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Effect of quartz sand on mechanical properties of waterborne adhesives

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Abstract: *In order to study the influence of quartz sand filler on the properties of water-based adhesives. Brinell rotational viscometer and universal testing machine were used to test the mechanical properties of adhesives incorporated with different particle sizes and different dosages. The test results show that when the particle size is greater than 280μm, the quartz sand is easy to sink to the bottom of the glue, which is not conducive to dispersion. When the dosage is constant, the smaller the particle size of quartz sand, the greater the viscosity of the liquid. The addition of quartz sand can significantly enhance the tensile properties of the adhesive after curing and the crack resistance in low temperature environment.*

Keywords: *Anti-slip thin layer, quartz sand, mechanical properties*

1. Introduction

Anti-skid layer is a kind of functional layer laid on the cement road surface, the main purpose is to improve the anti-skid performance of the road surface and reduce traffic accidents. It has the advantages of wear resistance, skid resistance and low cost. The anti-skid layer is fixed to the surface of the road by adhesive and gravel bonded to each other. Common adhesives are oil based and water based, the latter being widely used for its advantages of low VOC and low cost [1]. But there are also some defects, including: delamination, cracking and so on. Other studies have shown that quartz sand can enhance the mechanical properties of water-based cements, reduce temperature sensitivity and save construction costs by reducing the amount of adhesive used [2]. In order to summarize the effect of quartz sand on adhesive properties, the samples were tested by rotating viscosity test, bond strength test, tensile strength test and scanning electron microscope test.

2. Effect of quartz sand on adhesive material properties

2.1. Effect of quartz sand on the fluidity of adhesives

The viscosity of adhesive directly affects the fluidity of liquid in the construction process. Too much viscosity leads to difficult mixing, and the phenomenon of filler sinking is easy to occur. The particle size and content of quartz sand will directly affect the viscosity. Choose four different sizes of quartz sand particles (280 μm, 150 μm, 75 μm, 38 μm) added to the adhesive, the percentage of quartz sand quality adhesives set to 10%, 20%, 30%, 40%, 50%.After mixing, the viscosity of the mixture was tested, and the test results were shown in Table 1.

It can be seen from the data that the viscosity of the four particle sizes of quartz sand shows an upward trend with the increase of the dosage, indicating that the dosage is the key factor affecting the viscosity of the glue solution. When the particle size ranges from 280μm to 75μm, the viscosity data of the adhesive has good stability and small fluctuation range. The viscosity of adhesives added with 38μm quartz sand is much higher than other adhesives when the dosage is the same。This indicates that the smaller the particle size, the greater the influence on viscosity。When selecting 38μm quartz sand, the content should be controlled below 30%.

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Table 1: Results of rotational viscosity tests

Sample name	Particle size (μm)	dosage	Viscosity (mPa·S)
L_0	--	--	4370
L_1	280	10%	5297
L_2	280	20%	5721
L_3	280	30%	6117
L_4	280	40%	6937
L_5	280	50%	7418
L_6	150	10%	4486
L_7	150	20%	5361
L_8	150	30%	5583
L_9	150	40%	6210
L_{10}	150	50%	7404
L_{11}	75	10%	5078
L_{12}	75	20%	5626
L_{13}	75	30%	6139
L_{14}	75	40%	6792
L_{15}	75	50%	7545
L_{16}	38	10%	6462
L_{17}	38	20%	6622
L_{18}	38	30%	7545
L_{19}	38	40%	9323
L_{20}	38	50%	9381

2.2. Effect of quartz sand on adhesive bonding property

According to the test results in Table 1, 280μm quartz sand will produce bottoming phenomenon when it is mixed with the adhesive, and the bottoming filler will reduce the bond strength and affect the tensile property of the adhesive after curing. Therefore, 150μm and 75μm were selected as the ratio of adhesive, and the dosage was set as 10%, 20%, 30%, 40%, 50%. The content of 38 μm quartz sand is set to 10%, 20%, 30%.

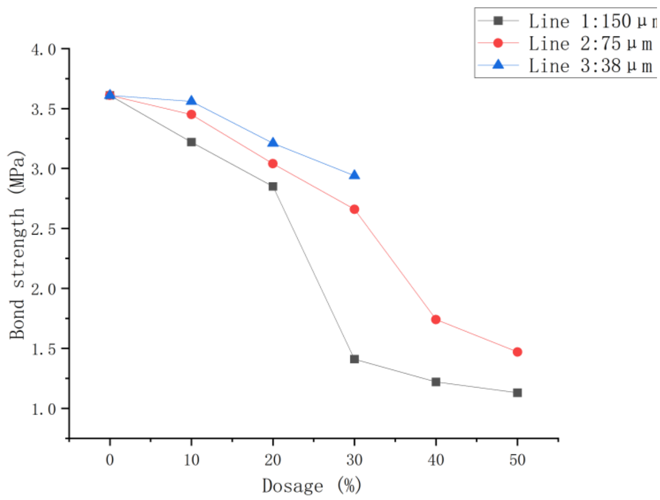

Figure 1: The trend of bond strength with dosage

The graph plotted from the experimental data is shown in Figure 1.The bond strength of the adhesive decreases with the increase of the content of quartz sand, among which the bond strength of the adhesive mixed with 150μm quartz sand is the most sensitive to the change of the content. When the content of 10%, the bond strength shows an obvious downward trend, which may be caused by the bottom of the filler in the process of solidifying the adhesive. When the dosage reached 20%, the drawing strength reached 2.85MPa, which decreased by 21% compared with the adhesive stock solution. When the dosage

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reaches 30%, the bond strength is lower than 2.0MPa, which does not meet the technical requirements of anti-skid coating. Therefore, the recommended dosage of 150μm quartz sand is below 20%.When the content of 200 mesh quartz sand is controlled within 30%, it can meet the requirements of the relevant specifications of 2.0MPa. When the amount of incorporation is controlled below 10%, the bond strength has little difference with L_0. When the dosage reached 20%, the drawing strength reached 3.04MPa, which decreased by 16% compared with the adhesive stock solution. When the incorporation amount is 30%, the bond strength reaches 74% of L_0. When the blending amount is 40%, the bond strength reaches 48% of L_0, which is lower than 2.0MPa required by the specification. Therefore, the incorporation ratio of 200 mesh quartz sand should be controlled within 30%.When the particle size of quartz sand is 38μm, the amount of incorporation has little influence on the bond strength. The strength of 30% incorporation is 19% lower than that of the adhesive stock solution, which is higher than the specification requirements of 2.0MPa. The reason may be that the particle size of quartz sand is too small in the glue liquid dispersion is better, not easy to produce bottoming phenomenon.

2.3. The influence of quartz sand on the tensile properties of adhesive

Choose L_0, L_6, L_{11}, L_{12}, L_{13}, L_{16}, L_{17}, L_{18}, L_{19} for sample preparation, wait for after curing remove tensile specimen on the universal testing machine to test. The sample molding and test process are shown in Figure 2 and Figure 3, and the experimental data are shown in Table 2

Figure 2: Sample preparation process

Figure 3: The stretching process of the sample

Table 2: Tensile strength and elongation at break of different samples

Sample name	Particle size (μm)	dosage	Tensile strength (MPa)	Elongation at break (%)
L_0	--	--	2.55	85.6
L_6	150	10%	2.75	78.5
L_7	150	20%	2.98	74.3
L_{11}	75	10%	3.04	76.2
L_{12}	75	20%	3.14	75.2
L_{13}	75	30%	3.33	70.3
L_{16}	38	10%	2.97	74.3
L_{17}	38	20%	3.06	72.1
L_{18}	38	30%	3.12	70.1
L_{19}	38	40%	3.50	65.9

From Figure 4 and Figure 5, it can be clearly seen that the incorporation of quartz sand can improve the tensile properties of the adhesive after curing. The dosage and tensile strength were positively correlated, and the elongation at break was negatively correlated.

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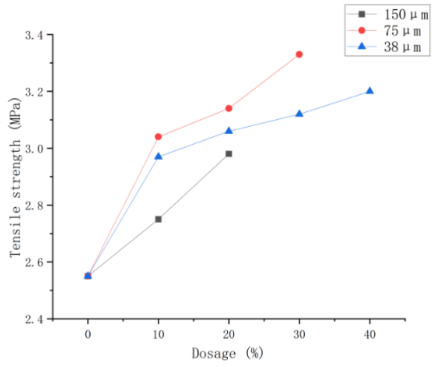

Figure 4: The trend of tensile strength with dosage

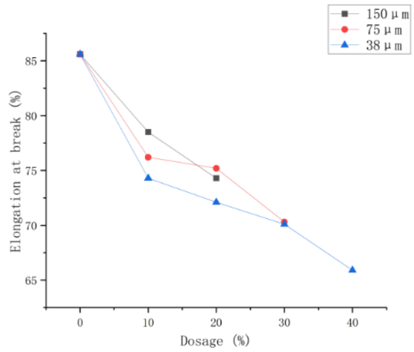

Figure 5: The trend of elongation at break with dosage

3. The dispersion of quartz sand in adhesive

In order to better analyze the curing effect and dispersion degree of quartz sand in binder, scanning electron microscopy (SEM) was used to study the microstructure of solidified quartz sand coated by binder.

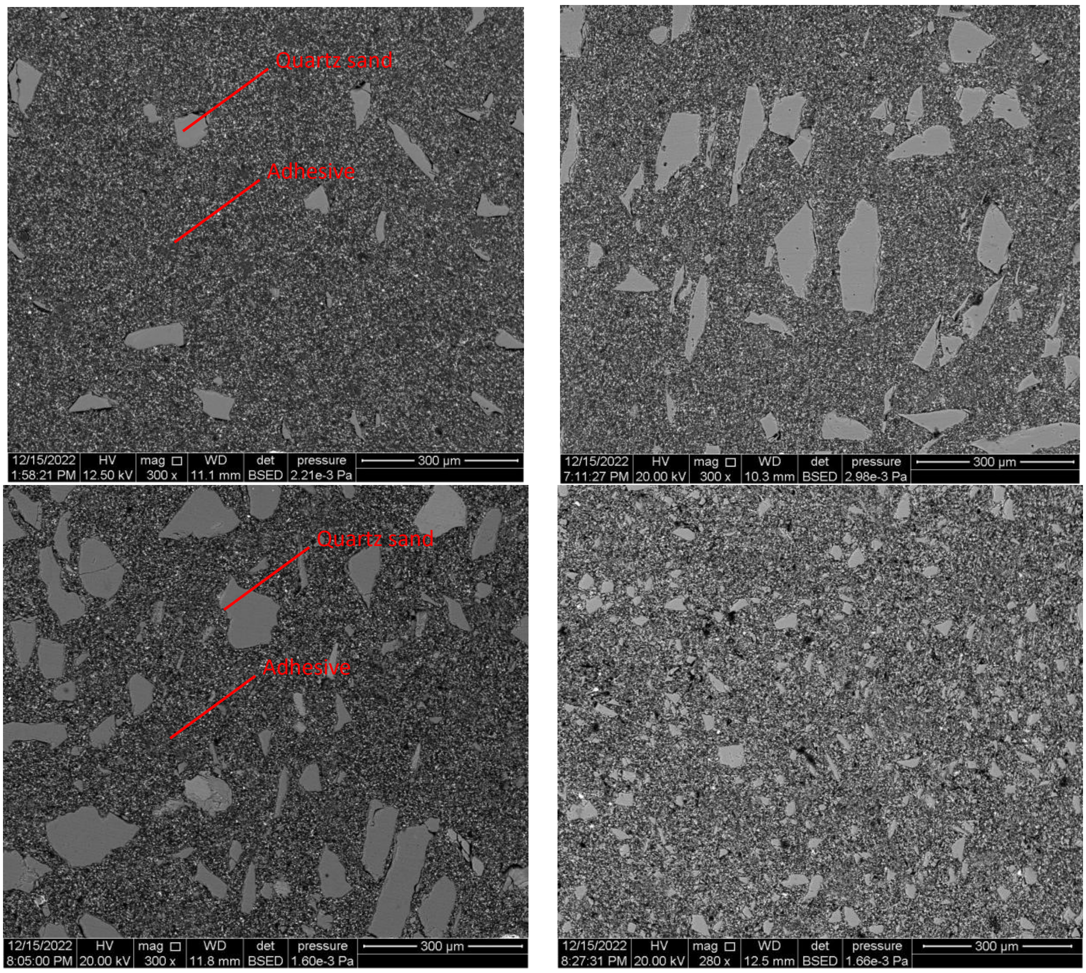

Figure 6: Dispersion of quartz sand in adhesives

It can also be seen from the Figure 6 that each particle size and each content of quartz sand are evenly dispersed in the adhesive, and there is no agglomeration phenomenon, which indicates that the adhesive has a good coating property on quartz sand.

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4. Low temperature cracking test of the adhesive

If the ambient temperature is relatively stable for a period of time after the completion of the thin-layer antiskid colored pavemen, the volume stability between the thin layer material and the cement concrete surface layer is maintained. The material properties of thin-layer antiskid colored pavemen are different from those of cement concrete, and the linear expansion coefficient of the former is greater than that of the latter. With the decrease of ambient temperature, the low temperature shrinkage rate of thin layer material is higher, which damages the stable state of both. According to the mechanical analysis, the joint surface of the two contains not only shear stress, but also considerable tensile stress. When the tensile stress exceeds the critical value, it will lead to cracking。 The larger the difference between the linear expansion coefficients, the more serious the cracking will be at low temperature [3].

When the temperature rises, the shear stress and compressive stress are the main joint surface of the two, because of their high compressive strength, so there will be no cracking failure.

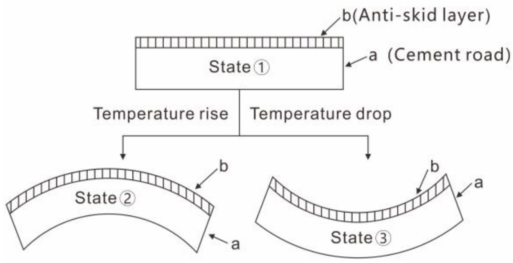

Figure 7: Diagram

Figure 7 shows the deformation behavior between the thin-layer antiskid colored pavemen and the cement concrete during rising and cooling. The test method was as follows: the adhesive was kept at -10°C for 4h and then placed at room temperature for 4h as a cycle. The lowest number of cycles for cracks appeared in adhesives of different proportions was observed and recorded. The results of the test are shown in Table 3.

Table 3: Results of low temperature tests

Sample number	Tensile strength	Sample status
L_0	2.55MPa	Microcracks appeared after curing, and penetrating cracks appeared after one freeze-thaw cycle
L_6	2.75MPa	Microcracks appeared after curing, and penetrating cracks appeared in the first cycle at the beginning of freeze-thaw
L_7	2.98MPa	Cracks appear after three freeze-thaw cycles
L_{11}	3.04MPa	
L_{12}	3.14MPa	
L_{13}	3.33MPa	Small cracks appeared when freeze-thaw cycles reached 3 times, and through cracks appeared when freeze-thaw cycles reached 7 times
L_{16}	2.97MPa	Small cracks began to appear after 5 freeze-thaw cycles, and cracks became larger after 7 freeze-thaw cycles, but no penetrating cracks appeared
L_{17}	3.06MPa	There were no cracks in freeze-thaw cycles for seven times
L_{18}	3.12MPa	
L_{19}	3.50MPa	

Adding filler to adhesive is an effective means to prevent crack. The adhesive without fine filler is more likely to produce microcracks in the curing stage. With the development of crack, rain water intrudes into the bonding interface and plays an irreparable damage role against the slippery thin layer. It can be proved that low temperature is an important factor in the development of fractures. When the content of fine filler reaches a certain amount, it is difficult for cracks to appear after 7 freeze-thaw cycles, which proves that increasing the content of quartz sand can improve the low-temperature crack resistance of thin layer. According to the elastic modulus measured by tensile test and the low temperature cracking theory, the low temperature cracking resistance has a certain relationship with the elastic modulus of the

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material.

5. Conclusion

The smaller the particle size of quartz sand is, the larger the viscosity is. The results of rotary viscosity and tensile test show that the particle size of 75 μm and the content of 30% quartz sand binder show the best application performance. Adding the modified quartz sand binder can significantly reduce the cost of construction raw materials and has positive promotion significance.

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