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Technical note

An experimental study on the acoustic absorption of sand panels

Lu Shuai [a], Xu Weiguo [a,b], Chen Yuxiao [a], Yan Xiang [a,b,*]

[a] School of Architecture, Tsinghua University, Beijing 100084, PR China
[b] Key Laboratory of Urban-Rural Eco Planning and Green Building, Ministry of Education, Tsinghua University, PR China

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ABSTRACT

Potentially sand panels could be used as novel sound absorbing materials that are fire resistant, environmentally friendly, mechanically strong and have good durability. However, the performance of sand panels as sound absorbers has not yet been studied. Results of measurements in a reverberation chamber of the random-incidence absorption coefficients of 13 different sand panel compositions and configurations with air gaps are reported. Also the flow resistivities and bulk densities have been measured. The results prove that sand panels could offer effective and wide-band acoustic absorption. As is the case with conventional sound absorbing materials, adding an air space is found to be the most effective way to widen the absorption bands and improve the overall absorption. Comparisons of the measured sand panel absorption data with predictions of the Delany and Bazley and Voronina models reveal that, while neither model is very accurate, the former gives more accurate predictions especially for sand panels with lower flow resistivity and smaller thickness.

1. Introduction

1.1. Research background

As undesirable noise has been regarded as a severe problem for the environment and public health, sound absorption materials are widely used nowadays in many indoor and outdoor occasions. Therefore, materials with effective absorption and other virtues like fire resistance, environmental harmlessness and low cost are in large demand. Sand panels are an innovative class of absorption materials developed in recent years. They are made out of natural sands with inorganic silicon-based solvent by relatively simple manufacturing process. Test data has shown that sand panels are fire resistant, environment friendly, mechanically strong and with good durability in severe environments (Table 1). These are significant advantages of sand panels over traditional sound absorption materials such as glass wool or rock wool. Compared to metallic absorption materials like aluminum foams or micro-perforated steel plates, sand panels are far more economical since their main ingredient is widely-distributed and easily-acquired sands. Moreover, the finishing of sand panels can be in different colors and with different natural textures (Fig. 1). They could also be made into curved shapes. As a result, sand panels have already been used in many projects in recent years (Fig. 2, the projects shown here are designed by the Building Acoustic Lab of Tsinghua University). However, there is no existing research that reports the sound absorption characteristics that sand panels can offer with different values of material parameters (flow resistivity, thickness, etc.). This lack of knowledge makes it difficult to obtain sand panels with desirable absorption coefficients for specific requirements, and thus significantly affects the application of this material. This paper seeks to address this problem.

1.2. State of the art

The sound absorption of materials is a topic that has been long studied. Delany and Bazley [1] investigated fibrous porous materials and provided a simple empirical model to predict the characteristic impedance and propagation coefficient based on flow resistivity. This model has been widely used for a long time because of its simplicity and good precision [2,3]. However, it is found to have the drawbacks of working well only for a limited variety of materials and being inaccurate for low frequencies due to its non-physical nature [4]. Some researchers have sought to modify the Delany and Bazley Model so that it could provide better fits for other specific materials [5,6]. Johnson et al. [7] and Allard [8] formulated a mathematical model to describe the propagation and absorption of sound in fluid-saturated porous materials based on Biot's research [9,10]. This model has a better accuracy but needs more parameters. Compared to typical porous materials,

* Corresponding author at: School of Architecture, Tsinghua University, Beijing 100084, PR China.
E-mail address: yx@abcd.edu.cn (X. Yan).

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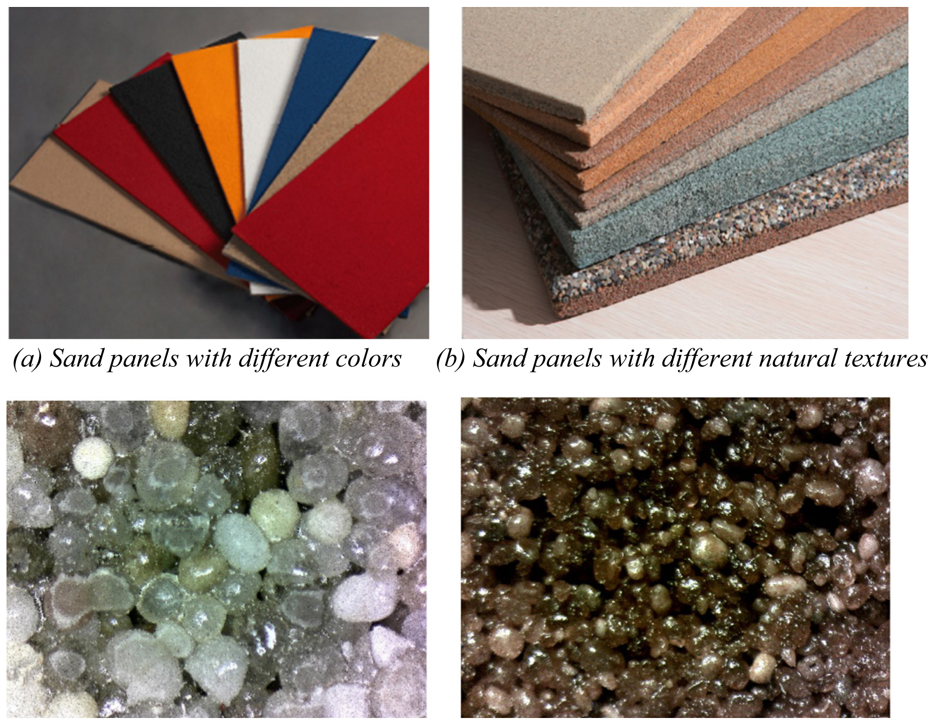
Table 1
Physical characteristics of a typical simple of sand panel.

Size	Density	Fire-resistance	TVOC (Total Volatile Organic Compounds)	Compressive strength
600 * 600 * 20 mm	$1.51 * 10^3$ kg/m^3	Non-combustible	0.062 mg/m^3 h	29.1 Mpa
Tensile strength	Bending strength	Impact strength	Percentage of moisture expansion	Frost test (25 cycles)
13.3 Mpa	24.7 MPa	15.6 kJ/m^2	0.16%	No wrecking occurred

Note: The test sample is manufactured by the Building Acoustic Lab of Tsinghua University. The fire-resistance is tested by the Tianjin Fire Research and Testing Center of the Ministry of Public Safety of the PR China. Other tests are conducted by the National Building Material Testing Center of the PR China.



(a) Sand panels with different colors *(b) Sand panels with different natural textures*

(c) Sand panels made of large particles *(d) Sand panels made of small particles*

Fig. 1. The appearance (a, b) and microstructure (c, d) of sand panels.

(a) The ceiling and columns are sand panels *(b) The ceiling is sand panels*

Fig. 2. A dining hall (a) and a lecture hall (b) that applied sand panels.

the porosity of sand panels is much lower and the flow resistivity is much higher (detail information in Section 2.1). Therefore, whether sand panels share similar patterns of sound absorption with fibrous porous materials still needs to be tested. Besides porous materials, there are also many researches that investigated the acoustic characteristics of granular materials, which have more similar microstructures to sand panels. Voronina and Horoshenkov [11] studied granular materials based on experimental data and developed a model that can predict their acoustic features using flow resistivity, porosity, tortuosity and structural characteristic. However, the predictive power of this semi-phenomenological model is found to be limited [12]. Moreover, the model is acquired from the data of only four kinds of granular materials (vermiculite, granulated rubber, perlite and granulated nitrile foam), and is found to be ineffective to predict the acoustic characteristics of polyurethane particles [13]. Therefore, whether this model is applicable to other materials like sand panels needs to be investigated. Horoshenkov and Swift [14] raised another model for granular