# Zeolite powder in Epdm rubber: Sound absorption effects

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**Abstract:** In order to enhance the sound absorption performance of ethylene-propylene-diene monomer (EPDM) rubber and develop a lightweight, cost-effective composite material with good sound absorption properties, especially in the low-frequency range, EPDM rubber was used as the matrix and zeolite powder (MS)as the filler. Porous sound-absorbing composite materials were prepared through mixing in a mixer and hot pressing in a vulcanizing machine, and their sound absorption properties were tested. By varying the content of MS, the thickness of the composite material, and the distance of the rear cavity, the sound absorption performance of the EPDM/MS porous sound-absorbing material was tested using an SW230 impedance tube. The experimental results showed that the sound absorption performance of the composite material improved with the increase of MS content. When the MS content was 20%and the sample thickness was 4 mm, the sound absorption coefficient of the composite material at 2500 Hz reached 0.65. When a certain thickness of cavity was placed behind the composite material, the sound absorption peak occurred only within specific frequency ranges. The experimental results indicate that the EPDM/MS porous sound-absorbing material has good sound absorption properties.

**Keywords:** Zeolite powder, Sound absorption coefficient, Rear cavity

## 1. Introduction

To enhance the sound absorption performance of sound-absorbing materials, they are often designed as porous materials. In recent years, sound-absorbing materials such as perforated panels, metal foam materials, and fibrous materials have been widely used. After lamination, preheating, and thermal mixing, porous laminated composite materials exhibit good sound absorption in the frequency range of 500–2000 Hz[1].Sound-absorbing materials made from recycled polyolefin packaging aluminum foil, expanded polystyrene, and coconut shell fiber through a two-stage compression molding method have better sound absorption performance than glass fiber[2].Nonwoven fabric laminated with aromatic polyamide layers obtained sound-absorbing materials with better sound absorption performance than glass fiber at 2000 Hz[3].Sintered aluminum fiber with a relative density of 0.6 g/cm³ and a thickness of 10 mm has an average sound absorption coefficient of 0.7 in the frequency range of 800–2000 Hz[4].Perforated panels with open-pore microstructures exhibit good sound absorption performance over a wide range of frequencies, but their mechanical properties have been less studied[5,6].Porous metal materials have excellent properties in terms of strength, thermal conductivity, heat absorption, and electromagnetic shielding, but their performance at low frequencies is poor, and they are expensive and difficult to process[7,8].Therefore, to improve the overall performance of materials, it is necessary to incorporate viscoelastic polymers into sound-absorbing materials.

Rubber, due to its excellent viscoelastic properties, is widely used in sound-absorbing materials. When sound waves are transmitted to rubber, the viscoelasticity in the glass transition region of rubber is utilized to dissipate energy, thus giving rubber good damping properties [9,10].

In this study, a multifunctional, lightweight, porous sound-absorbing material with good sound absorption performance, especially at low frequencies, was developed using EPDM as the matrix and

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zeolite powder as the filler. The sound absorption performance of the composite material and its influencing factors were also investigated.

## 2. Experimental section

### 2.1. Preparation of sound-absorbing composite materials

The EPDM used in this study was provided by Shanghai Guang jiao Co., Ltd. Zeolite powder, which has a pore and cavity system with molecular dimensions (typically 0.3–2.0 nm), possesses unique properties such as molecular sieving, adsorption, catalysis, ion exchange, ion selectivity, acid resistance, thermal stability, multi-component nature, high biological activity, and detoxification capabilities. The zeolite powder used here is of Grade 5, supplied by Ping Xiang, Jiangxi. The framework structure of the zeolite powder is shown in Figure 1.

After mixing the EPDM on a two-roll mill (SK-160B) at a temperature of 60°C for 10 minutes, zeolite powder was added and the mixing continued for an additional 40 minutes. Once the zeolite powder was uniformly distributed in the rubber, the EPDM-zeolite mixture was hot-pressed at a temperature of 160°C and a pressure of 10 MPa for 3 minutes to produce samples with thicknesses of 1 mm,2 mm,3 mm, and 4 mm, respectively.

Figure 1 Framework structure of zeolite powder

### 2.2. Acoustic performance testing

In accordance with the requirements of ISO 10534-2, the experiment employed the SW230 impedance tube from Beijing Soun don Company, as shown in Figure 2, to measure the sound absorption coefficient of the composite material at frequencies ranging from 100 to 2500 Hz.

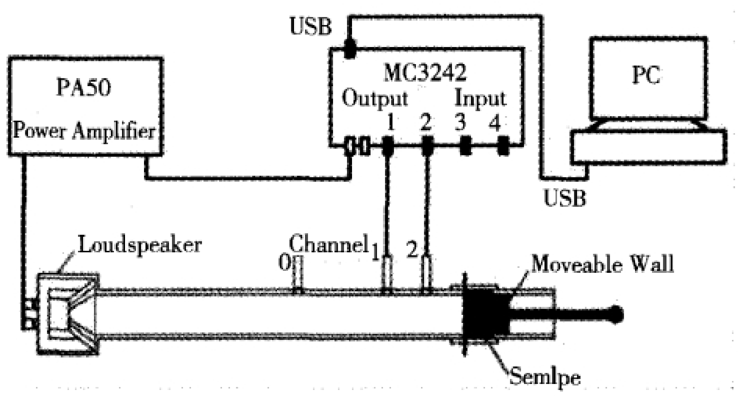


Figure 2 Schematic diagram of the SW230 impedance tube installation for sound absorption testing

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### 2.3. Mechanical performance testing

An HD026NE electronic fabric strength tester from Nantong Hong da Experimental Instrument Co., Ltd. was used to conduct the tests in accordance with the requirements of GB/T 528-92. Specimens were cut into dumbbell shapes using a mold, with a length of 115 mm, a width of 25 mm at the widest point, and a width of 6 mm at the narrowest point. The initial gauge length was 25 mm, and the tensile rate was set at 500 mm/min.

### 2.4. Scanning electron microscopy (SEM)analysis

The surface morphology and structure of the specimens were observed using a JSM-5600LV scanning electron microscope (SEM)produced by JEOL, Japan.

## 3. Experimental results and analysis

### 3.1. Influence of zeolite powder content on sound absorption coefficient

Figure 3 shows the effect of zeolite powder content (MS)on the sound absorption coefficient. As indicated in Figure 3, the sound absorption coefficient of the composite material increases with the addition of zeolite powder. The sound absorption coefficient of pure EPDM is below 0.20 in the frequency range of 100–2500 Hz. However, after the addition of zeolite powder, the sound absorption coefficient of the composite material increases significantly, with values in the low-frequency range (100–500 Hz) reaching 0.02–0.28 and in the mid-frequency range (500–2500 Hz) reaching 0.28–0.45. This improvement is attributed to the formation of uniform cavities within the composite material as the zeolite powder content increases. These cavities cause the incident sound waves to resonate and effectively increase the material's thickness, thereby reducing the transmission of sound wave energy. Additionally, the viscous internal friction between the zeolite powder particles and between the zeolite powder and rubber converts sound energy into heat, which is dissipated. Furthermore, the presence of zeolite powder creates air layers within the matrix material. The movement of air within these layers rapidly converts sound energy into heat, enhancing the sound absorption effect and increasing the sound absorption coefficient.

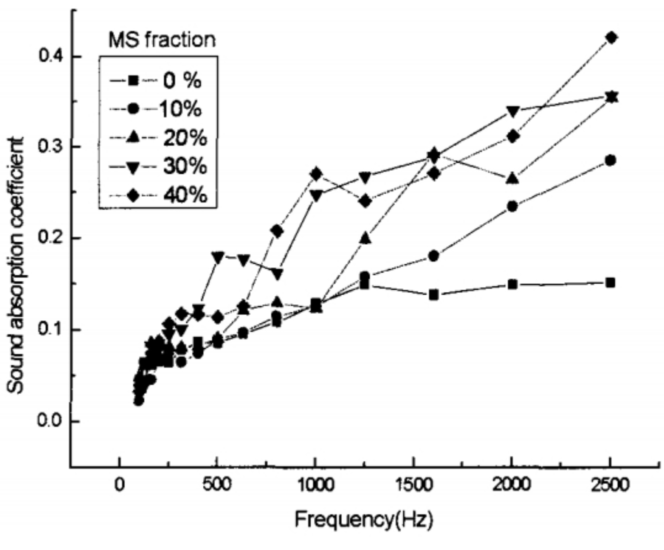


Figure 3 Effect of MS content on sound absorption coefficient

Figure 4 shows the effect of MS content on the sound absorption peak. As indicated in Figure 4, there is a certain relationship between the sound absorption peak of the sound-absorbing material and the content of zeolite powder in the material. When the content of zeolite powder is low (below 20%), the composite material has fewer cavities, resulting in a lower sound absorption peak. As the content of zeolite powder increases, the sound absorption performance of the material in the low-frequency range is enhanced when the zeolite powder content in the composite material exceeds 30%. This is because the increase in the

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number of cavities in the material forms a network-like structure, increasing the internal surface area of the material. This enhances the contact with sound waves, causing the incident sound waves to be attenuated more quickly within the material, thereby increasing the internal energy dissipation and improving the sound absorption peak.

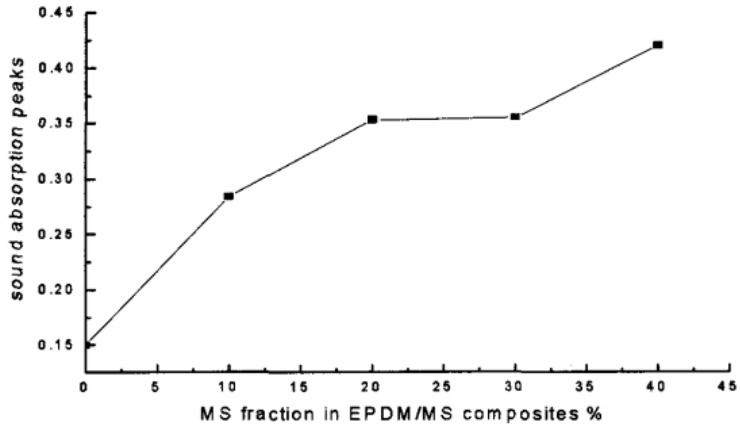


Figure 4 Effect of MS content on the sound absorption peak

### 3.2. Influence of sound-absorbing material thickness on sound absorption performance

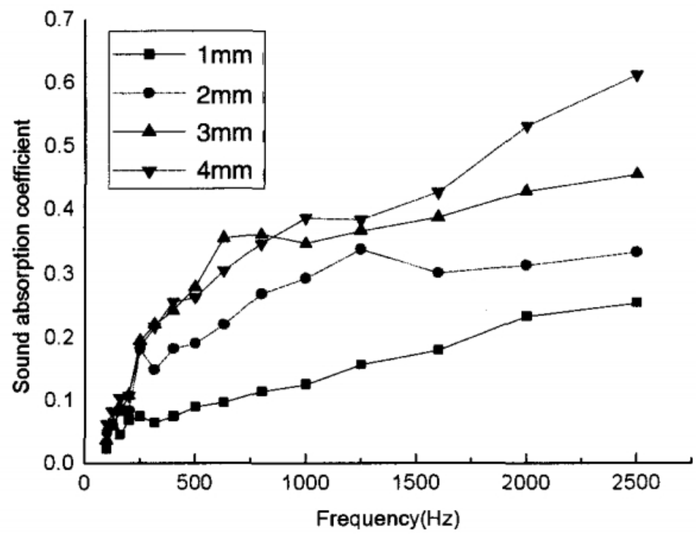


Figure 5 Effect of thickness on the sound absorption performance of the composite material

Figure 5 shows the effect of thickness on the sound absorption performance of the composite material when the MS content is 30%. As indicated in Figure 5, when the MS content is 30%, the sound absorption coefficient of the sample increases with the increase in thickness. When the thicknesses are 1 mm,2 mm,3 mm, and 4 mm, the sound absorption coefficients of the composite material vary little in the frequency range of 100–450 Hz. This is because at low frequencies, the vibration amplitudes of the air inside the material and the material matrix are small, and only a small amount of sound energy is converted into heat and dissipated, resulting in a low measured sound absorption coefficient.

In the frequency range of 450–2500 Hz, as the sample thickness increases from 2 mm to 3 mm and 4 mm, the sound absorption coefficient of the material increases rapidly, and distinct peaks appear. The sound absorption curves of the samples with thicknesses of 2 mm,3 mm, and 4 mm show similar trends. According

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to the porous sound absorption mechanism and Rayleigh's sound absorption model, increasing the thickness of the material can increase the material's acoustic impedance and the propagation distance of sound waves within the material, thereby enhancing the sound absorption performance. This may be because the motion speed of the polymer molecular segments in the composite material is close to the material's resonant frequency, making the viscoelastic losses of the large molecules more pronounced and resulting in sound absorption peaks.

Additionally, as the material thickness increases, the propagation distance of sound waves within the material is extended, allowing more cavities within the sample to participate in the sound absorption process and thus improving the material's sound absorption performance. Therefore, increasing the thickness of the material can enhance the sound absorption effect of the sound-absorbing material in the low-frequency range.

### 3.3. Influence of rear cavity on sound absorption performance

During the application of porous sound-absorbing materials, there is often an air layer (rear cavity) between the material and the rigid wall. In the experiment, a rear cavity was added to the back of a 3 mm thick EPDM/MS composite material. The effect of the depth of the rear cavity on sound absorption performance is shown in Figure 6. As indicated in Figure 6, when the rear cavity increases from 0 mm to 10 mm, the average sound absorption coefficient of the composite material increases by 74.6%, and the sound absorption peak shifts from 0.42 at 2500 Hz to 0.74 at 1000 Hz. When the cavity thickness reaches 50 mm, the sound absorption peak is 0.76 at 480 Hz. As the cavity thickness increases, the sound absorption peak gradually shifts towards lower frequencies, while the sound absorption performance in the mid-and high-frequency ranges decreases.

This phenomenon occurs because, under the influence of sound waves, the composite material undergoes bending deformation, which alters the air density within the cavity and leads to energy conversion and dissipation. Additionally, resonance between the material and the air in the rear cavity at certain specific frequencies results in energy consumption. Moreover, the combination of the composite material and the rear cavity forms a sound-absorbing structure, which enhances the sound absorption effect of the fibrous material across a broad frequency range, particularly in the low-frequency range.

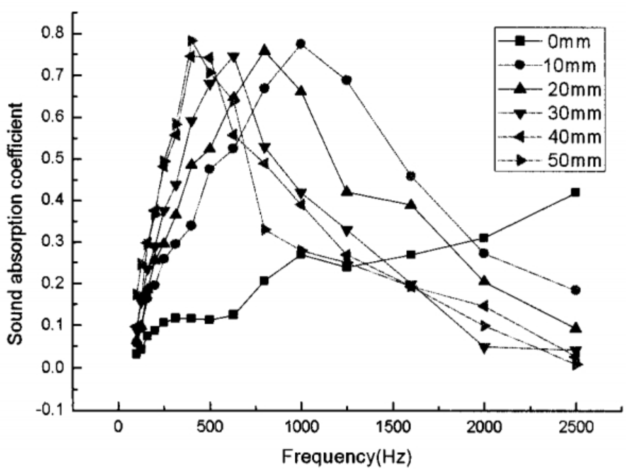


Figure 6 Effect of rear cavity depth on sound absorption performance

### 3.4. 3Zeolite powder's impact on composite strength

Figure 7 shows the effect of MS content on the tensile properties of the composite material. As indicated in Figure 7, the mechanical properties of the composite material improve with the increase in MS content. Pure EPDM is a completely elastic material. When the MS content is 10%, the elongation at break of the composite material decreases, while the tensile stress increases by 78%. When the MS content exceeds 20%, the tensile stress of the composite material increases rapidly, almost linearly with the MS content, while the

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elongation at break decreases sharply. This is because MS restricts the movement of the EPDM polymer chains, reducing the elasticity of the composite material. At the same time, MS balances the internal stress of the rubber, allowing the polymer chains to effectively bear external stress, thereby increasing the tensile strength of the composite material.

The addition of MS enhances the strength of the composite material and improves its mechanical properties, providing mechanical assurance for the application of EPDM/MS composites.

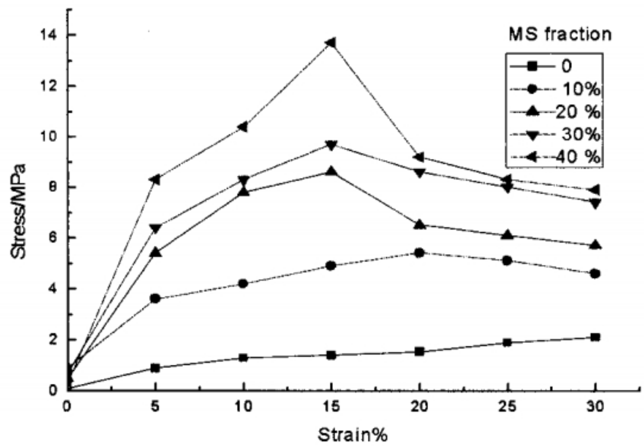


Figure 7 Effect of MS content on the tensile properties of the composite material

## 4. Conclusions

The content of zeolite powder, the thickness of the composite material, and the depth of the rear cavity all have certain effects on the sound absorption performance of the material.

When the content of zeolite powder is 40%and the thickness is 1 mm, the sound absorption coefficient at 2500 Hz is 0.45.

When the thickness of the material is increased to 4 mm and the content of zeolite powder is 20%, the sound absorption coefficient of the composite material at 2500 Hz is 0.65.

The addition of a rear cavity behind the composite material can enhance the sound absorption coefficient at specific frequencies.

The incorporation of MS improves the tensile strength of the composite material, providing mechanical assurance for its engineering applications.

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