SOUND ABSORPTION IMPROVEMENT FOR CEMENTITIOUS MATERIALS

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ABSTRACT

Acoustical material plays a number of roles that are important in acoustic engineering such as the control of room acoustics, industrial noise control and studio acoustics. Sound absorptive materials are generally used to counteract the undesirable effects of sound reflection by hard, rigid and interior surfaces and thus help to reduce the reverberant noise levels. Cementitious materials may be used as interior finishing for interior surfaces in buildings. This paper review of sound absorption studies for cementitious materials for their potential benefits in sound absorption and investigate some finishing cementitious materials added with porous and fibrous materials to improve the sound absorption performance. Sprayed cement mortar containing cotton fibers and perlite of an amount of perlite in the region of 80% in relation to the cotton fibers gave the best results. Also sprayed fibrous cement mortar based on mixture of mineral wool and cement binders achieved high sound absorption.

RÉSUMÉ

Matériau acoustique joue un certain nombre de rôles qui sont importants dans l'ingénierie acoustique tels que le contrôle de l'acoustique des salles, contrôle du bruit industriel et acoustique de studio. Absorbants phoniques sont généralement utilisés pour contrer les effets indésirables de la réflexion du son par les surfaces dures, rigides et de l'intérieur et ainsi contribuer à réduire les niveaux de bruit de réverbération. matériaux à base de ciment peut être utilisé comme finition intérieure pour les surfaces intérieures des bâtiments. Cette revue papier des études d'absorption acoustique de matériaux cimentiers pour leurs avantages potentiels de l'absorption acoustique et d'enquêter sur certains matériaux de finition à base de ciment a ajouté avec des matériaux poreux et fibreux pour améliorer les performances d'absorption acoustique. mortier de ciment projeté contenant des fibres de coton et de perlite d'un montant de perlite dans la région de 80% par rapport aux fibres de coton a donné les meilleurs résultats. Également pulvérisé mortier de ciment fibreux à base de mélange de laine minérale et de liants de ciment atteint haute absorption acoustique.

1. INTRODUCTION

Sound absorptive materials are generally used to counteract the undesirable effects of sound reflection by hard, rigid and interior surfaces and thus help to reduce the reverberant noise levels [1], [2]. In order to have good sound absorption performance, the material should be in porous or fibrous form; the energy is lost by viscous dissipation when sound waves propagate into the material [3]. Sound absorbing materials have been developed as an engineering control to reduce reverberation and overall sound levels [4].

2. MEASUREMENT OF SOUND ABSORPTION COEFFICIENT

The performance of sound absorbing materials in particularly is evaluated by the sound absorption coefficient (α) [5], [6]. Alpha (α) is defined as the measure of the acoustical energy absorbed by the material upon incidence and is usually expressed as a decimal varying between 0 and 1.0. Values are usually provided in the literature at the standard frequencies of 125, 250, 500, 1000 and 2000 Hertz [5], [7].

In comparing sound absorbing materials for noise control purposes, the noise reduction coefficient (NRC) is commonly used. NRC is the average usually stated to the nearest multiple of 0.05, of the coefficient at four frequencies 250, 500, 1000 and 2000 Hz [8]. It is intended for use as a single number index of the sound absorbing efficiency of a material. The NRC value provides a decent and simple quantification of how well the particular surface will absorb the human voice [9].

Harris [8] describes the four factors that affect the sound absorption coefficient:

- Nature of the material itself
- Frequency of the sound
- The angle at which the sound wave strikes the surface of the material
- Air gap

Measurement techniques used to characterize the sound absorptive properties of a material are [10], [11]:

- Reverberation room method [ASTM C423]
- Impedance tube methods [ASTM E 1050]

Impedance tube method uses plane sound waves that strike the material straight and so the sound absorption coefficient is called normal incidence sound absorption coefficient, NAC [7]. Impedance tube method is faster and generally reproducible and, in particular, requires relatively small circular samples, either 100 or 29 mm in diameter for low and high frequency measurements. In the impedance tube method, sound waves are confined within the tube and thus the size of the sample required for test needs only be large enough to fill the cross section of the tube. Thus this method avoids the need to fabricate large test sample with lateral dimensions several times the acoustical wavelength.

Two fixed microphone impedance tube or transfer function method (ASTM E 1050), which is relatively recent development can be used. In this technique, a broadband random signal is used as a sound source. The normal incidence absorption coefficients and the impedance ratios of the test materials can be measured.

For this investigation, PULSE acoustic material testing tube, type 4206 (B&K) and impedance Tube Kit (50Hz - 6.4 kHz) were used for sound absorption measurements in conjunction with the software 7758 for determining the sound absorption coefficients for the tested samples [12].

Reverberant Method for measuring sound absorption is concerned with the performance of a material exposed to a randomly incident sound wave, which technically occurs when the material is in diffusive field. However creation of a diffusive sound field requires a large and costly reverberation room. Since sound is allowed to strike the material from all directions, the absorption coefficient determined is called random incidence sound absorption coefficient. This method is clearly explained in [ASTM C423]. The measurements of reverberation time in room under consideration were carried out in the reverberation room without and with the sample according to [ASTM C423]. Where the tested sample was applied to a substrate and tested according to the mounting methods stated in the standard in ASTM E795.

The analyzer of B&K's portable PULSE connected with condenser microphone type 4189, omni directional loudspeaker type 4292 (B&K), power amplifier 2716 (B&K) and the soft ware type 7842 have been used for measuring the reverberation time. Where the noise signal generated from the pulse generator that excites the reverberation room with and without the sample. The reverberation time for decay 60 dB is determined with and without the tested sample then the sound absorption coefficients is calculated using these measurements.

3. LITERATURE REVIEW

N. Neithalath, J. Weiss, and J. Olek evaluated three classes of specialty cementitious materials for their potential benefits in sound absorption including a Foamed Cellular Concrete (FCC), Enhanced Porosity Concrete (EPC) incorporating 20-25% open porosity, and a Cellulose Cement Composite (CCC). The FCC specimens showed absorption coefficients ranging from 0.20 to 0.30, the higher value for lower density specimens. The closed disconnected pore network of FCC resulted in a reduced absorption, even though the porosity is relatively high. The most beneficial acoustic absorption was observed for EPC mixtures. By engineering the pore structure by careful aggregate grading as in EPC, or incorporating porous inclusions like morphologically altered cellulose fibers, cementitious materials [13].

L. Arnaud and V. Cerezo study the acoustical properties of various formulations of concrete containing vegetable particles. Such material is made up with hemp shives mixed with lime binders. Thus, this concrete presents a high porosity related to the microscopic porosity of the shives and the macroscopic porosity due to the arrangement of particles resulting in sound absorption between 0.5 and 1 [14].

Knapen E., Lanoye R., Vermeir G., Lauriks W., Van Gemert D showed that polymer-modified porous cement mortars can be an alternative for the more conventional sound absorbing materials. They linked the acoustic behaviour to the polymer/cement ratio, the sand/cement ratio, compaction and size of the sand. These were connected to pertinent physical parameters (porosity, flow resistance, tortuosity, etc.) and those parameters were in turn linked to measured sound absorption [15].

Piti Sukontasukkul investigated the sound properties of crumb rubber concrete panel. The crumb rubber was used to replace fine aggregate at ratios of 10%, 20% and 30%. Results indicated that sound absorption coefficients α-values is low at the low frequency ranges of 125 and 250 Hz, However, at the mid-frequency (500 Hz), the crumb rubber concrete began to show slightly higher α-values. The ability to absorb sound by all crumb rubber concrete lightweight concrete was found to be much better than that of plain concrete for frequencies greater than 1000 Hz. This indicated that crumb rubber concrete is a better sound absorber at the high-frequency range than plain concrete [16].

4. EXPERIMENTAL WORK

The following cementious materials were investigated in this study:

1- Conventional cementsand mortar
2- Cementitious mortar altered with cotton fiber and expanded mineral (perlite)
3- Cementitious mortar altered with mineral fiber

The measurements have been carried out according to ASTM C423 ASTM E 1050 standards.

4.1 Conventional cements and mortar

The materials used in this investigation are ordinary Portland cement (OPC) and ultra fine sand (UFS). The UFS was added to the OPC at different weight ratios from 0 to 10% and the best sound absorption was as shown in table (1) and figure (1). The measurements have been made using pulse acoustic material testing tube type 4206 (B&K). The results of measurements show that the conventional cementsand mortar have low sound absorption coefficient at all frequency range from 100 to 6300 as shown in figure (1).

Frequency, Hz	α of Mortar with cotton
125	0.03
250	0.04
500	0.06
1000	0.07
2000	0.05
4000	0.07
NRC	0.06

Table 1: Sound absorption coefficient of the tested ordinary cement mortar

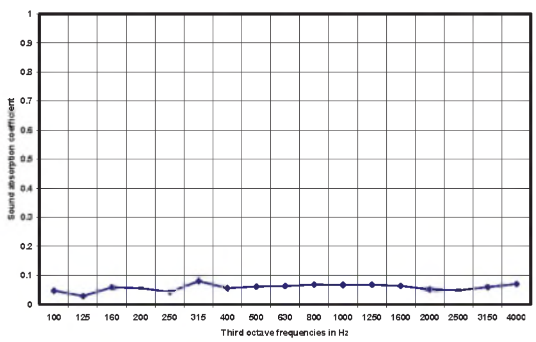

Figure 1 Sound absorption coefficient of ordinary cement mortar.

4.2 Cementitious material altered with cotton fiber and perlite

This investigation relates to a finishing mortar for sound-absorbing coating of inner walls, ceilings and the like in buildings. It may be applied directly on concrete or some other carrying material or on underlying insulation material, such as mineral wool. The finishing mortar according to the investigation is characterized in that it comprises cotton fibers and expanded mineral, such as perlite. Cement finishing mortar consisting essentially of: perlite; and cotton fibres, wherein a weight ratio of perlite to cotton fibres is in the range of 10%-250% preferably 80%. The mortar was present as a water dispersion with a content of solids which makes it suitable for spraying, the content of solids then preferably being 200-300 g/l. A dry volume weight of perlite was in the range of 35 to 125 kg/m3 dependent on particle size

The mortar sprayed on to a metal plate of length 3 and width 3.5. The metal substrate fixed to the floor of the reverberation room. The perimeter edges sealed with acoustic sealant. The thickness of the tested mortar was 10 mm. The measurements have been carried out in acoustics laboratory of housing and building research center according to ASTM C423.

Figure (2) shows the sound absorption coefficient for the tested mortar containing cotton fibers and perlite of different weight ratio. Where the highest sound absorption achieved for mortar containing cotton fibers and perlite of weight ratio 80%

Also the sound absorption coefficient for a tested mortar with cotton fibers only have been measured where the cotton fiber is applied by spraying on in two steps with intermediate drying. The cotton fiber mixture which is sprayed consists of cotton having suitable grinding degree, water, mica, biolite, muscovite, and silicaber to obtain different effect. The thickness of cotton layer was 4 mm.

Figure (3) shows the sound absorption coefficient of the tested mortar with cotton fibers only. The sound absorption effect of the tested mortar containing cotton fibers and perlite according to this research is shown in Table 2 and also compared to finishing mortar containing only cotton fibers.

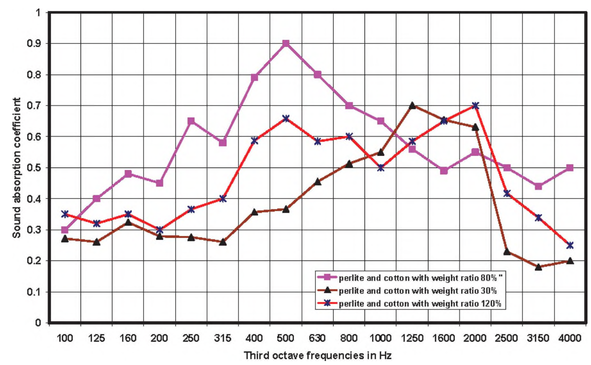

Figure 2. Sound absorption coefficient of the tested mortar with different containing perlite and cotton with weight ratio

Frequency, Hz	α of Mortar with cotton	α of Mortar with cotton fibres and perlite
125	0.40	0.40
250	0.55	0.65
500	0.75	0.90
1000	0.50	0.65
2000	0.25	0.55
4000	0.20	0.50
NRC	0.5	0.7

Table 2: Sound absorption coefficient of the tested mortar containing cotton fibers and perlite

From the results of measurements it is clear that the sound absorption of mortar altered with cotton fiber and perlite achieved good sound absorption due to the increase of porosity. Also the sound absorption of mortar altered with expanded material (perlite) are better than mortar with cotton because during admixing of the expanded material the air penetration of the mortar after drying will be maintained, which means that improve the acoustic properties

4.3 Cementitious material altered with mineral fiber

Two sprayed cement mortar have been tested in the reverberation room according to ASTM C423 as follows:

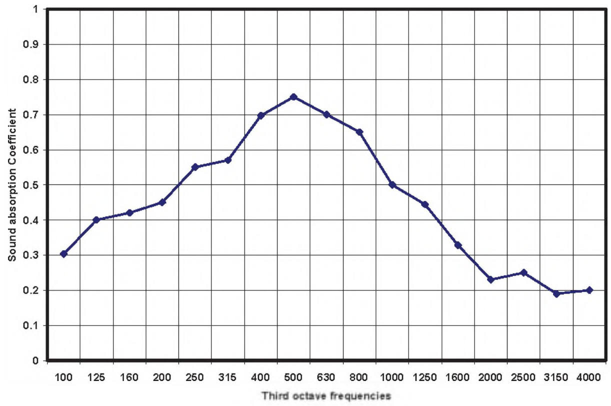

Figure 3 Sound absorption coefficient of the tested mortar with cotton fibers only

1- Sprayed cement material type 1

The sound absorption coefficient of fibrous cement material has been measured. This sample is a sprayable blend used for acoustic correction and made of mineral wool and hydraulic and inorganic binders of 25 mm thickness. The mortar sprayed on to a metal substrate of length 3 m and width 3.5 m. The metal plate fixed to the floor of the reverberation room. The perimeter edges sealed with acoustic sealant. The measurements are carried out in the reverberation room of acoustics laboratory in housing and building research center where the tested sample is sprayed on metal panel on the floor of the reverberation room. Figure (4) and Table 3 shows the sound absorption at third octave frequencies from 100 to 4000.

2- Sprayed cement materials type

The sound absorption coefficient of fibrous sprayed material is based on mixture of mineral wool and cement binders. This sample has been sprayed of thickness 10 mm on metal plate of area 10.5 m^2 on the floor of the reverberation room. Figure (5) and Table 4 shows the sound absorption at third octave frequencies from 100 to 4000.

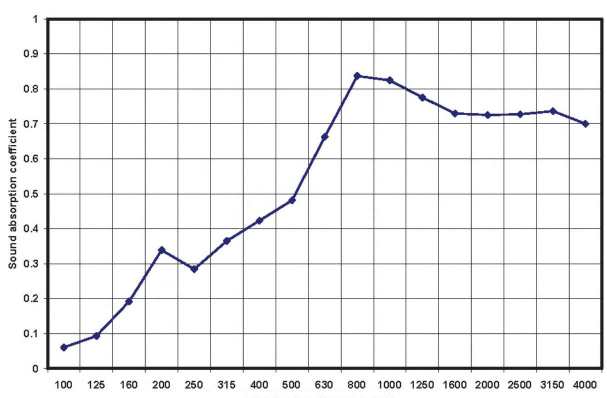

Figure 4 Sound absorption coefficient of sprayed fibrous cement sample type 1 of 25mm thickness

Figure (4), (5) show the sound absorption coefficient of sprayed fibrous cement samples where the sound absorption coefficient achieved good sound absorption. But the sound absorption coefficient of the sprayed fibrous cement mortar type 1 is better than sprayed fibrous cement mortar type 2 at the low frequencies due to the increase of thickness.

5. CONCLUSION

This paper investigated the sound absorption of some cementitious materials that may be used as interior finishing for interior surfaces in buildings improve the indoor acoustic performance. The experimental work indicated that the sound absorption of sprayed cement mortar can be improved by adding cotton fibers and perlite. An amount of perlite in the region of 80% in relation to the cotton fibers gives the best results. Also sprayed fibrous cement material based on mixture of mineral wool and cement binders can achieve high sound absorption that can be used as interior finishing specially for coating high ceiling

Frequency, Hz	α of Mortar with cotton
125	0.1
250	0.28
500	0.48
1000	0.82
2000	0.73
4000	0.7
NRC	0.55

Table 3: Sound absorption coefficient of sprayed fibrous cement sample type 1 of 25mm thickness

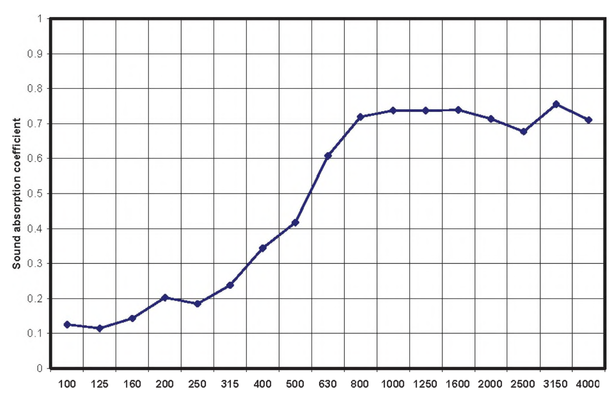

Figure 5 Sound absorption coefficient of sprayed fibrous cement sample type 2 of 10 mm thickness

Frequency, Hz	α of Mortar with cotton
125	0.1
250	0.18
500	0.42
1000	0.74
2000	0.71
4000	0.7
NRC	0.5

Table 4: Sound absorption coefficient of sprayed fibrous cement sample type 2 of 10mm thickness

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