Experimental Study on Sound Absorption Performance of a New Inorganic Sound-absorbing Material

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Abstract. A new inorganic sound-absorbing material is proposed with the background of the subways reduce the noise pollution by grouting behind the track wall. By using the standing wave tube method, we investigate the sound absorption coefficients of this new inorganic sound-absorbing material with water cement ratios of 3.0, 4.0, 5.0 and 6.0. The results show that: when the water cement ratio is 5.0 and the frequency is 1250Hz, the sound absorption coefficient reaches 0.53; when the water-cement ratios are 6.0 and 4.0 and the frequency is 3150Hz, the sound absorption coefficients also reach more than 0.5. The average sound absorption coefficient and noise reduction coefficient of the new inorganic sound-absorbing material reach more than 0.2 in the frequency range of 20-4000Hz. This material has sound absorption performance and the best sound absorption effect is achieved when the water-water ratio is 4.0.

Keywords: Inorganic sound-absorbing material, Standing wave tube method, Sound absorption coefficient, noise reduction coefficient.

1 Introduction

While the rise of urban subway and rail transit brings convenience to people, noise pollution occurs accordingly. Noise pollution, as one of the four major environmental pollution in the world, poses a serious threat to the life of buildings, people's physical health and mental state[1].The use of cement-based porous sound-absorbing materials is an effective way to control noise pollution. Foreign scholars [2-5] have prepared porous sound-absorbing materials by using Portland cement and other materials, and the average sound absorption coefficient can reach 0.6. They studied the sound absorption performance of cement-based sound absorption materials under different

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structures, different admixtures and other factors[6-8], the sound absorption coefficient can be up to 0.8. In this paper, the noise pollution caused by subway traffic is solved by post-wall grouting, but the traditional cement-based porous sound-absorbing materials are not suitable for it. Utilizing the sound absorption performance of cement-based sound-absorbing materials, domestic scholars[9-15] have prepared porous sound-absorbing materials, the average sound absorption coefficient can also reach 0.6. Although domestic scholars started late on the sound absorption performance of cement-based sound-absorbing materials, they[16-18] have also made considerable achievements. Therefore, in this paper, a new inorganic sound-absorbing material is proposed, and the sound absorption performance of this material with different water-cement ratios is studied through experiments.

2 Composition analysis of the new inorganic sound-absorbing material

The new inorganic sound-absorbing material is a new type of hydraulic binding material, which is mainly composed of A material and B material. A material is composed of sulphoaluminate cement and additive TA, and B material is composed of gypsum, lime and additive TB. In this experiment, additive TB is composed of 1 # small material and 2 # small material, as shown in Figure 1.

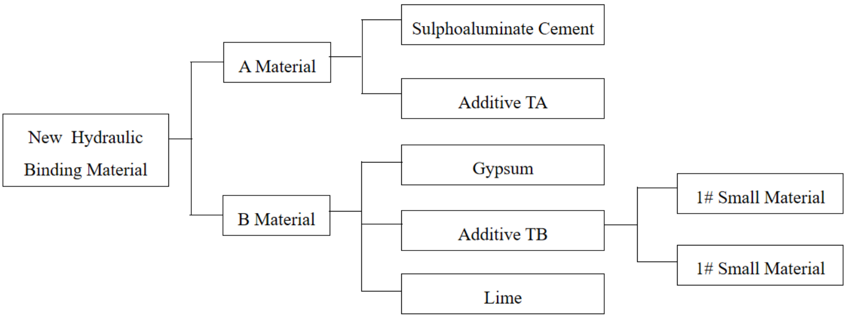

Fig. 1. Constitutional diagram of the new hydraulic binding material

In the new hydraulic binding material, the mass ratio of sulphoaluminate cement and additive TA in A material is 100:30, and the mass ratio of gypsum, lime and additive TB in B material is 100:25:5, where 1 # small material accounts for 4% of the gypsum quality, and 2 # small material accounts for 1%.

(1) Sulphoaluminate cement

As the main component of the new inorganic sound-absorbing material, sulphoaluminate cement will have physical and chemical reaction mixed with water, which effectively promotes the condensation and hardening of the new hydraulic binding material and improves the compressive strength of the new hydraulic binding material. Its main components are shown in Table 1.

Table 1. Chemical composition of sulphoaluminate cement

Sample	Chemical composition /%								
	CaO	Al_2O_3	SiO_2	SO_2	Fe_2O_3	Ti_2O	MgO	K_2O	P_2O_5
Con-tent	41.51	40.05	6.53	7.16	1.55	1.69	0.79	0.61	0.10

(2) Gypsum

The fast dissolution rate of gypsum in the new hydraulic binding material can effectively reduce the material's condensation time, accelerate the hardening speed , and provide early strength for the binding material. Gypsum will produce micro-expansion when the binding material condenses and hardens, which can reduce the dry shrinkage deformation of the binding material. At the same time, gypsum can improve the corrosion resistance of the binding material, and provide enough calcium sulfate for the hydration of calcium sulphoaluminate to produce ettringite. The gypsum used in this experiment is dihydrate gypsum (CaSO4.2H2O), and its main components are detailed in Table 2.

Table 2. Chemical composition of gypsum

Sample	Chemical composition /%						
	CaO	Al_2O_3	SiO_2	SO_2	Fe_2O_3	MgO	K_2O
Content	46.61	0.20	1.30	48.34	0.04	3.46	0.05

(3) Lime

The lime used in this test is quicklime, and its main component is CaO. As an alkaline oxide, quicklime at room temperature reacts chemically with reactive oxides (silicon oxide, alumina, etc.)in the clinker of sulphoaluminate cement to generate hydraulic hydration productshydrated calcium silicate and hydrated calcium sulphoaluminate, which promote the generation of ettringite. The main chemical components of the quicklime used in this paper are detailed in Table 3.

Table 3. Chemical composition of lime

Sample	Chemical composition /%							
	CaO	Al_2O_3	SiO_2	SO_2	Fe_2O_3	MgO	K_2O	Na_2O
Content	97.69	0.32	0.51	0.38	0.23	0.76	0.04	0.07

(4) Additives

The additives used in this experiment are developed independently after years of repeated tests, mainly divided into two kinds. One is additive TA, whose main components are suspending agent, retarder and dispersant; the other additive TB is mainly composed of 1 # small material and 2 # small material according to 4% and 1% of the gypsum mass respectively, and the main components are suspending agent ,quick setting and early strength agent, 1 # and 2 # are shown in Figure 2 and Figure 3.

Fig. 2. 1 # small material

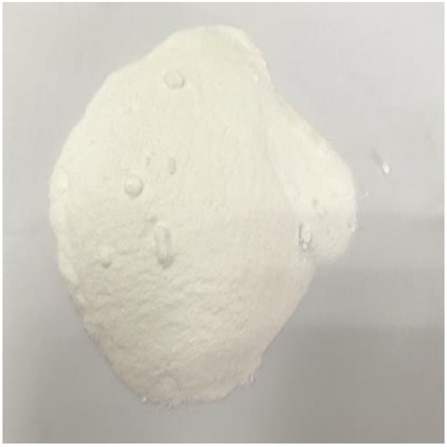

Fig. 3. 2 # small material

The use of additives TA and TB makes the new hydraulic binding material condense and harden under high water-cement ratios, and the setting time is controllable, which provides the necessary conditions for the formation of the new inorganic sound-absorbing material.

3 Fabrication of the new inorganic sound-absorbing material specimens

This paper investigates the sound absorption performance of the new inorganic sound absorbing materials with high water-cement ratios, the material ratios are shown in Table 4.

Table 4. The ratios of the new inorganic sound-absorbing materials

Number	A material / g			Aadmixture		B material / g					Admixture	
	cement	TA	water	F/g	Z/%	Gypsum	lime	2#	1#	water	F/g	Z/%
C6.0	100	30	780	0.39	30%	100	25	4	1	780	0.39	30%
C5.0	100	30	650	0.39	30%	100	25	4	1	650	0.39	30%
C4.0	150	45	780	0.59	30%	150	37.5	6	1.5	780	0.59	30%
C3.0	200	20	660	0.66	30%	200	30	8	2	660	0.66	30%

Note: The letter C in the table is the water-cement ratio, and the value after C is the size of the water-cement ratio; The letter F indicates the cement foaming agent; The letter Z denotes expanded perlite; Percentages represent volume percentages.

According to the frequency range of the noise wave in the research background and the basic requirements of the standing wave tube absorption coefficient test system for sound-absorbing specimens, the specimens with a height of 30mm, 60mm, 90mm and 120mm were fabricated, as shown in Figure 4 and Figure 5.

4 Study on the sound absorption performances of the new inorganic sound-absorbing material

Test the sound absorption performance of materials according to the requirements of GBJ 88-85 “Specification for Measuring Sound Absorption Coefficient and Acoustic Impedance Rate of Standing Wave Tube Method”. The sound absorption coefficients of the new inorganic sound- absorbing material at different frequencies are shown in Table 5.

Fig. 4. binding material

Fig. 5. sound-absorbing specimen

Table 5. Test results of sound absorption coefficient

Test block number / Frequency /Hz	C6.0	C5.0	C4.0	C3.0
200	0.10	0.08	0.08	0.09
250	0.10	0.08	0.08	0.09
315	0.10	0.11	0.10	0.11
400	0.13	0.12	0.11	0.11
500	0.13	0.13	0.16	0.13
630	0.18	0.17	0.20	0.17
800	0.24	0.23	0.35	0.20
1000	0.45	0.42	0.37	0.32
1250	0.31	0.53	0.23	0.37
1600	0.31	0.24	0.31	0.29
2000	0.30	0.26	0.34	0.23
2500	0.30	0.35	0.43	0.34
3150	0.50	0.53	0.53	0.51
4000	0.39	0.45	0.43	0.36
Average sound absorption coefficient α	0.25	0.26	0.27	0.24
Noise reduction coefficient, NRC	0.27	0.27	0.28	0.23

According to the data analysis in Table 5, when the frequencies are less than 630Hz, the sound absorption coefficients of sound-absorbing materials are less than 0.2, but when the frequencies are greater than 630Hz, the absorption coefficients of sound-absorbing materials are greater than 0.2, which shows that the new inorganic sound-absorbing material studied in this paper has poor sound absorption effect on low frequency noise, but has good effect on medium frequency noise. For the sound-absorbing specimen with a water-cement ratio of 5.0, the sound absorption coefficient can reach 0.53 when the frequency is 1250Hz, for the sound-absorbing specimens with water-cement ratios of 6.0 and 4.0, the sound absorption coefficients also reach 0.50 and 053 when the frequency is 3150Hz, respectively.

In order to study the relationship between the sound absorption coefficients and the frequencies of the new inorganic sound-absorbing material, the relationship curves of the sound absorption coefficients with frequencies of the new inorganic sound-absorbing material under different water-cement ratios are shown in Figure 6.

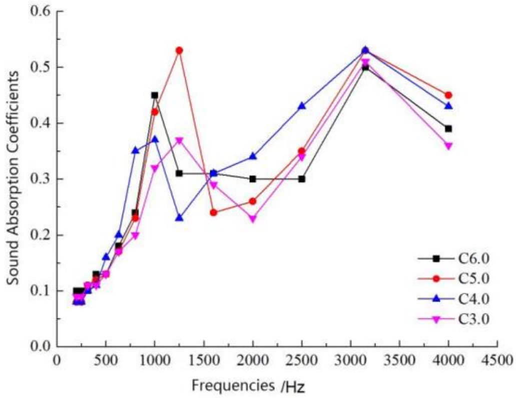

Fig. 6. Curves between sound absorption coefficients and frequencies

As can be seen from Figure 6, the sound absorption coefficients change in wave with the increase of frequencies, and the change trends are basically the same, with peaks at around 1000Hz and 3150Hz. In the medium frequency band, the sound absorption coefficients are generally more ideal, but in the low frequency band, the difference in the sound absorption coefficients is not significant. This is because the low frequency sound waves have high energy, strong penetration ability. When sound waves through the sound-absorbing material, loss of sound energy is small. And medium frequency sound waves have low energy is low, weak penetration ability. When sound waves through the material, they encounter pores constantly reflected, and constantly collide and friction with the pore walls, making the consumption of sound energy larger. Although the sound absorption performance of the new inorganic sound-absorbing material is poor in the low frequency band and in the middle frequency band is good, the sound absorption performance of the new inorganic sound-absorbing material cannot be comprehensively evaluated. Therefore, the average sound absorption coefficients and the noise reduction coefficients of the new inorganic sound-absorbing material under different water-cement ratios are analyzed, as shown in Figure 7.

Figure 7 shows the relationship curves between the water-cement ratios and the average sound absorption coefficients and noise reduction coefficients of the new inorganic sound-absorbing material. It can be seen from Figure 7 that the average sound absorption coefficients and noise reduction coefficients of the new inorganic sound absorption material are both greater than 0.2, indicating that the new inorganic sound-absorbing material has the sound absorption function and belongs to the sound-absorbing material. With the increase of water-cement ratios, the average sound absorption coefficients and noise reduction coefficients of the new inorganic sound-absorbing material both increase first and then decrease. It indicates that the size of water-cement ratios have certain influence on the sound absorption performance of the sound-absorbing material. And the noise reduction coefficients at the water-cement ratios of 3.0,4.0,5.0 and 6.0 are 0.23,0.28,0.27 and 0.27, respectively, the average sound absorption coefficients are 0.24,0.27,0.26, and 0.25. It can be seen that, when the water-cement ratio is 4.0, the average sound absorption coefficient and the noise reduction coefficient both achieve the maximum value of 0.27 and 0.28, respectively. Therefore, it is initially determined that the new inorganic sound-absorbing material have the best sound absorption performance when the water-cement ratio is 4.0.

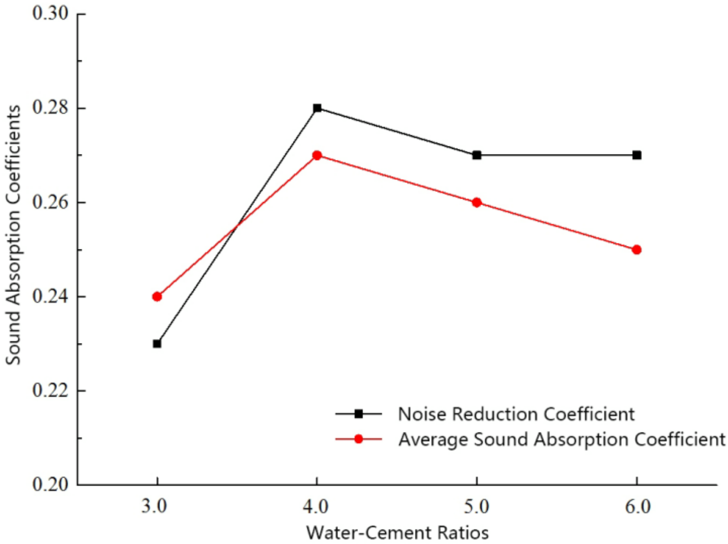

Fig. 7. Curves of sound absorption coefficients and water-cement ratios

5 Conclusion

(1) When the water-cement ratio is 5.0 and the frequency is 1250Hz, the sound absorption coefficient reaches 0.53; the sound absorption coefficients also reaches more than 0.5 when the water-cement ratios are 6.0 and 4.0 and the frequency is 3150 Hz.

(2) When the frequency is in the range of 20-4000Hz, the average sound absorption coefficient and noise reduction coefficient of the new inorganic sound-absorbing material reach more than 0.2. The material has sound absorption performance, and the sound absorption effect is the best when the water-water ratio is 4.0.

Acknowledgments

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