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ACOUSTIC CHARACTERISTICS OF AN HYDROPONIC MATERIAL

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ABSTRACT

Green materials developed in recent decades have found numerous applications. These materials are designed to be recycled after their primary use, reducing waste and environmental impact. Hydroponic systems, widely used for growing plants without direct soil use, often employ alternative sublayers such as expanded clay, glass wool, perlite, paper, hemp and similar materials immersed in water. This study focuses on wheat grains planted on porous sublayers, including hemp, paper, wood chips, triturated sugarcanes from river water, oak leaves, layers of grass. As the wheat plants grew, their roots penetrated these porous materials, forming a single, compact material with a rigid skeleton. In the second stage, the resulting material was dried to thicknesses of 5 and 10 cm and tested using an impedance tube. Acoustic absorption at normal incidence was measured. The results indicate that hydroponic materials have excellent acoustic absorption properties, making them suitable for use in acoustic applications.

Keywords: *Hydroponic, acoustic measurements, absorption coefficient, impedance tube; sustainable constructions.*

1. INTRODUCTION

Hydroponics is a method of growing plants with minimal soil and water. Hydroponic systems enable plants cultivation without direct reliance on soil. This technique uses substrates made from alternative materials, such as expanded clay, rock wool, perlite, paper, hemp, wood chips and natural wool, combined with nutrient solutions or water [1]. Hydroponic cultivation is being studied as an alternative to traditional agricultural production, particularly for growing wheat or other crops while minimizing soil and water usage. One major advantage of hydroponic systems is their ability to produce crops in the absence of soil-borne diseases and pests, thereby reducing the need for chemical pesticides [2]. Additionally, hydroponic systems allow for significantly faster crop production compared to traditional soil-based farming. Today, hydroponic systems are mainly developed to provide animal feed as an alternative to synthetic or chemical processed options. Furthermore, hydroponic farming is being explored as a potential food source for future space missions [3]. In these contexts, plants are grown to provide food for space missions or for potential future colonies on the Moon or Mars. Studying hydroponic systems for human nutrition also offers a solution to challenges related to food production in the context of climate variability, population growth, and freshwater depletion. In the future, hydroponic crops could be used in regions with limited natural resources or extreme weather conditions. Since the Middle Ages, hydroponic cultivation has been a part of Christian Easter traditions. It has historically been used to grow plants for decorating church altars during Easter, as shown in Figure 1. During the Easter period, the faithful would prepare jute sheets on which they sowed wheat, watering them every evening. Within a few weeks, the wheat grew to about 20 cm in height, adorning church altars.

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Figure 1. Plants used to decorate church altars during the Easter period.

2. MATERIALS AND METHODS

The hydroponic material model was designed to create layers of sound-absorbing materials. In this study, wheat was selected as the primary plant, although other grains such as corn, chickpeas, and beans could also be used. The germinating seed produces a plant above the surface, while the roots penetrate the underlying porous layer, forming a rigid network that compacts the material [4].

The objective of this research is to develop plant-based material layers using hydroponic systems. Layers of varying thicknesses were developed using different porous substrates, which served as growth media for wheat grains [5]. The grains were cultivated at room temperature and watered daily with small amounts of water. The material was housed in food-grade plastic containers and placed in an outdoor environment, where temperatures ranged from about 18°C at night to 35°C during the day.

The porous substrates used include hemp, shredded paper, wood chips, shredded river canes. Wheat grains were germinated on these porous layers, and over a two-week period, the plants grew to a height of 20 cm. During this process, the roots penetrated the porous substrates, forming a compact material with a rigid internal structure. Once dried, the water content was completely removed, yielding a material with promising acoustic properties. Various acoustic tests were performed on the resulting green tiles, which were composed of different porous sublayers [6]. Samples with thicknesses ranging from 5 cm to 10 cm were prepared for testing. The primary aim of this research is to assess the sound absorption coefficient of the tiles at different thicknesses. Measurements were performed using an impedance tube, which determines the sound absorption coefficient at normal incidence over a frequency range of 100 Hz to 2 kHz. The tests were conducted in accordance with the ISO 10534-2 standard [7]. The impedance tube used has the following features: internal diameter of 10 cm (corresponding to an upper frequency limit of 2 kHz), a length of 56 cm, as shown in Figure 2, and two microphones placed 10 cm apart, allowing measurements starting from 100 Hz.

Figure 2. Impedance tube used for measuring the absorption coefficient.

The wheat was sown on a layer of loose granular material. As the roots developed, they formed a rigid skeletal structure, which served as the basis for subsequent sound absorption measurements. Figure 3 shows the grain stalks that grow as the seeds on this material.

Figure 3. Germination of wheat grains.

Figure 4 shows the grain seeds that have grown on the loose granular material to give rise to the grain stalks.

Once the hydroponic material is fully grown, it is dried to create a new type of sound-absorbing material, whose acoustic characteristics are the focus of this study. The resulting material features a rigid skeletal structure formed by the roots, which have penetrated the loose granular substrate during growth. Figure 5 displays the final hydroponic material, showcasing its rigid root-based structure. This drying process results in a completely natural material suitable for acoustic applications.

Figure 4. Grain seeds were grown on the loose granular material, giving rise to grain stalks.

The sound absorption performance of the material varies depending on the type of porous substrate used. The following figures present the absorption coefficients for each material tested:

- Figure 6: absorption coefficient of hemp-based substrate.
- Figure 7: absorption coefficient of wood chips substrate.
- Figure 8: absorption coefficient of triturated paper substrate.
- Figure 9: absorption coefficient of triturated cane substrate.

Figure 5. New hydroponic material with a rigid substrate structure.

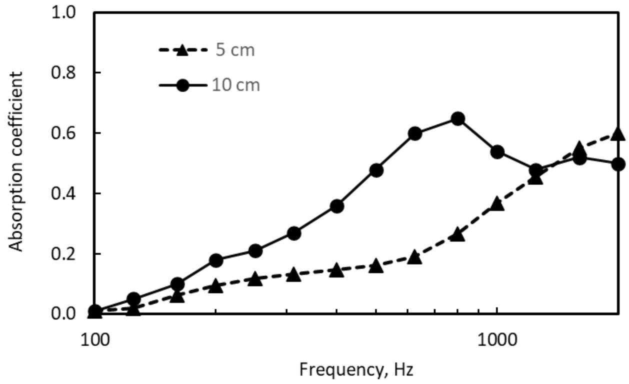

Figure 6. Absorption coefficient of hemp-based substrate.

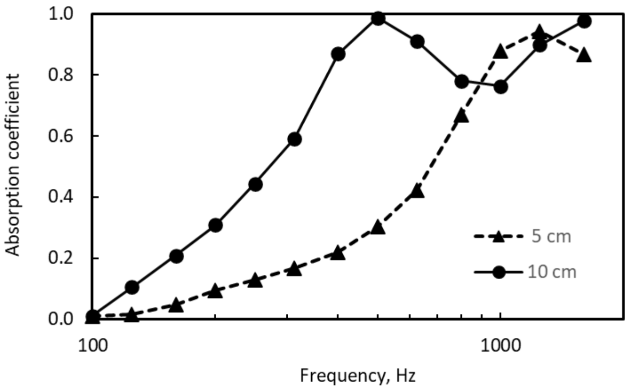

Figure 7. Absorption coefficient of wood chips substrate.

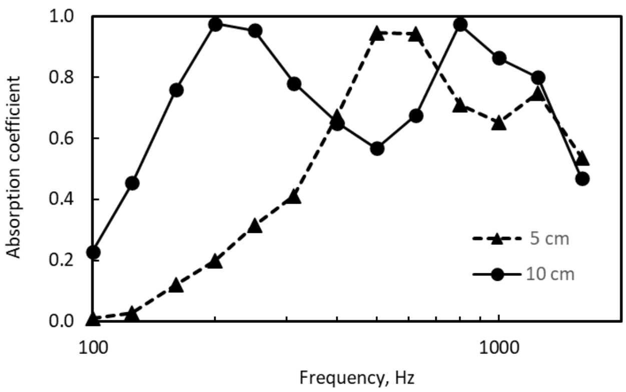

Figure 8. Absorption coefficient of triturated paper substrate.

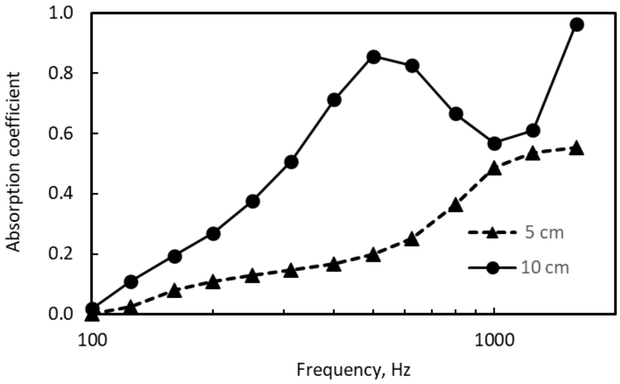

Figure 9. Absorption coefficient of triturated canes substrate.

3. DISCUSSION

For hemp-based substrate samples, when composed of 5 cm thickness, the highest values of absorption around 0.55-0.60 are observed at 2 kHz, while for 10 cm, the highest values are around 800 Hz of the same magnitude. However, the absorption performance at low frequencies remains close to zero [8]. In the case of wood chips, the maximum peak performance is centered on 1600 Hz for a 5 cm thickness and on 630 Hz for a 10 cm thickness. These peak values are around 0.95 and 1.0, which is the best performance. When the substrate consists solely of triturated paper, the absorption coefficients are highly effective, reaching a value of 1.0 at 500 Hz for a 5 cm thickness and at 250 Hz and 800 Hz for a 10 cm thickness. This is significantly remarkable since the absorption at low frequencies is always a challenge for commercial panels, unless their thickness is considerably high. When the substrate consists of triturated canes, the significant absorption is registered with the 10 cm sample, reaching peak values of 0.86 at 625 Hz and 0.96 at 2000 Hz.

4. CONCLUSIONS

The sustainable concept of preserving soil for agriculture can be effectively explored through hydroponic systems. Up to date, hydroponic systems have not been widely used for interior design or architectural finishes. However, this study demonstrates the functionality of green tiles in terms of absorption. A significant change in architectural design is possible by adopting strategies that reduce CO2 emissions and incorporate local, recycled materials aligned with the sustainability principles. Future research studies will focus on applying these green tiles to real case studies by measuring the reverberation before and after installation [9-10].

5. ACKNOWLEDGMENTS

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