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Technical note

Sound reduction in samples of environmentally friendly building materials and their compositions

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ABSTRACT

In order to reduce the negative effect on the environment, environmentally friendly materials are being chosen for the construction of buildings more and more frequently. The building materials that are now used more commonly are clay, straw and reeds. The sound insulation properties of these environmentally friendly materials have not yet been examined thoroughly. This paper presents most commonly used sound reduction indexes R_W that have been measured in the semi-anechoic chamber and determined during the simulation. It has been found that adobe, pressed straw and reeds (oriented parallel to the sound transmission) are suitable for low-frequency sound insulation. The material with the best sound reduction index was adobe. The sound reduction index R_W of a 200 mm thick adobe wall reached up to 43 dB.

1. Introduction

Propagating noise has a negative impact on the environment [10,1] causing harm both to the ecosystem and the humans [8]. If noise penetrates into residential areas, sound insulation of buildings is increased. Building's constructional elements must be able to protect residents from the negative effect of noise caused by the surroundings [9,5]. During the construction of a building, it is important to choose materials with good sound insulation. Sound insulation of building walls, in accordance with international standards ISO 12354 is described by the following values: sound reduction index – R_W and sound level difference – $D_{nT,w}$ [11,13,17].

Density, stiffness and porosity of a building material have a big influence on its sound absorption or sound insulation [4]. Most commonly used materials in the northern part of mid-latitude climate zone are silicate bricks, expanded clay bricks, aerated concrete blocks, concrete, reinforced concrete, rock wool and polystyrene. These materials are well researched and their sound insulation properties are known [16], but the production of these materials consumes a lot of energy and leads to the adverse environmental impacts [6].

Environmentally friendly building materials can be used in order to reduce the negative human effect on the environment [7,19]. The variety of such materials is very wide: wood, straw, reeds, plants with strong fiber, such as flax and hemp, and calcined clay.

Wood is mostly used for building's walls as well as for interior and exterior decoration. Sawdust obtained by crushing wood is mixed into adobe or concrete as a filler [12]. Adobe or pressed straw plastered with clay is used as the filler of the wall. Reeds and bulrush are used for roof covering. Strong fiber flax and hemp are used for building's insulation.

Jimenez Espada, Chilekwa, and Oldham examined and established sound absorption coefficient (α) of reeds [14,3,15,18] and Han–Seung–Yan established sound absorption coefficient of rice straw, but there is not much information about sound reduction index (R_W) of log walls, adobe, pressed straw, straw–clay and reeds. In order to determine the sound reduction index of these materials, their samples have been measured in the semi-anechoic chamber.

The goal of this work was to determine the sound reduction index of pine logs, pressed straw, reeds, straw–clay and sawdust concrete materials that are used to build walls.

2. Materials and methods

2.1. The equipment of the research

The research of material acoustic properties has been carried out in the semi-anechoic chamber. The internal surface area (walls, ceiling and frame) which is covered with 0.25 m cut out acoustic

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foam plates (cutting step – 0.15 m). The overall view of the semi-anechoic chamber is shown in Fig. 2.1.

The semi-anechoic chamber is divided into two rooms split by a double wall and a room for the measurement equipment. The first room is called the source room of the outgoing sound. The second room is called the receiving room of the incoming sound. The total volume of the receiving room is 31.5 m^3 and the total volume of the source room is 38.5 m^3. The chamber is isolated from rigid contact with the room walls, ceiling and floor. The semi-anechoic chamber is isolated from the enclosing room by individual slab, and the source room of the chamber is not connected with the receiving room of the chamber as required by standard ISO 10140. In the wall that splits the rooms, there is an opening in which the 1.0 × 1.0 m test sample is tightly secured. Several microphone positions can be installed in both (outgoing and incoming sound) chamber rooms. Before the beginning of researches, constructions with known sound insulation were measured and it was found, that during calculation T_0 = 0.2 s shall be used instead of reverberation time T_0 = 0.5 s as indicated in the standard.

Equipment used for the acoustic measurements: real-time sound spectrum analyzer "Bruel&Kjaer mediator 2260", two microphones Bruel&Kjaer 4189, microphone calibrator, power amplifier Bruel&Kjaer, dodecahedron speaker Bruel&Kjaer Omni Power Type 4292.

The sound is generated from the sound source situated with the minimum distance of 0.7 m away from the wall. One microphone is positioned in the source room where the sound source is and the other microphone is positioned in the receiving room. Microphones are positioned 1.5 m above the chamber floor and 1.2 m away from the sample. The measurements are repeated three times to set the standard error. The sound insulation level of the tested materials is determined by the sound level difference found in source and receiving roomssil between which the sample is tightly secured [2].

Measurements in the semi-anechoic chamber have been done in accordance with ISO 10140-2:2010 standard Acoustics – Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation. Sound insulation R_W of the structure is found from the formula:

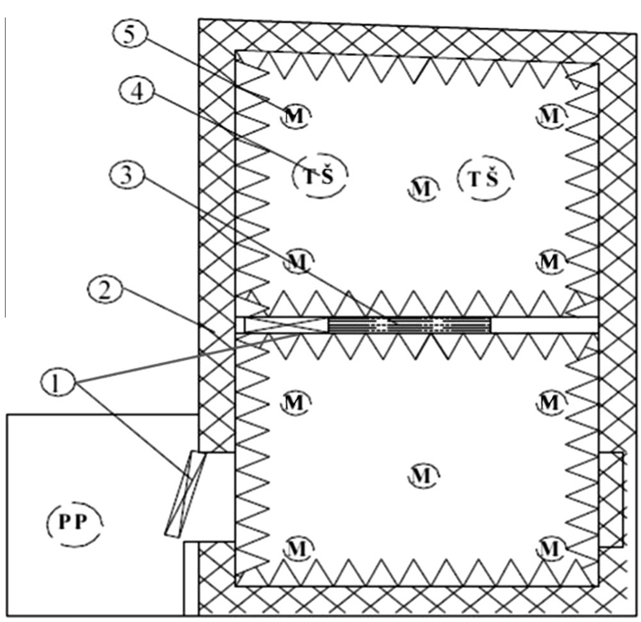

Fig. 2.1. View of the noise suppression chamber from above: 1 – door; 2 – chamber partitions covered with foam; 3 – cage for mounting the researched samples; 4 – positions of noise sources (TŠ); 5 – microphone positions (M); PP – data recording and processing room.

$$R_W = L_1 - L_2 + 10lg\frac{S}{A}, \text{dB} \tag{1}$$

where L_1 – average sound pressure level in the outgoing sound chamber, dB; L_2 – average sound pressure level in the incoming sound chamber, dB; S – structure's area, m^2;

Overall sound absorption in the incoming sound chamber is found from the formula:

$$A = \frac{1.163 \cdot V}{T}, \text{dB} \tag{2}$$

where V – volume of the incoming sound chamber, m^3; T – measured reverberation time, s.

2.2. Preparation of samples

Environmentally friendly materials most commonly used in the construction of walls were manufactured and the minimum thickness has been chosen.

2.2.1. Adobe sample preparation

Clay flour, rye straw and water were used for manufacturing the adobe sample. Clay was mixed with water in a ratio of 3–2 and the mixture was left to swell for 30 min. Straws were soaked in the prepared clay puree and were put on the net. After 10 min the straws were put into the press. The pressed adobe block was left untouched for twenty-four hours. Later the block was removed and left to dry for 14 days at 20 °C temperature. The thickness of the adobe sample was 200 mm, density was 200 kg/m^3.

2.2.2. Straw–clay sample preparation

The straw–clay sample was manufactured by JSC "Ecococon". Pressed straws were placed in a wooden frame and two great walls were plastered with 25 mm of clay on both sides. The thickness of the sample was 400 mm, the overall density −190 kg/m^3.

2.2.3. Log wall sample preparation

The sample was notched from pine logs and the spaces between logs were sealed with flax fiber. The thickness of the log wall was 150 mm, and the density was 300 kg/m^3.

2.2.4. Sawdust concrete sample preparation

Cement-bonded sawdust can be called environmentally friendly because it is based on softwood sawdust (90%). 2% of Portland cement and 8% of special minerals were used to bind wood together. Hollow blocks were filled with concrete which formed the static main body of the structure. The overall density of the sample was 500 kg/m^3, the thickness was 200 mm.

2.2.5. Pressed straw sample preparation

In order to find the sound insulation coefficient and the low-frequency sound insulation properties, 50 mm, 100 mm, 150 mm and 200 mm thick, 1 m^2 area pressed straw samples were prepared. Rye straw was put into a wooden frame which walls made out of nets. The straw was hand pressed. Once the sample was prepared, it was weighed, the mass of the frame was subtracted and the density of the straw was found. The density of the straw in the sample was 90 kg/m^3.

2.2.6. Reed sample preparation

In order to find the sound insulation coefficient of reed sample, 50 mm, 100 mm, 150 mm and 200 mm thick, 1 m^2 area reed samples were prepared. The reed samples were not close packed in order to maintain their structure. Reeds were placed in a wooden frame which walls were made out of nets. Any additional form of binder was not used. Reeds were orientated in two ways – lengthwise