Effect of Emulsion Powder Content in VAE Emulsion on Tensile Properties of Joint Filler

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Abstract: The traditional joint filler used in our country is easy to be damaged by the environment. At present, polymer composite is used to form a new type of polymer joint filler (NPJF) to improve the properties of joint filler. In this paper, by comparing and testing the various indexes of the joint filler under tensile load under the condition of 5 kinds of latex powder content, the performance of the joint filler after molding was studied. The results show that the tensile strength and tensile modulus of the joint filler increase with the increase of latex powder content, the elongation at break and peak strain decrease first and then increase. The influence of the amount of latex powder on the tensile properties of the joint filler mainly lies in the improvement of the aggregate ash ratio, the formation of the film structure and the change of the overall microstructure.

1 Preface
In the design and actual construction of cement concrete pavement, a large number of road gaps are usually set to prevent the concrete pavement from shrinkage and expansion and forming cracks due to ambient temperature, humidity and use[1][2].

The traditional joint filler has poor environmental adaptability, weak abrasion resistance and poor durability, and the concrete pavement is easily affected by the environment and use to form shrinkage and expansion, which puts forward high requirements for the deformation performance of joint filler. Because the polymer material has good durability, strong bonding property, strong deformation property, excellent waterproof property, low cost and environmental protection, and can be hydrated with cement and mutually react to form a polymer film, the new polymer joint filler obtained by the combination of organic polymer and cement has more excellent bonding property, flexibility, durability, corrosion resistance and environmental adaptability. Through reasonable material selection and improved design, the new polymer joint filler can overcome the problems existing in the use of traditional joint filler, and is more suitable for practical application, with a broad development prospect.

VAE emulsion powder[3][4] is a linear macromolecule material. When mixed with cement-based joint filler, VAE emulsion will be formed quickly in case of water. With the progress of cement hydration reaction, VAE emulsion particles interact with cement to improve the performance of joint filler. Therefore, it is of great significance to study the effect of VAE emulsion powder on the...
performance of cement pavement joint filler. Liu Jiawei\cite{5} and others prepared a modified cement-based anti-rust coating by adding VAE emulsion, and studied the bonding performance of modified coating through grip-wrapping test and salt spray test. Sakai et al.\cite{6} studied the effect of EVA latex powder on the mechanical properties and microstructure of cement mortar, and proved that the membrane structure and particle size effect of polymer formation can change the strength and deformation properties of mortar. Nong Jinlong et al.\cite{7} prepared a variety of polymer emulsion (rubber powder) modified adhesive mortar, and through oblique shear, direct shear, bending and axial tensile tests, focusing on the study of different curing system, age, bonding method, bonding substrate and other factors on the styrene-butadiene emulsion modified adhesive mortar law and action mechanism.

Based on this, the tensile test of polymer joint filler with different amount of VAE emulsion powder was carried out in this paper. The effects of VAE emulsion powder on the tensile properties of polymer joint filler were studied with strength, modulus, elongation at break, peak strain as indexes, and the mechanism analysis of the effects of VAE emulsion powder on the properties of polymer joint filler was carried out\cite{8}.

## 2 Specimen preparation and test design

### 2.1 Specimen preparation

The test pieces in this study have cement mortar base materials on both sides, the middle is connected by wooden blocks, and the bottom is supported by glass. Cement mortar base material shall be prepared according to the Technical Specification for Construction of Cement Concrete Pavement Joint Material in Airport Yard (GJB6951-2010).

In this test, five groups of contrast experiments are arranged to control the amount of latex powder. The latex powder is added in the form of powder. Each raw material is prepared as shown in Table 1. It is prepared according to the dosage of emulsion powder of 0, 2.5, 5, 7.5 and 10 grams, and it is marked as J1, J2, J3, J4 and J5. The emulsion powder adopts 5044N vinyl acetate/ethylene copolymer emulsion powder produced by WACKER, Germany. See Table 2 for technical indexes.

| Test No. | Proportioning parameters | VAE Emulsion | Quartz Powder | P·O 42.5 Cement | Latex powder | SN-5040 Dispersant | SN-345 Defoamer | DN-12 Film forming aid |
|----------|--------------------------|---------------|----------------|-----------------|--------------|------------------|------------------|-----------------------|
| J1(DZ)   | 0                        | 100           | 29.2           | 15.8            | 0            | 1.02             | 0.73             | 6                     |
| J2       | 2.50%                    | 100           | 29.2           | 15.8            | 2.5          | 1.02             | 0.73             | 6                     |
| J3       | 5.00%                    | 100           | 29.2           | 15.8            | 5            | 1.02             | 0.73             | 6                     |
| J4       | 7.50%                    | 100           | 29.2           | 15.8            | 7.5          | 1.02             | 0.73             | 6                     |
| J5       | 10.00%                   | 100           | 29.2           | 15.8            | 10           | 1.02             | 0.73             | 6                     |

Note: the amount of latex powder is the percentage of the mass of latex powder to the mass of emulsion.
Table 2 Technical Indexes of Latex Powder

| Appearance       | Solid content | Ash content | Stable System    | Particle size | Water Solubility | Corresponding emulsion Tg | Corresponding emulsion MFT |
|------------------|---------------|-------------|------------------|---------------|------------------|---------------------------|----------------------------|
| White Powder     | 99±1%         | 10±2%       | Polyethylene Enol| 400μM         | ≤4%              | 5%                        | 0°C                        |
|                  |               |             | Sieve residue    | 0°C           |                  | 0°C                       |                            |

The preparation steps of the test piece are as follows: firstly, add dispersant, film forming aid and half part of defoamer respectively to the emulsion and use the mixer to stir evenly, then add the fully mixed cement, talcum powder and latex powder into the emulsion and keep stirring at high speed for 10 min, add another half part of defoamer and keep stirring at low speed. After the mixture is mixed evenly, use a glass rod for manual mixing to reduce air bubbles, and use a syringe to extract the mixture for pouring between cement-based materials. In order to ensure that the specimen surface is flush with the upper surface of the base material and cushion block after the specimen is cured and dried, the joint filler shall be slightly higher than the base material and cushion block during pouring. And then carry out the next test. Refer to Fig.1 for standard joint filler and Fig.2 for specific dimensions after forming the test piece.

2.2 Tensile performance test design

In this study, HS-3001B electronic tensile testing machine was used for tensile test. The clamping device applied tensile force to bonding material through cement mortar base materials on both sides, as shown in Fig.3 and Fig.4. The test piece was stretched at a loading rate of 5mm/min under standard conditions until the test piece was destroyed. The force and displacement data were recorded. Each group tested 3 test pieces, and the test results were taken as the average value of 3 groups of data.

The effects of different amount of latex powder on the tensile properties of the fully molded NPJF specimens were studied. The tensile properties of the NPJF specimens after 28 days curing under standard conditions were tested. The tensile properties of the joint materials were analyzed by four properties indexes, namely tensile strength, tensile modulus, tensile elongation at break, tensile peak strain.
3 Analysis of test results

3.1 Analysis of tensile test results

The tensile strength index mainly refers to the tensile strength and tensile modulus. The tensile strength refers to the tensile peak stress, which reflects the maximum stress that the material can bear under the tensile action. The tensile modulus refers to the stress value corresponding to the material specimen under the tensile action when it reaches 60% of the original specimen width, which reflects the ability of NPJF to resist deformation. The above figure reflects the influence of the amount of emulsion powder on the tensile strength and tensile modulus.

It can be seen from the figure that the tensile strength and tensile modulus have obvious positive correlation with the amount of latex powder, and the similarity between the two figures is relatively high. When the amount of latex powder increases from 0% to 2.5%, the tensile strength and tensile modulus increase rapidly, with the growth rate of 18.8% and 18.7% respectively; when the amount of latex powder increases from 2.5% to 10.0%, the growth rate of tensile strength and tensile modulus obviously tends to be flat. In the other three sections of the amount of latex powder: 2.5% to 5%, 5% to 7.5% and 7.5% to 10%, the growth rate of tensile strength is 4.3%, 5.2% and 2.7%, and the growth rate of tensile modulus is 4.3%, 4.7% and 2.2%, respectively. When the content of latex powder is...
10%, the tensile strength is 0.403MPa, and the tensile modulus is 0.407MPa.

3.2 Analysis of tensile deformation index

The tensile deformation index is mainly reflected by the tensile elongation at break $\delta_{t,b}$ and the tensile peak strain $\varepsilon_{t,p}$. The tensile elongation at break $\delta_{t,b}$ refers to the ratio of the displacement value when the material specimen is damaged to the original length under tensile action; the tensile peak strain $\varepsilon_{t,p}$ refers to the strain when the specimen reaches the peak stress under tensile action. The above figure shows the influence of the amount of emulsion powder on the tensile elongation at break and the tensile peak strain.

It can be seen from the figure that when the amount of emulsion powder is less than 2.5%, the test piece $\delta_{t,b}$ decreases rapidly with the increase of the amount of adhesive powder; when the amount of emulsion powder is 2.5%, $\delta_{t,b}$ reaches the minimum, 245.3%; when the amount of emulsion powder is more than 2.5%, $\delta_{t,b}$ increases slightly with the increase of the amount of adhesive powder.

When the amount of latex powder is less than 2.5%, the amount of $\varepsilon_{t,p}$ of the specimen decreases obviously with the amount of latex powder. When the amount of latex powder is 2.5%, the amount of $\varepsilon_{t,p}$ reaches to the minimum, which is 0.651; then the amount of $\varepsilon_{t,p}$ rises rapidly with the amount of latex powder, and when the amount of latex powder is 10%, the amount of $\varepsilon_{t,p}$ of the specimen is the maximum, which is 0.786.

4 Mechanism Analysis

The experimental results show that the tensile properties of NPJF can be significantly improved with the increase of the content of VAE in the range of 0%-10%. The main reasons are as follows:

The first one is that with the increase of the content of VAE emulsion powder, more inorganic materials such as water solution are replaced and the overall ash-aggregate ratio is improved with the constant content of polymer in NPJF. At the same time, the polymer molecules can be combined with the hydrates inside NPJF, forming interweaving network structure between each other, enhancing the binding force between each part, making the viscosity of NPJF increase.

And another is the dispersion of rubber powder and cement particles in the polymer emulsion, the change of the amount of latex powder also affects the internal microstructure of the emulsion, and then affects the overall macro-mechanical properties of the polymer. When VAE emulsion powder was mixed with the mixed solution, VAE emulsion powder condensed with other powders inside NPJF to form agglomerate polymer, and the polymer formed membrane structure after water volatilization. The particle size of VAE emulsion powder is larger than the particle size of cement particles. The particles with different particle sizes are intermixed and combined to reduce the pores between the particles,
which makes the whole interior of the material more dense and improves the density of NPJF, which makes the bonding between the membrane structures more tight and also improves the continuity of polymer membrane structure. The membrane structures are interconnected and tend to be complete, which improves the internal structure as well as tensile mechanics and deformation properties of NPJF, and thus the tensile properties of NPJF are improved.

5 Conclusion
In this paper, the effects of different amounts of VAE emulsion powder on the tensile properties of NPJF are studied. The main conclusions are as follows:

(1) The tensile property of NPJF is obviously improved by adding VAE emulsion powder, and the load bearing capacity of the test piece is enhanced, which can effectively resist the tensile or cracking of the joint width due to the change of temperature difference. In this test, when the amount of latex powder is 10%, the tensile strength and modulus are maximum.

(2) With the increase of the amount of VAE emulsion powder, the tensile deformation property of NPJF decreased first and then increased. At the same time, the effect of latex powder on the elongation at break of NPJF is smaller, and the effect on peak strain is larger.

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