HK.NCCP
International Journal of Intelligent Information and Management Science
ISSN: 2307-0692, Volume 5, Issue 4, August 2016

Study on the Performance of Cement-Based Foamed Sound Absorbing Material

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Abstract: Based on the molding craft of foam concrete, by adding the enhancer with good dispersity polypropylene fiber and some auxiliary materials, a new cement-based foamed sound absorbing material was prepared. Such material has advantages like excellent sound absorption property, low cost and non-pollution.

Keywords: Sound absorption coefficient; Foamed concrete; Cement-Based

1. Introduction

With the development of transportation industry, traffic noise pollution has become increasingly widespread and severe. The issue of noise control has attracted attention from governments and scientific and technical workers of various countries. At present, the main solution is to reduce noise by absorption[1-2]. Sound absorbing materials can be divided into porous sound absorbing material and resonance sound absorption structure material according to the sound absorption mechanism. Porous sound absorbing material has advantages like great high-frequency sound absorption coefficient and small specific gravity, but its low-frequency sound absorption coefficient is low[3]. Resonance sound absorption structure material possesses high low-frequency sound absorption coefficient, but its sound absorption frequency band is narrow and the processing performance is poor.

As a new sound absorbing material, the study on foamed sound absorbing material has already involved metal material, high polymer material, inorganic material and organic-inorganic hybrid material. They have different characteristics and practical values. Among them, foamed metal involves high cost and the technological condition cannot be controlled easily. Besides, foamed plastic also has disadvantages like easy aging[4-6]. Cement-based foamed material has many sealed pores, so it is often applied as heat-insulating material, and seldom used as sound absorbing material directly.

Based on foamed concrete, by adding auxiliary materials like fiber and air entraining agent, this experiment prepared a cement-based foamed sound absorbing material with compact, uniform and fine interpenetrated pore structure. This material has advantages like low cost, high durability, simple technology and non-pollution.

2. Test

2.1. Test materials

The raw material adopted in this experiment is ordinary Portland cement; the foaming agent is surfactant-based foaming agent; auxiliary raw materials include polypropylene fiber, air entraining agent and water reducing agent.

Ordinary Portland cement: PO42.5 ordinary Portland cement. Its physical properties are presented in Table 1.

2.2. Sample preparation

The Mix proportion is shown as Table 2.

Table 1. Physical properties of PO42.5 ordinary Portland cement

Specific surface area m2/kg	Setting time /h		Rupture strengthMPa		Compressive strengthMPa	
	Initial setting	Final setting	3d	28d	3d	28d
381	2.5	4.0	5.83	8.88	27.2	53.1

Table 2. Mix proportion

Cement	Mixture ratio	Water reducing agent	Air entraining agent	Polypropylene fiber	Foaming agent
700g	0.30	0.9%	0.1%	0.5%	7%

Cement, water and water reducing agent were weighed according to the mixture ratio, and they were added to the neat paste stirrer. They were stirred at a low speed for 120s; 15s later, they were stirred at a high speed for 120s to gain the cement paste. The foaming agent was weighed according to the mixture ratio, and a defined amount of water was added. Then they were put into the foaming machine for foaming. After abundant foam was obtained, they were put into the blender together with the cement paste. After stirring for 60s, air entraining agent was added and stirred for 15s. Finally, they were put into the mould, and then maintenance and demoulding was conducted according to the requirements (Fig. 1).

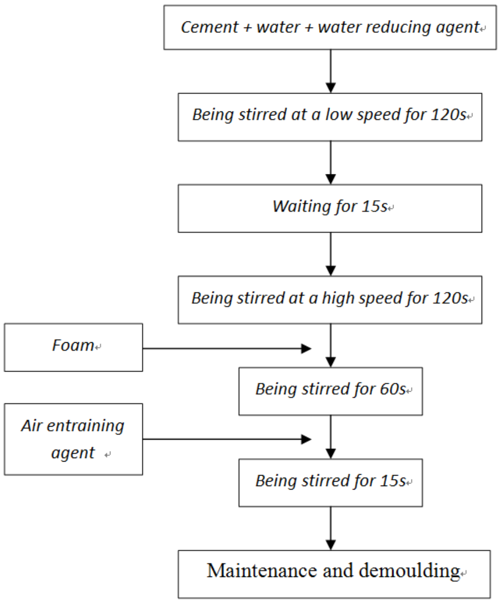

Figure 1. Process routing

2.3. Test of sound absorption property

AWA6122A standing wave tube sound absorption coefficient tester was used to measure the sound absorption coefficients of the material in various frequency bands.

3. Result and Analysis

3.1. Influence of foam content on sound absorption property

Foam is an indispensable part of preparing porous sound absorbing materials. In the molding process, foam will be added into the cement paste and stirred to make the paste contain abundant sealed pores. The sealed pores are connected through additives, and foam content will directly influence the quantity of sealed pores in the paste. Therefore, foam content is closely related to the porosity of materials[7].

Fig. 2 is the changing curve about the sound absorption coefficient of materials with foam content. According to Fig. 2, the sound absorption coefficient of materials increases with the rise of foam content. Sealed pores formed after foam is added is the foundation for interpenetrated pores, so the proportion of interpenetrated pores in the test bock will increase with the rise of foam content; meanwhile, the sound absorption property will also be improved. However, when the foam content reaches a certain limit value, the strength cannot be guaranteed and even the test-piece cannot be formed. Thereby, foam content must be considered by combining comprehensive mechanical properties with sound absorption property.

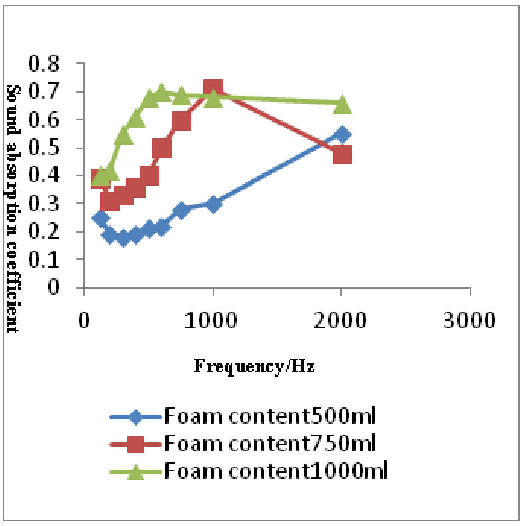

Figure 2. Influence of foam content on sound absorption property

3.2. Influence of air entraining agent dosage on sound absorption property

The uniform and fine sealed pores produced by the foaming agent in foamed concrete are contrary to the interpenetrated pores required by porous sound absorbing materials. How to change sealed pores into interpenetrated pores becomes the key point. Air entraining agent will be added during the later period of stirring foamed concrete. Due to the existence of numerous sealed pores, the resistance borne by air entraining agent when it plays an entraining role will decrease. The fine sealed pores will be connected under the effect of air entraining agent, thus abundant interpenetrated pores are obtained. Generally speaking, when the air entraining agent dosage is higher, more interpenetrated pores can be gained and the corresponding sound absorption effect will be better. However, the dosage has a limit. When this limit is exceeded, the proportion of interpenetrated pores will stop increasing. Therefore, big dosage is not necessarily equal to good sound absorption effect. Fig. 3 is the sound absorption frequency curve of the material when the air entraining agent content is 0, 0.07% and 0.1%.

According to Fig. 3, when the air entraining agent content is 0, 0.07% and 0.1%, the average sound absorption coefficient of the test-piece increases at first and then decreases. When the air entraining agent dosage is 0.07%, the maximum average sound absorption coefficient can be gained. Sound absorption coefficient does not increase with the rise of air entraining agent dosage. When no air entraining agent is added, only fine sealed pores exist in the foamed concrete, which goes against absorption of sound wave. When the air entraining agent dosage becomes 0.1%, the air entraining content rises with the increase of its dosage. Numerous bubbles are triggered, and bubble combination phenomenon is aggravated. The diameter of interpenetrated pores is too large, thus the sound absorption property is reduced.

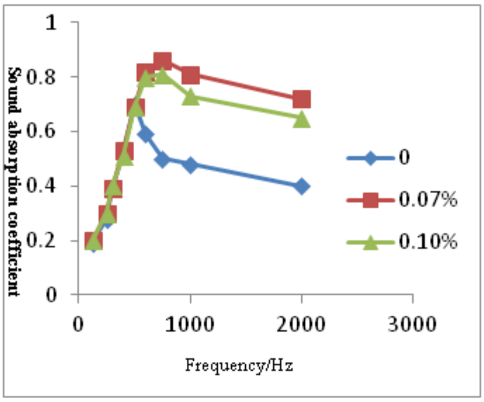

Figure 3. Influence of air entraining agent dosage on sound absorption property

3.3. Performance comparison with other sound absorbing materials

At present, frequently studied inorganic sound absorbing materials include cement – expanded perlite system and cement – ceramsite system[8]. Fig. 4 is the schematic diagram for the sound absorption curve of three different types of porous sound absorbing materials with the thickness of 5cm. According to Fig. 4, cement-based foamed porous sound absorbing material has the best sound absorption property, and the average sound absorption coefficient is 0.59, followed by 0.43 of perlite porous sound absorbing material and 0.32 of ceramsite porous sound absorbing material. Especially in the low-frequency band of 500Hz, the average sound absorption coefficient of cement-based foamed sound absorbing material reaches 0.42, which is improved when compared with 0.26 of perlite porous sound absorbing material and 0.18 of ceramsite porous sound absorbing material. For porous sound absorbing materials, the first resonance frequency should be in an ideal low-frequency band on the premise that the loss of high-frequency sound absorption ability is not huge. Therefore, cement-based foamed sound absorbing material possesses a higher application value.

Cement-based foamed sound absorbing material contains abundant interpenetrated pores; the pore distribution is uniform and the sizes are even. Perlite porous sound absorbing material and ceramsite porous sound absorbing material contain abundant pores, but there are few interpenetrated pores and the sizes vary greatly. When such phenomena are reflected in sound absorption coefficient (as shown in Fig. 4), the first resonance frequency of cement-based foamed sound absorbing material appears in a lower frequency band when compared with the first resonance frequency of perlite porous sound absorbing material and ceramsite porous sound absorbing material. Therefore, as for the situation in which the sound absorption property of porous sound absorbing materials in low-frequency band is poor, cement-based foamed sound absorbing material possesses a relatively higher sound absorption property.

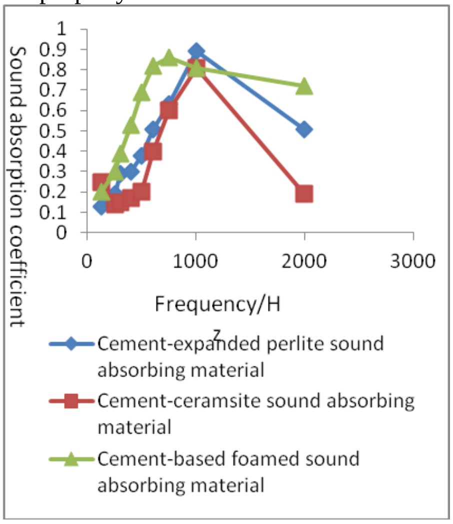

Figure 4. Schematic diagram for the comparison among different sound absorbing materials

3.4. Influence of fiber content on sound absorption property

Fig. 5 is the changing curve about the sound absorption coefficient of materials with polypropylene fiber content. According to the figure, the average sound absorption coefficient of materials is 0.57, 0.53 and 0.54 respectively when the polypropylene fiber content is 0.50%, 1.00% and 1.50%. However, in the low-frequency band of smaller than 500Hz, the sound absorption property of materials increases with the rise of fiber content, and the average sound absorption coefficientis0.39, 042 and 0.45respectively. The sound absorption coefficient in the low-frequency band is mainly decided by porosity inside the material. Owing to the increase of fiber content, cement paste will encounter more resistance in the foaming and entraining process. Thus the inside porosity will drop and the low-frequency sound absorption property will increase. However, lower porosity is not necessarily equal to better low-frequency sound absorption property. If the inside porosity is too low, the penetration resistance of sound wave will be too large and the penetration amount in the low-frequency part can be affected. As a result, the sound absorption coefficient declines. Meanwhile, high-frequency sound absorption is mainly conducted on the surface, so the high-frequency sound absorption coefficient will not change much. Sound absorbing materials have an optimum scope of fiber content. In this test, the best comprehensive performance can be gained when the polypropylene fiber content is 0.50%.

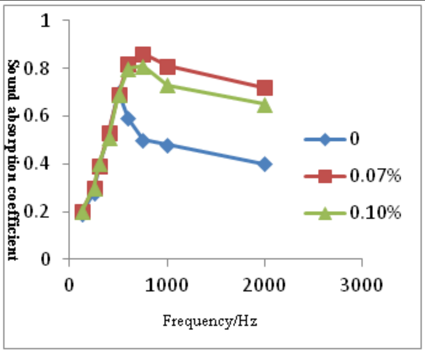

Figure 5. Influence of fiber content on the sound absorption coefficient of materials

3.5. Influence of dorsal cavity on sound absorption property

By setting the cavity with a certain thickness behind the material, the sound absorption property in the low-frequency band can be improved. The sound absorption coefficient of sound absorbing materials is decided by acoustic impedance which includes acoustic resistance and acoustic reactance. Loss and sound absorption of materials is decided by acoustic resistance which won't be affected by frequency. However, acoustic reactance presents a function relationship with frequency, so it will influence frequency characteristics of materials. If the ratio between acoustic resistance and acoustic reactance is great, the frequency selectivity of materials will be strong. On the contrary, if the ratio is small, the selectivity will be weak. In the low-frequency band, frequency selectivity depends on the elasticity of materials. Therefore, low-frequency absorption can be improved by increasing the material thickness and cavity. In this way, the internal structure of materials will not change, so the average sound absorption coefficient of materials does not increase.

Fig. 6 is the changing curve about the sound absorption coefficient of materials with dorsal cavity thickness. According to the figure, with the increase of dorsal cavity, the low-frequency sound absorption property will be improved gradually and the resonance sound absorption peak moves toward the low-frequency end. When the dorsal cavity thickness is 3cm, 5cm and 7cm, the average sound absorption coefficient of materials is 0.60, 0.61 and 0.59respectively. In another word, the average sound absorption coefficient of materials almost remains unchanged, which accords with the sound absorption mechanism. Therefore, frequency characteristics of sound absorbing materials can be changed on the premise of not adding the material thickness, i.e. the material cost by changing the dorsal cavity.

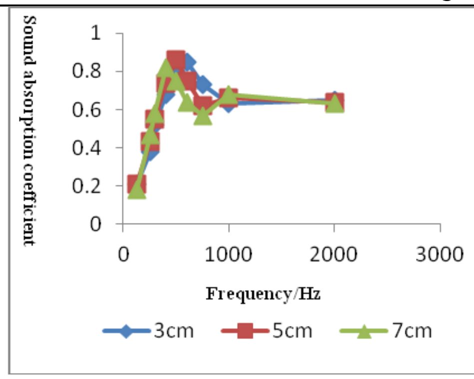

Figure 6. Influence of cavity resonance structure on the sound absorption coefficient of materials

3.6. Influence of hydrophobic treatment on sound absorption property

According to Fig. 7, after hydrophobic treatment, the average sound absorption coefficient of materials under dry state decreases by 20.7%. Especially in the high-frequency band, the sound absorption coefficient drops obviously. However, materials after soaking have a higher average sound absorption coefficient than untreated materials (Fig. 8). As for the reason, after hydrophobic treatment, water absorption of materials decreases substantially and water entering the pore reduces. Meanwhile, the damage degree of pore structure is reduced.

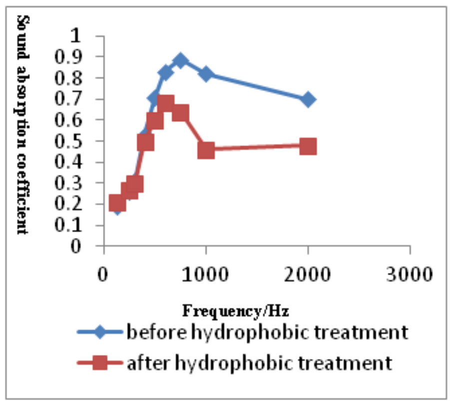

Figure 7. Sound absorption property of materials after hydrophobic treatment under dry state

4. Conclusions

Foam content has an obvious influence on the sound absorption property of test-piece, but higher foam content does not necessarily mean better comprehensive performance. Foam content should be determined by comprehensively considering factors in two aspects covering mechanical properties and acoustic properties of the material.

When the air entraining agent dosage is 0.07%, the maximum average sound absorption coefficient can be reached, and the sound absorption coefficient does not increase with the rise of air entraining agent dosage. If the air entraining agent dosage is excessive, bubble combination phenomenon inside the material will be aggravated, the diameter of interpenetrated pores will be too large, and the sound absorption property can be reduced.

Compared with the internal pores of cement – expanded perlite system and cement – ceramsite system, the internal pores of cement-based sound absorbing material are fine and distributed evenly. The average sound absorption coefficient is 0.59 and even reaches 0.42 in the low-frequency band of 500Hz. Therefore, its sound absorption property is excellent.

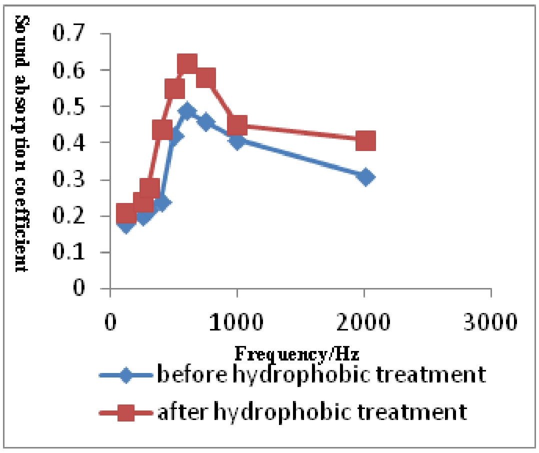

Figure 8. Sound absorption property of materials after hydrophobic treatment under wet state

By adding polypropylene fiber, the sound absorption property of samples can be improved. It has an optimum value. When the dosage reaches the optimum value, the best sound absorption property can be gained.

It is an effective means of improving the low-frequency sound absorption coefficient to increase the dorsal cavity thickness of materials, but the average sound absorption coefficient of materials will not increase.

Hydrophobic treatment for the material surface can obviously increase the material stability under wet environment.

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