correspond to high efficiency in dissipating acoustic energy due to the viscous and thermal effects occurring in the interconnected pores. Additionally, the presence of different scales of porosity enhances sound absorption [7].

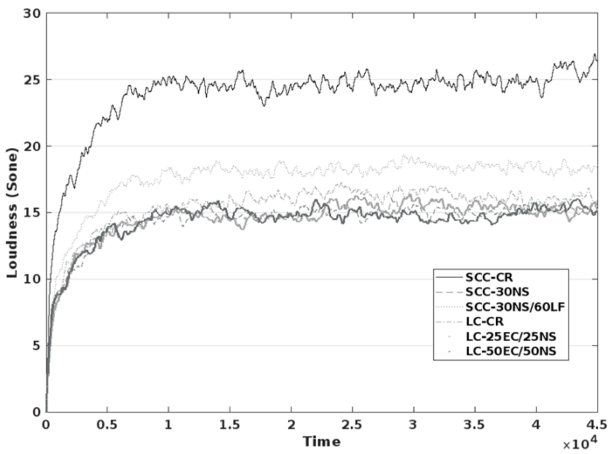

Figure 1. Loudness results.

4. CONCLUSIONS

The conclusions drawn from this study are shown below:

- The level of acoustic insulation of the tested concrete has been determined through comparative analysis. The concrete with the highest acoustic insulation capacity was the one corresponding to LC/BBA-50EC/50NS, and the one with the least acoustic insulation capacity was LCC-CR, which shows that lightweight concrete with a high BBA application rate leads to improved acoustic insulation. The greatest insulation effect occurs at high frequencies (4000Hz and 8000Hz).
- The sound quality of the noise transmitted by the concrete specimens was also studied. The highest level of loudness corresponds to SCC-CR concrete.

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