EFFECT OF STYRENE-ACRYLIC EMULSION ON THE PROPERTY OF SULPHOALUMINATE CEMENT PASTE

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Abstract

The polymer sulphoaluminate cement is composed of styrene-acrylic emulsion and sulphoaluminate cement. The resistance of polymer sulphoaluminate cement to sulfate attack, permeability and mechanical properties are studied in the paper. The experimental results show that the permeability of the cement paste is improved with the increase of amount of styrene-acrylic emulsion. When the ratio of polymer to cement increases from 0% to 15%, the penetrative height of the hardened cement paste decreases by 70%. The resistance to sulfate attack of cement paste is also improved with the increase amount of styrene-acrylic emulsion. Styrene-acrylic emulsion has little effect on the flexural strength. When the amount of polymer to cement is less than 15%, the 28d flexural strength are bigger than 7.1MPa. Total porosity gradually decreases slightly with the increase of the ratio of polymer to cement, in other words, the cement paste becomes more close-grained.

1. INTRODUCTION

Impermeability and resistance to sulfate attack are the important factors with regard to the concrete durability. A lot of engineering structures, such as underground structures, bridges, tunnels and so on, are serviced in the circumstance of moist, water and corrosive solution. Because the concrete suffered for infiltrating, eroding and freeze-thawing, the durability of concrete structures is reduced gradually. Impermeability and resistance to sulfate attack can be improved by addition of polymer into Portland cement [1-3]. Further more, polymer cement has been used in constructions in the circumstance of moist, water and corrosive solution [4-6]. Sulphoaluminate cement has many excellent performances such as high early age strength, fast hardening, and tiny expanded. Sulphoaluminate concrete made by special admixture has favorable impermeability and resistance to sulfate attack [7]. It has been used in defending and repairing projects of bridge. But the porosity of this material is still relatively high after hardened. The impermeability and resistance of Sulphoaluminate concrete to sulfate attack still need to be improved. As the development of polymer materials science, polymer with its good flexible, good bond behavior and compatible with cement was widely used. In this paper, styrene-acrylic emulsion was synthesized in experiment, and the
influence of styrene-acrylic emulsion on impermeability and resistance to sulfate attack of sulphoaluminate cement paste was investigated.

2. EXPERIMENTAL PROCEDURES

2.1 Raw materials
Cement used in experiment was 425 sulphoaluminate cement. Styrene-acrylic emulsion was synthesized in experiment, in which solid content was 47% and average particle size was nearly 200 nm. Polycarboxylate superplasticizer was produced by Taozheng Chemical Ltd and its solid content was 28%.

2.2 Experimental methods
(1) Flexural strength testing
4×4×16 cm³ prisms were cast and cured for 1 day under the conditions of relative humidity of 95% at 20°C, then put into water to stated age after stripping. The w/c ratio of the samples for strengths test is 45%.

(2) Impermeability of cement
40×40×160 mm³ prisms and truncated cones with upper diameter of 70mm and lower diameter of 80 mm were cast and cured for 28 days. The water-cement ratio and cement-sand ratio were 0.5 and 0.33. At first the pressure was 0.2MPa for 2h, and then increased at the rate of 0.1MPa /1h until it reaches 1MPa which was maintained for 8h. The samples were split. The height of infiltration was measured at five points.

(3) Resistance to sulfate attack
The samples were prepared, the w/c ratio of the samples for strengths test is 45%, and molded according to GB2420 - 81, 10×10×60 mm³ prisms were cast and cured for 7 days at the temperature of 20°C. The prisms were divided into 4 groups. Two groups were cured in water at the temperature of 20°C for 28 days, the others were cured in sodium sulfate solution at the same temperature and stated age. In the process of curing, the solution should be titrated with dilute sulfuric acid to neutralize Ca(OH)₂ every day, and keep its PH was kept at about 7.0. Coefficient of resistance to sulfate attack, K, was calculated according to GB2420 - 81 as below:

\[ K = \frac{R_1}{R_2} \]

where \( R_1 \) is the flexural strength of samples which was cured in sodium sulfate solution for 28d. \( R_2 \) is the flexural strength of samples which was cured in water for 28d.

3. RESULTS AND DISCUSSION

3.1 Effect of styrene-acrylic on impermeability of sulphoaluminate cement
The ratio of polymer to cement, P/C, is selected as 0%, 2.5%, 5.0%, 7.5%, 10% and 15% respectively. The polymer sulphoaluminate cement is composed with the synthesized styrene-acrylic emulsion and sulphoaluminate cement. The influence of P/C on penetrative height of the polymer sulphoaluminate cement mortar was shown in Table 1 and Figure 1.

Table 1 show that the permeation height of polymer cement reduces with the increase of styrene-acrylic emulsion. When the ratio of polymer to cement increases from 0% to 15%, the...
permeate height of the cement mortar decreases from 30 mm to 9 mm, in other words, decreases by 70%. It is concluded that styrene-acrylic emulsion could improve the impermeability of the cement. As the polymer have good filming and deformation properties which rely on the flexibility of polymer. Styrene-acrylic emulsion has good flexibility and bond behavior, which could fully adapt to the volume changes of cement and mortar in the process of hydration and hardening. This characteristic prevents cracks from forming and expanding. The impermeability is related closely to the pore of the hardened cement paste. The quantity of interconnected pores [8-9] is reduced in the hardened cement paste if styrene-acrylic emulsion is added. Therefore, the impermeability of the polymer sulfoaluminate cement is enhanced. In addition, the polymer particles can play a role in filling the capillaries or micro-cracks of cement paste, also have a role in the impermeability increasing. In this experiment, the average diameter of the styrene-acrylic emulsion is 200 nm, and it can fill in some pores of the hardened cement paste, thereby the impermeability of cement paste is enhanced.

Table 1: Influence of P/C on permeation height of the polymer cement

<table>
<thead>
<tr>
<th>Sample</th>
<th>B0</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>B5</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/C %</td>
<td>0.0</td>
<td>2.5</td>
<td>5.0</td>
<td>7.5</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Permeation height /mm</td>
<td>30</td>
<td>24</td>
<td>21</td>
<td>17</td>
<td>15</td>
<td>9</td>
</tr>
</tbody>
</table>

Figure 1: Influence of P/C on the impermeability of the polymeric cement

3.2 Effect of styrene-acrylic on resistance to sulfate attack

The ratios of polymer to cement are 0.0%, 2.5%, 5.0%, 7.5% and 10.0%, respectively. The corresponding samples are named as C0, C1, C2, C3 and C4. The samples are cured in the water and in the 3% Na₂SO₄ liquor separately.
Table 2 shows that the coefficient of resistance to sulfate attack of polymer sulfoaluminate cement paste gradually increases with the increase of the ratio of polymer to cement. It is indicated that styrene-acrylic emulsion could improve the resistance to sulfate attack of polymer sulfoaluminate cement paste. The reason is that the filling effect of polymer particles makes it difficult for the sulfate ion to penetrate into the cement paste. Thus the corrosion resistance is enhanced.

<table>
<thead>
<tr>
<th>Sample</th>
<th>3%Na₂SO₄ Solution</th>
<th>Water</th>
<th>Coefficient of resistance to sulfate attack/K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flexural strength/MPa</td>
<td>Flexural strength/MPa</td>
<td></td>
</tr>
<tr>
<td>C0</td>
<td>11.2</td>
<td>10.8</td>
<td>1.04</td>
</tr>
<tr>
<td>C1</td>
<td>11.0</td>
<td>10.1</td>
<td>1.09</td>
</tr>
<tr>
<td>C2</td>
<td>10.8</td>
<td>9.6</td>
<td>1.13</td>
</tr>
<tr>
<td>C3</td>
<td>10.9</td>
<td>9.5</td>
<td>1.15</td>
</tr>
<tr>
<td>C4</td>
<td>11.4</td>
<td>9.7</td>
<td>1.18</td>
</tr>
</tbody>
</table>

3.3 Effect of styrene-acrylic on flexural strength of sulfoaluminate cement

The polymer sulfoaluminate cement is mainly used to protect the surface of concrete construction from eroding. So the flexural strength of the polymer cement is required strictly. Figure 2 shows that the influence of the styrene-acrylic emulsion on the flexural strength of sulfoaluminate mortar. When the ratio of polymer to cement increases from 0% to 15%, the flexural strength of the polymer sulfoaluminate cement both drop slightly at 3d and 28d. And the flexural strength increases when the ratio of polymer to cement continues to increase. The minimum flexural strength is above 7.1MPa at 28d. The sulfoaluminate cement mortar remains preferable flexural strength after the addition of styrene-acrylic emulsion, which shows that the styrene-acrylic emulsion and sulfoaluminate cement have good compatibility. When the ratio of polymer to cement is 7.5%, the flexural strength is low. It may be related with the dosage, film-forming properties and network structure of styrene-acrylic emulsion.
Figure 2: Influence of P/C on flexural strength of polymeric cement

3.4 Influence of the styrene-acrylic to the paste pore structure

Table 3 shows analysis of the polymeric cement paste modified by styrene-acrylic emulsion. The ratios of polymer to cement are 0.0%, 2.5%, 5.0%, 7.5% and 10.0%, respectively. As can be seen from Table 3, total porosity gradually decreases slightly with the increase of the ratio of polymer to cement, in other word, the cement paste becomes more close-grained when the ratio of polymer to cement increases. The innocuous pores are the most in cement paste when the ratio of polymer to cement is 7.5%. The reason is that the styrene-acrylic disperses equably in the cement. It is related closely to the film-forming properties and network structure of styrene-acrylic. Thus more close-grained cement forms.

Table 3: Pore structure analysis of polymeric cement paste

<table>
<thead>
<tr>
<th>Sample</th>
<th>P/C/%</th>
<th>Pore size distribution /nm</th>
<th>Innocuous pores</th>
<th>Harmful pores</th>
<th>Total porosity/%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;25</td>
<td>25~50</td>
<td>50~100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>A0</td>
<td>0.0</td>
<td>4.26</td>
<td>4.48</td>
<td>8.37</td>
<td>7.29</td>
</tr>
<tr>
<td>A1</td>
<td>2.5</td>
<td>7.27</td>
<td>6.16</td>
<td>7.67</td>
<td>1.68</td>
</tr>
<tr>
<td>A2</td>
<td>5.0</td>
<td>5.57</td>
<td>6.36</td>
<td>5.31</td>
<td>1.40</td>
</tr>
<tr>
<td>A3</td>
<td>7.5</td>
<td>4.24</td>
<td>6.76</td>
<td>5.23</td>
<td>1.55</td>
</tr>
<tr>
<td>A4</td>
<td>10.0</td>
<td>4.73</td>
<td>6.14</td>
<td>5.03</td>
<td>1.75</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

1. The impermeability of the cement is improved with the increase of styrene-acrylic emulsion. When the ratio of polymer to cement increases from 0% to 15%, the permeate height of the hardened cement paste decreases by 70%.

2. The resistance to sulfate attack of the cement is improved effectively with the increase of styrene-acrylic emulsion.

3. Styrene-acrylic emulsion has little effect on the flexural strength of sulphoaluminate cement. When the ratio of polymer to cement is less than 15%, the flexural strength of the cement at 28d is all above 7.1MPa.
4. Total porosity gradually decreases slightly with the increase of the ratio of polymer to cement, in other words, the cement paste becomes more close-grained.

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REFERENCES