Sound absorption coefficient changes of acoustical plates made of expanded perlite in moist environment

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Abstract

Expanded perlite is a porous, lightweight, fire resistant and moisture retaining material with sound and thermal insulation properties. In this research, acoustical behaviour of plates made of expanded perlite was studied experimentally. Since these plates are used for sound absorption the acoustical parameter selected for this study is "sound absorption coefficient". Preliminary experiments indicated that moisture reduced the sound absorption coefficient on plates and there is not much significant difference between the dry and 50% humid conditions. However, there is a significant difference in acoustical properties for the 50% - 95% humid conditions. Thus, this interval was studied in detail. A number of expanded perlite plates having different mixtures were prepared and tested. It was observed that coating of expanded perlite particles with sodium silicate increased moisture resistance, and that the addition of mineral fibre into the mixtures increased the strength and sound absorption coefficient of the plates.

1 Introduction

Perlite which is a siliceous volcanic rock, which expands by ten to thirty times of its original volume when heated up to 700-1200 ° C. In situ and prefabricated building materials made of expanded perlite are used widely as thermal insulation materials. It is used in other industries as filler, filter, abrasive and moisture retaining material. Expanded perlite, with its open pore structure, is also very suitable as a sound absorbing material. It is used mostly in spray form in paints and plastering for acoustical purposes. However, the moisture retaining properties of perlite restricts its usage and the effect of moisture on acoustical properties has not been considered in the literature. The aim of this study is to determine the sound absorbing properties of plates made of expanded perlite in moist environments.

2 Experimental study and methods

The initial stage of this research was to find out, whether the moisture affects the acoustic properties of the plates made of expanded perlite and how it might be possible to produce plates with both sound absorbing and moisture resisting properties. It is known that, for a moisture-proof material with good sound absorbing properties; porous admixtures with high tortuosity, low flow resistance and water repelling qualities are needed [1]. Thus, four different types of plates, with five samples from each type were prepared as shown in Table 1. The plates were prepared from the commercially available perlite rendering aggregates with different mixing ratios.

Former researches show that silicone emulsions for treating silicate particulate matter such as perlite and vermiculite are used to make it water-resistant [2]. It is known that, by using silicate of sodium (Na_2SiO_3), silication of expanded perlite particles increases water vapour resistance of the material [3]. Therefore, silicate of sodium was used as water repelling material.

Instead of organic fibre, inorganic fibre was preferred because it is not causing any changes or corrupting the material structure. After comparing with glass wool rock wool was used because of the fact that, its density is 200 kg/m^3 whereas the other's density is 125 kg/m^3, and in addition to that, its compression strength is more than glass wool. As a result, rock wool was used in mixture as mineral fibre.

Four different sample plate groups, which consist of at least 5 pieces in each group, were prepared by using the materials given above. The parameters, which affected acoustic and hygroscopic properties of the porous material, were tested with plates and their acoustic behaviours compared in moist environment. Plates are given below:

1. Perlite-Cement Plate : PCP
2. Silicate Perlite – Cement Plate : SPCP
3. Perlite Rock Wool Fibber- Cement Plate : PTCP
4. Silicate Perlite Rock Wool Fibber-Cement Plate : SPTCP

At first, mixtures whose ratios given in Table-1 were prepared. Then they were moulded into steel model with a diameter of 90 mm and a thickness of 30 mm, before being compressed with a vibrator. In order to avoid being shrinkage, samples were placed in a water vessel, with their smaller sides facing down and completely under water, and were kept so for seven days. At the end of seven days, in order to dry static environment, they were put into a climate chamber, where the temperature was kept between 23 ° C ± 2 °C and the relative humidity between 50 % ± 5. In order to find out their dry weight, the samples were dried at 105 ° C± 5 ° C until there was no change in their weight. Mixing ratio and production process of plates are given in Table-1.

Table 1. Mixing ratio and production process of sample plates

CODE	MIXING RATIO	PRODUCTION PROCESS
PCP	1,3 m^3 Perlite 150 kg Cement 300 lt Water	Firstly expanded perlite and cement were mixed as dry and then were cast in steel mould after adding water.
SPCP	1,3 m^3 Silicate Perlite 150 kg Cement 300 lt Water	Expanded perlite granules were coated with Na_2SiO_3. It was sieved through a 4 mm sifter. Initially, prepared particles were mixed with cement, then were cast in steel mould after adding water.
PTCP	1,3 m^3 Perlite 1,3 m^3 Rock wool fibre 150 kg Cement 500 lt Water	Firstly, rock wool fibre, expanded perlite and cement were mixed as dry, then were cast in steel mould after adding water.
SPTCP	1,3 m^3 Silicate Perlite 1,3 m^3 Rock wool fibre 150 kg Cement 500 lt Water	Expanded perlite granules were coated with Na_2SiO_3. It was sieved through a 4 mm sifter. Initially, rock wool fibre, expanded perlite and cement were mixed as dry, then were cast in steel mould after adding water.

2.1 Testing of acoustical plates made of expanded perlite

2.1.1 Mass density

Le Chattelier balloon was used to find the mass densities of the samples. It was filled with benzine in balloon whose neck part was graded between 0.0 – 1.0 mm. Plates were ground in ceramic plate and were sieved through a 75 mm sifter. They were dried at 105 °C ± 5 °C in a disinfecting-oven until there was no change in their weight. Ground and dried parts were weighted with sensitive balance and then were poured into Le Chattelier balloon. After this process , level of benzine in balloon rose proportionally to its volume. This new volume on the graded balloon neck was read. New volume was used in the following equation to find the mass density. The results of the tests are given Table 2.

$$\rho' = Wk/V_B \tag{1}$$

where, ρ' : mass density, gr/ cm^3, Wk : dry weight gr, V_B : bulk volume cm^3

Table 2. Mass Density of sample plates

	95 % CONFIDENCE INTERVAL				
SAMPLE PLATE CODE	diameter	thickness	V (volume)	V_B	ρ'
	mm	mm	cm^3	cm^3	gr/cm^3
PCP	89.4±0.47	29.0±0.47	180.22±5.69	3.01±0.233	3.51±0.022
SPCP	88.0±0.91	28.7±0.53	174.77±4.83	3.15±0.392	3.22±0.061
PTCP	88.4±0.90	28.0±0.90	172.14±7.84	3.62±0.269	3.43±0.246
SPTCP	87.5±1.22	28.9±0.24	174.05±4.52	3.38±0.157	3.35±0.149

2.1.2 Porosity and effective porosity

The mass densities which were found to be 3.22– 3.51 gr/ cm^3 are mostly near to the values of mass density of cement (2.95-3.15 gr/ cm^3) . Using cement as binding material has been effective on this result. By comparing the plates, it was shown that, the process of silication of perlite granules increased pore volume and the process of addition fibres in mixture increased void volume but not bulk volume.

After mass density, bulk volume and pore volume mentioned in 1.2 were found, porosity was calculated by using equation (2). Equation (3) was also used to find effective porosity. The results of the tests are given Table 3.

$$P = V_v / V \tag{2}$$

$$P_e = \rho_w - \rho_d \tag{3}$$

where,P: porosity, V_v : void volume, cm^3 ,V: overall volume, cm^3 ;
P_e: Effective porosity, ρ_w: wet (saturated) density, gr/ cm^3, ρ_d : dry density gr/cm^3

Table 3. Porosity and Effective Porosity of sample plates

	95 % CONFIDENCE INTERVAL				
SAMPLE PLATE CODE	ρ_d	ρ_w	P_e	V (volume)	V_v	P
	gr/cm^3	gr/cm^3	%	cm^3	cm^3	
PCP	0.43±0.03	0.94±0.05	50.5±2.6	180.22±5.69	176.6±5.5	97.99±0.12
SPCP	0.47±0.01	1.03±0.03	55.2±2.6	174.77±4.83	171.3±4.7	98.05±0.07
PTCP	0.55±0.02	1.10±0.04	55.0±3.3	172.14±7.84	169.1±8.0	98.23±0.19
SPTCP	0.52±0.01	1.10±0.02	57.0±1.7	174.05±4.52	170.9±4.4	98.18±0.22

2.1.3 Permeability test

Permeability tests of samples (PCP and SPTCP) were measured with Capillary Flow Porometer by Porous Material, Inc. This device performs Bubble Point, Capillary Flow Porometry and Gas Permeability (Darcy's Permeability Constant). Tests are based on ASTM F-316-86 and F-778, and on B.S. 3321 and

6410. The normal sample holder is designed for flat samples of 1 3/8” diameter and thickness of up to 1”. The gas permeability test uses a dry sample and records the pressure and flow rate of gas passing through the sample at various pressures.

The reason of sending two samples to test, PCP and SPTCP, is to enable comparing the inside structure. PCP plates are the barest plates which include expanded perlite, cement and water, whereas SPTCP is the sample plate in which rock wool fibres were added to Na_2SiO_3 coated perlite granules which are then mixed with cement. The results are given figure 1.

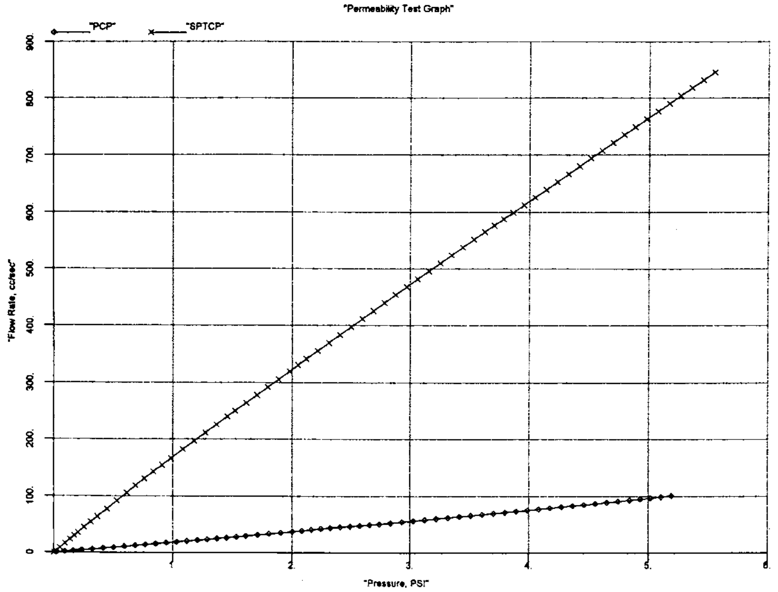

Figure 1. Permeability tests of PCP and SPTCP

3 Measuring sound absorption coefficients of plates in moist environment

3.1 Climate chamber

Climate chamber was designed and constructed to moisturise sample plates made of expanded perlite. The dimensions of the climate chambers are 800x500x500 mm and its upper section is transparent and constructed with Plexiglas. As this chamber is in a room where all environmental conditions can be controlled, no thermal insulation is needed on the Plexiglas faces. Upper section has a temperature sensor connected to a thermostat, a humidity sensor connected to a hygrostat and a fan circulating hot and cold air within the chamber.

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Microprocessors of thermostat and hygrostat have the ability to make six programs one after the other. Within upper section there are two perforated shelves on which to put sample plates and to provide easy circulation in chamber.

Lower section of the climate chamber has two parts. One of them for increasing and the other is for decreasing the humidity. Both of them have separate connections to the upper section. The working temperature range is 5 °C- 40 °C and humidity range is 10% - 98% in the climate chamber.

3.2 Two microphone impedance tube controlled computer

It was necessary to make quick measurements without changing the conditions of the sample plates. It was decided to employ a , " two microphone impedance tube" under computer control [4] because with this method it is possible to work with relatively small samples.

The impedance tube is a steel tube with a test specimen at one end and a loudspeaker at the other. Microphones are mounted at two locations along the wall of the tube. For communication with the computer, a data acquisition card was used. The interior section of the tube is circular and has a diameter of 90 mm. Thickness of the tube is 10 mm, so the outside diameter of the tube is 100 mm. Also the length of the tube is 1000 mm. For this apparatus, the upper measurement frequency is (f_m) 1894 Hz. ¼" microphones located with 60 mm spacing were mounted outside the wall of the tube. The system is composed of five parts. These are computer, computer input- output units , sample holder, impedance and pink-noise generator and microphones.

1/3 octave band absorption coefficients of the specimens were measured between 300-1800 Hz frequencies. The transfer responses of microphones were collected at each frequency, and then reflection coefficients and absorption coefficients were calculated by the following equations, respectively:

$$r = (H.e^{jkd} - 1) / (1 - H.\ e^{-jkd}) \tag{4}$$
$$\alpha = 1 - |r|^2$$
$$k = 2\pi / \lambda$$

where,d = Distance between microphones ,H = Transfer response between microphones R = Reflection coefficient, α = Absorption coefficient

3.3 Sound absorption coefficient of plates made of expanded perlite

During the research aiming to figure out the behaviour of acoustical plate made of expanded perlite in moist environment, it was determined after the preliminary experiments that, there was no significant difference between dry and 50% humid conditions and the necessary humidity range to be researched was 50% - 95% [5]. Therefore, in this study sound absorption coefficients of a number of samples, with different mixtures, were measured as dry (Wk), under natural humidity (Wn), after being saturated with water (Wk), after being semi-saturated with water(Wk/2), after being kept under 50, 60, 70, 80, 90, 98 % humid conditions (W50, W60, W70, W80, W90, W98) between 300 – 1800 Hz frequencies. Results are given Figure 2, 3, 4 and 5.

PCP is the barest among the other plates. Its mixtures consist of only expanded perlite, cement and water (Table 1). Regarding Figure 2, plate behaves as sound reflector, when it is saturated. SPCP is more absorbent than PCP. SPTSP is the most absorbent plate among the other plates. Process silication of perlite granules avoids connection between granules faces because micro-size granules stick each other when coated, so medium becomes porous with open pores. This process also contributes to insulation of granules against moisture since it is coated. The addition of mineral fibbers into this mixtures increases permeability of the plates as well as the sound absorption coefficients of the plates (See Figure 5).

Difference between sound absorption coefficient of dry condition and that of 98 % humid condition of the samples is about 0.10 – 0.30. When the plates were saturated with water, this difference increases to 0.40 – 0.60 on the average. When plates are moisturized, their sound absorption coefficient values get near to those of plates under dry and natural humid conditions. However, when they are saturated they behave as sound reflector. It is also concluded that, the fact that the sound absorption coefficients under saturated-with-water condition rise to higher values, is for the reason that; the water can not reach to tiny capillary pores with the effect of surface tension and however, when the sound wave enters these pores, the pore absorbs the sound energy like a resonator and therefore the sound wave which can not exit the pore is absorbed.

4 Analysis and Conclusion

An experiment was performed in order to determine whether the porous structure and moisture retaining properties of perlite results in any changes in its acoustical properties. During preliminary experiments, it was determined that, when plates were moisturised and especially saturated with water, their sound absorption coefficients diminish. In order not to increase their resistance to moisture without changing its acoustical properties, plates with different mixture proportions were prepared. Parameters indicating the acoustical and hygric properties, were tested on those plates.

Regarding the porous structure of the plates, the fact that porosity is 97-98 % whereas the effective porosity is 50-57%, indicate that, the difference amount inbetween is composed of inconnected and impermeable capillary pores. Effective porosities of SPCP and SPTCP turn out to be higher than the other plates, showing that, silication of perlite granules decrease the number of particle

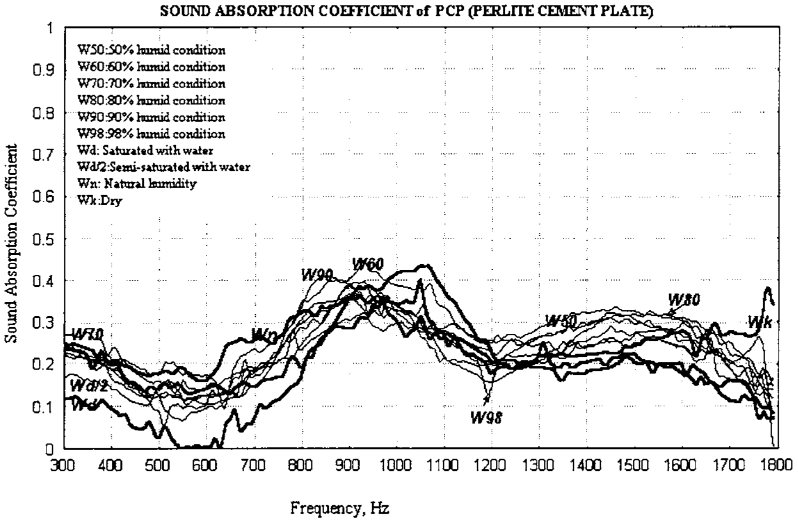

Figure 2. Sound absorption coefficients of PCP

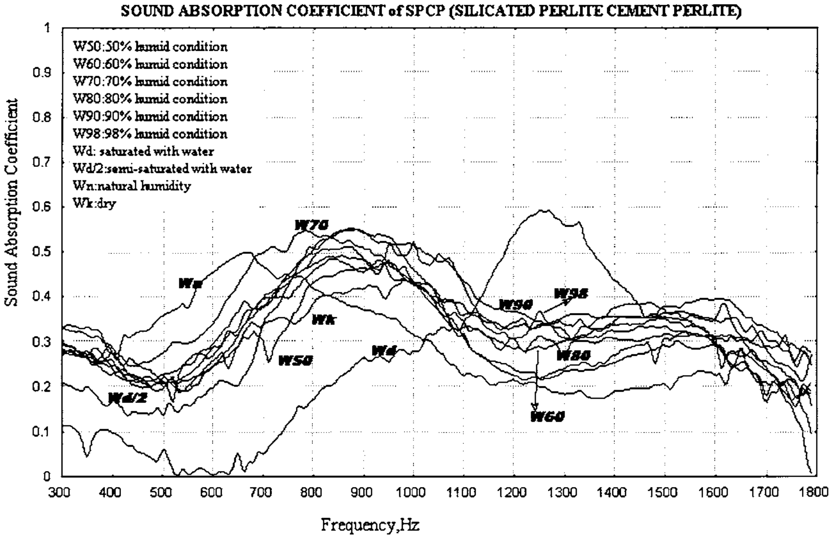

Figure 3. Sound absorption coefficients of SPCP

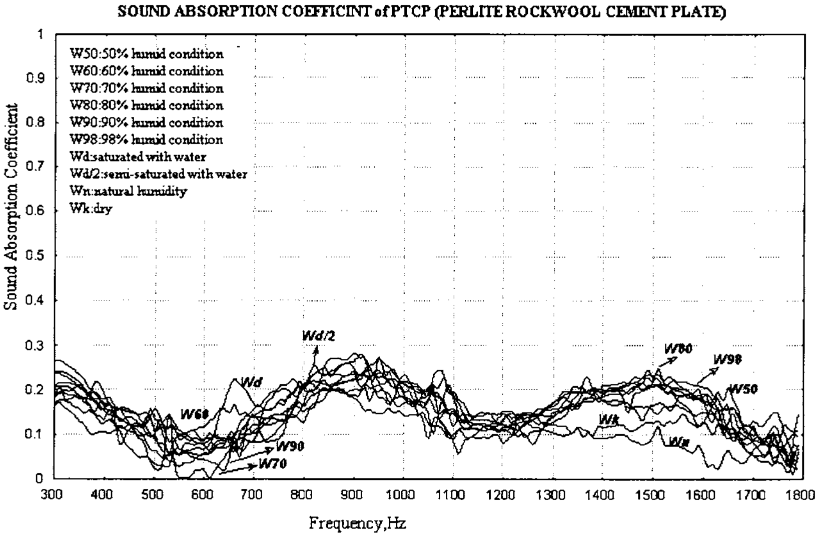

Figure 4. Sound absorption coefficients of PTCP

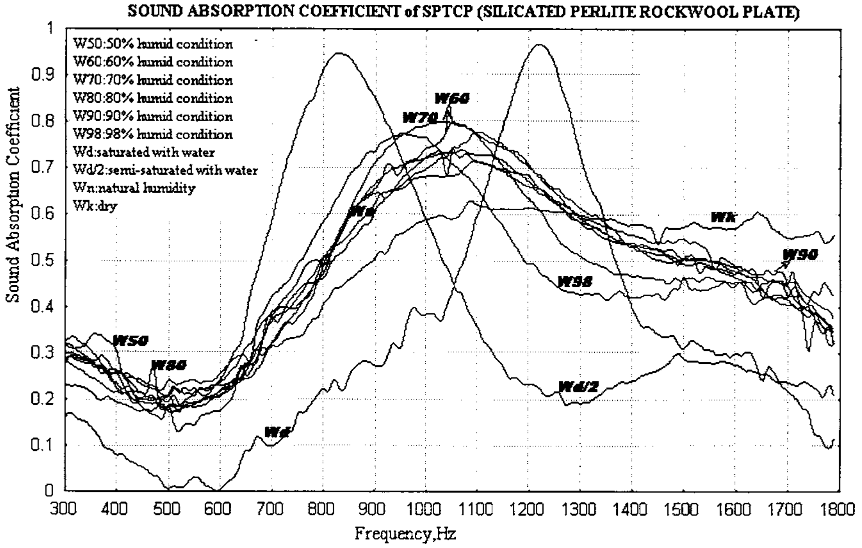

Figure 5. Sound absorption coefficients of SPTCP

surfaces touching each other and therefore enlarge particle granules where fibreous structure increase the connection between pores. It is also seen that, in comparison with PCP, SPTCP plate including fibre and silicated perlite in its formation is a more permeable structure.

SPTCP plate proved to confirm the model that was aimed to be derived: Its properties indicating its acoustical features (like porosity, permeability, etc.) were found to be about desired values and therefore this yielded a favourable sound absorption. The plate behaved as a good sound absorbent.

As mentioned before along with its experiment result figures, it was clearly seen that, moist disturbs the acoustical properties of materials made of expanded perlite. An important finding of the research is that, moist resistance of materials with expanded perlite, which are poor in that aspect, can be improved with special mixture materials to be selected without harming the acoustical properties of the material with expanded perlite.

The plate proving to be the best among all is the SPTCP, Silicated Perlite Rock wool Cement Plate. It is more rigid than the others, has a higher permeability and however is the one with the most number of connections between the pores.

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