Effect of VAE Latex Powder Addition on Tensile and Shear Properties of Styrene-Acrylate Based Cement Composite Joint Compound

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Abstract.In order to study the effect of VAE latex powder on the tensile and shear properties of styrene-acrylic emulsion-based cement compound joint compound (PCJS), the tensile test and shear test of PCJS under different VAE latex powder content (0~5%) were carried out. The test results show that the incorporation of VAE latex powder improves the tensile and shear mechanical properties of PCJS. When the amount of latex powder is 5%, compared with PCJS without latex powder, the shear modulus of PCJS increased by 32% and 35%; with the increase of VAE latex powder, the tensile and shear deformation properties of PCJS increased first and then decreased. When the amount of latex powder was 3%, the shear deformation performance of PCJS is the best; the incorporation of VAE latex powder has no obvious effect on the tensile elongation improvement of PCJS at break. In addition, the mechanism analysis of the effect of VAE latex powder on tensile and shear properties of PCJS was carried out.

1. Introduction
At present, the airport runways in China are mostly cement concrete pavements. Although the roads have high strength and good integrity, they often have a shortened service life due to the destruction of joint fillers at the road joints [1]. In addition, the cement concrete pavement passes through Long-term use and the influence of the external environment will inevitably lead to cracks. If not treated in time, it will also have serious consequences for pavement use [2]. Therefore, the selection of good performance joint fillers is essential for the normal use of cement concrete pavement.

The polymer emulsion is a stable system in which the polymer is uniformly dispersed in water in the form of fine particles, and has the characteristics of easy film formation, good toughness, excellent mechanical stability and chemical stability [3,4], and is incorporated into the cement pavement caulking. The material can significantly improve its performance in all aspects. Therefore, domestic and foreign scholars have carried out a large number of experimental researches on the performance of polymer emulsion-based cement composite joint compound, and obtained many research results with practical application value. Liu Jiwei et al [5] studied the mechanical properties and durability of styrene-butadiyl emulsion-based cement composite joint compound. When the content of styrene-butadiene emulsion was 15%, the flexural strength, tensile strength and impermeability of cement pavement joints were found. The best performance; Peng Guang et al [6] studied the deformation properties of styrene-acrylic emulsion-based cement pavement joint fillers,
found that the incorporation of styrene-acrylic emulsion improved the deformation performance of cement pavement joints; Yang Zhenghong et al. [7] A new type of styrene-butadiene polymer emulsion-based cement joint compound was developed and tested for mechanical properties. It was found that this type of joint filler is an ideal pavement joint filler; Zhu Congjin et al. [8] studied the ratio of dust to powder. The effect of the ash-acrylic emulsion-based composite joint compound on the shear properties of the styrene-acrylic emulsion composite joint filler was found to increase the shear performance of the styrene-acrylic emulsion-based composite joint compound. Zhu Mingsheng [9] studied the styrene-acrylic emulsion dosage. The influence of the styrene-acrylic emulsion on the performance of joints on cement pavements was found to significantly improve the workability and water demand of joints on cement pavements; CJ Zhu et al. [10] studied the ratio of cement to styrene-acrylic acid. The effect of the shear properties of emulsion-based cement composite joint compound, It was found that with the increase of cement ratio, the shear strength and shear modulus of cement joint fillers increased gradually, and the shear deformation performance of joint fillers was significantly improved. O Onuaguluchi et al. [11] studied acrylic emulsion-based cements. The mechanical properties of the composite joint compound were found to improve the tensile properties and shear properties of the cement joint compound. Most of the above studies are on the effect of single polymer emulsion on the performance of joints in cement pavement. The effects of polymer latex powder and polymer blending on the performance of cement paving joints have been rarely studied.

Therefore, the tensile test and shear test of styrene-acrylic emulsion-based cement composite joint compound with different VAE latex powder content were carried out. The strength, modulus, elongation at break and peak strain were used as indicators to study VAE latex. The effects of powder content on tensile properties and shear properties of styrene-acrylic emulsion-based cement joint fillers were investigated. The mechanism of VAE latex powder on the properties of styrene-acrylic emulsion-based cement joint fillers was analyzed.

2. test

2.1. Test raw materials

Styrene-acrylic emulsion: Acronal S400F ap styrene-acrylic emulsion, the main technical indicators are shown in Table 1; VAE latex powder: 5044N VAE redispersible latex powder, the main technical indicators are shown in Table 2; cement: PO 42.5 Portland cement Talc powder: 200 mesh ultrafine talcum powder; defoamer: NOPCO NXZ type defoamer; dispersant: SN-DISPERSANT 5040 dispersant; filming aid: DN-12 type filming aid; water: tap water.

| Table 1. Technical Specifications of Styrene-Acrylate Emulsion |
|------------------|------------------|
| Name             | Exterior         | Solid content  | 50% aqueous solution viscosity | PH value |
| Styrene-acrylic emulsion | White powder     | ≥98%           | ≥10                           | 6~8      |
|                   |                  |                |                               | 2 °C     |

| Table 2. Technical Specifications of VAE Emulsions |
|------------------|------------------|
| Name             | Exterior         | Solid content  | 50% aqueous solution viscosity | PH value |
| VAE rubber powder | Milky white liquid | (48±2)%        | 500~1500                     | 7.5~9.0  |
|                   |                  |                |                               | 14~23 °C |
2.2. Mix ratio
In this test, VAE latex powder was added in the form of powder. The ratio of fixed powder to liquid (the ratio of the total mass of powder to the mass of styrene-acrylic emulsion) was 0.4:1, according to the amount of VAE latex powder (0~5%). Six sets of mix ratios were designed, and the numbers were sequentially J1~J6, as shown in Table 3. The amount of VAE latex powder is the percentage of the mass of the latex powder to the mass of the styrene-acrylic emulsion.

Table 3. Mix ratio of VPCJS (styrene-acrylic emulsion-based cement compound joint compound mixed with VAE latex powder)

| Sample | Styrene-acrylic latex | Emulsion powder | Cement | Talcum powder | Dispersing agent | Defoam agent | Coalescing agent |
|--------|-----------------------|-----------------|--------|---------------|------------------|---------------|------------------|
| J-1    | 100                   | 0               | 10     | 30            | 0.84             | 0.70          | 5                |
| J-2    | 100                   | 1               | 10     | 29            | 0.84             | 0.70          | 5                |
| J-3    | 100                   | 2               | 10     | 28            | 0.84             | 0.70          | 5                |
| J-4    | 100                   | 3               | 10     | 27            | 0.84             | 0.70          | 5                |
| J-5    | 100                   | 4               | 10     | 26            | 0.84             | 0.70          | 5                |
| J-6    | 100                   | 5               | 10     | 25            | 0.84             | 0.70          | 5                |

2.3. Preparation of test pieces
1. After weighing according to the mixing ratio, the dispersing agent, the film forming auxiliary agent and the half defoaming agent are sequentially added to the styrene-acrylic emulsion, and the mixture is uniformly stirred;
2. Mix cement, talcum powder and VAE latex powder, stir evenly, add to the above prepared emulsion, stir at high speed for 10 min with a stirrer, add another half of defoamer, stir at low speed for 5 min, then manually stir with glass rod. 5 min, making a joint filler;
3. Place the mold of the joint material after dust removal horizontally, and use the syringe to extract the mixed joint material for pouring. The filling material should be slightly higher than the substrate and the block when filling;
4. After the filling is completed, the test piece is placed under standard curing conditions for maintenance, and after 28 days, the mold is removed and numbered.

In the test, the joints of the joint material are cement mortar base materials, the size is 75mm*25mm*12mm, the mixing ratio is cement: sand: water=1:2:0.4; the length of joint filler is 50mm, the width is 12mm, the height is slightly higher than the substrate and the block.

2.4. Test methods
The test was divided into 12 groups of 5 specimens each, and the test results were averaged five times. Among them, six sets of test pieces were used for tensile performance test, and six sets of test pieces were used for shear performance test. This test uses the equipment of HS-3001B universal electronic testing machine, as shown in Figure 1. The test method is as follows:
1. Fix the test piece in the fixture to ensure that the test piece and the fixture are in the same plane;
2. Turn on the testing machine. When performing the tensile test, the clamp is stretched at a loading rate of 5 mm/min until the test piece is broken, as shown in Figure 2. When the shear test is performed, the two side clamps are loaded at 5 mm/min. The rate is separated upward and downward until the test piece is broken, as shown in Figure 3. Record the force and displacement at the time of destruction;
3. Perform data processing and draw plots.
3. test results and analysis

3.1. Effect of VAE Latex Powder Content on Tensile Properties of PCJS

The tensile properties of a material are properties exhibited by the material under axial tensile loading and can be measured by the tensile strength, tensile modulus, elongation at break and peak strain of the test material [12]. Figures 4a–d show the effect of VAE latex powder on PCJS tensile strength, tensile modulus, elongation at break and peak strain. It can be seen from Fig. 4a, 4b that as the amount of VAE latex powder increases, the tensile strength and tensile modulus of PCJS increase gradually, and the growth rate of tensile modulus is greater than the tensile strength, with no latex powder. Compared with the PCJS blended, the tensile strength and tensile modulus of PCJS increased by 13% and 32%, respectively, when the VAE latex powder was 5%. It can be seen that the incorporation of VAE latex powder has an effect on the tensile modulus and tensile strength of PCJS, but the effect on the tensile modulus of PCJS is more significant; from 4c and 4d, the elongation of PCJS is observed. The long-term and peak strains increased first and then decreased with the increase of VAE latex powder. When the VAE latex powder was 2% and 3%, the elongation at break and peak strain of PCJS reached the maximum. The elongation at break and peak strain increased by 2% and 10%, respectively, compared to PCJS without latex powder. When the VAE latex powder was 5%, the elongation at break and peak strain of PCJS reached the minimum, the elongation at break and peak strain were reduced by 20% and 19%, respectively, compared to PCJS without latex powder. It can be seen that the incorporation of VAE latex powder does not significantly increase the elongation at break of PCJS. As the amount of VAE latex powder increases, it will lead to a decrease in
elongation at break; when the amount of VAE latex powder is 3% The peak strain of PCJS is significantly improved. When the VAE latex powder is more than 3%, the peak strain of PCJS is significantly reduced.

3.2. Effect of VAE Latex Powder Content on Shear Properties of PCJS

The shear properties of a material are the mechanical properties and deformation properties exhibited by the material when subjected to shear loads perpendicular to the axis of the material. Generally, the shear strength, shear modulus, elongation at break and peak strain of the test material are tested. Performance is reflected [13]. Figures 5a~d show the effect of VAE rubber powder on PCJS shear strength, shear modulus, elongation at break and peak strain. It can be seen from Fig. 5a, 5b that with the increase of the amount of VAE latex powder, the shear strength and shear modulus of PCJS tend to increase gradually, and the shear strength of PCJS increases from 0.421Mpa to 0.486 Mpa, the growth rate is 0.065Mpa, the shear modulus of PCJS increases from 0.228Mpa to 0.301Mpa, and the growth rate is 0.073Mpa, which accounts for 15% and 32% of the PCJS shear strength and shear modulus of latex-free powder. %. It can be seen that the incorporation of VAE latex powder can significantly improve the shear strength and shear modulus of PCJS, and the improvement effect on shear modulus is better than shear strength. It can be seen from Figures 5c and 5d that the influence of the incorporation of VAE latex powder on the deformation properties (elongation at break and peak strain) of PCJS is significantly different from the effect on mechanical properties (shear strength and
shear modulus). With the increase of VAE latex powder, the elongation at break and peak strain of PCJS increased first and then decreased. When the content of VAE latex powder was 3% and 5%, the elongation at break of PCJS The maximum and minimum values were respectively 348% and 302%, accounting for 115% and 99.7% of the elongation at break of PCJS without latex powder; when the VAE latex powder was 3% and 5%, PCJS The peak strains reached the maximum and minimum values of 2.243 and 1.868, respectively, accounting for 109% and 90% of the peak strain of PCJS without latex powder. It can be seen that when the VAE latex powder content is 3%, the deformation performance of PCJS is the best.

**Figure 5. Effect of VAE latex powder on shear properties of PCJS**

4. **Mechanism**

The incorporation of VAE latex powder improves the tensile and shear mechanical properties (strength and modulus) of PCJS for two main reasons. On the one hand, the particle size of VAE latex powder is small. After being incorporated into PCJS, it can fill its internal pores, reduce the number of pores, refine the pore structure, thereby improve the compactness of PCJS and enhance the integrity of the structure, thus improving the PCJS pull. Stretching and shearing mechanical properties; on the other hand, after the VAE latex powder is incorporated into PCJS, it replaces part of the inorganic powder, which indirectly increases the amount of polymer in PCJS, improves the poly-ash ratio, and the polymer molecules pass. Combined with the internal hydration products of PCJS to form a mutually interwoven network structure, the bonding condition of each component is improved,
and the viscosity of the internal structure of PCJS is increased, thereby enhancing the tensile and shear mechanical properties of PCJS.

With the increase of VAE latex powder content, the tensile and shear deformation properties (elongation at break and peak strain) of PCJS increased first and then decreased, mainly because the addition of PCJS component after the incorporation of VAE latex powder. The content of organic polymer in the polymer enhances the "flexible characteristics" of the polymer itself, thereby improving the deformation performance of PCJS. However, as the amount of VAE latex powder increases, the internal pores of PCJS gradually decrease, and the compactness gradually increases. The polymer is more tightly bound to the cement hydration product, thereby inhibiting the free shrinkage of the internal molecular structure of PCJS, resulting in a decrease in the deformation properties of PCJS.

5. Conclusion
Based on the strength, modulus, elongation at break and peak strain, the effects of VAE latex powder (0~5%) on the tensile properties and shear properties of PCJS were studied. The main conclusions are as follows:

(1) With the increase of the amount of VAE latex powder, the tensile and shear mechanical properties of PCJS are gradually enhanced. When the amount of latex powder is 5%, the tensile modulus and shear modulus of PCJS are significantly improved. Compared with PCJS without latex powder, the tensile modulus and shear modulus are increased by 32% and 35%.

(2) With the increase of VAE latex powder content, the tensile deformation performance of PCJS showed a trend of increasing first and then decreasing. When the amount of latex powder was 2% and 3%, the elongation at break and the peak strain of PCJS peaked respectively, but the effect of latex powder on the elongation at break of PCJS was not obvious.

(3) With the increase of VAE latex powder content, the shear deformation performance of PCJS increases first and then decreases. When the amount of latex powder is 3%, the shear deformation performance of PCJS is the best.

References
[1] WANG Qunqun. Analysis of Disease Treatment Measures and Prevention Countermeasures for Cement Concrete Pavement[J]. Transportation Energy Conservation and Environmental Protection, 2017, 13(03): 68-71.
[2] Wu Xianhui, Sha Aimin, Zhang Juan. Cement pavement disease-genetic relationship chain and digital coding[J]. Journal of Chang'an University (Natural Science Edition), 2015, 35(02): 19-25.
[3] Zheng Shaopeng, Niu Kaimin, Tian Bo, Chen Liangliang, Cheng Zhihao, Xu Yuxi. Effect of polymer emulsion on rheological properties of cement mortar[J]. Journal of Building Materials, 2017, 20(06): 962-969.
[4] HAN Yusheng, LI Na, HAN Weiwei. Study on the Influence of Polymer and Mineral Admixture on the Performance of Cement Mortar[J]. Roadbed Engineering, 2017(05): 119-124.
[5] LIU Jiwei, ZHOU Mingkai, CHEN Wei, HAO Wenbin, Xu Fang, FANG Dong. Study on properties and mechanism of styrene-butadiene emulsion modified cement mortar[J]. Journal of Wuhan University of Technology, 2013, 35(01): 40-43.
[6] Zhu Congjin, Bai Erlei, Xu Jinyu, Nie Liangxue. Effect of gray powder on shear properties of styrene-acrylic emulsion-based cement composite joint compound[J]. Bulletin of Bulletin, 2017, 36(08): 2576-2582.
[7] Peng Guang, Xu Jinyu, Ren Weibo. Study on Deformation Performance of Polymer Cement Road Surface Filling Materials[J]. Bulletin Bulletin, 2017, 36(09): 2894-2899.
[8] Yang Zhonghong, Yin Yilin, Qu Shenghua, Ding Yan. Development of polymer modified cement mortar repairing materials for roads[J]. New Building Materials, 2006(02): 1-4.
[9] ZHU Mingsheng. Research on polymer emulsion cement mortar repairing materials [J]. Science and Technology, 2010 (19): 218-219.

[10] Zhu C J, Bai E L, Jin-Yu X U, et al. Effects of Cement-Powder Ratio on Shear Properties of Styrene-acrylic Emulsion Based Cement Compound Joint Sealant [J]. Bulletin of the Chinese Ceramic Society, 2017.

[11] Onuaguluchi O, Ratu R, Banthia N. The effects of CaCl2 -blended acrylic polymer emulsion on the properties of cement mortar [J]. Materials & Structures, 2018, 51(2): 50.

[12] SUN Zhenping, YE Danmei, FU Lefeng, ZHENG Baicun, FENG Zhongjun, XIE Huidong. Influence of gas content of polymer modified cement mortar on mechanical properties[J]. Journal of Building Materials, 2013, 16(04): 561-566.

[13] LI Wei, LIAO Wei-zhang, WANG Bo. Experimental study on shear resistance of polymer modified cement mortar layer and concrete joint surface[J]. Construction Technology, 2016, 45(10): 86-90.