Mechanical Behavior of Cement Mortar with Different Polymer Type

Yanping Yin¹, Shuhua Wu², Huaxin Chen³, *, Lifang Song⁴, Min Zhang⁵

¹Doctoral student, School of Materials Science and Engineering, Chang’ an University, Xi’an 710061, Shaanxi, China; ypyin@chd.edu.cn
²Doctoral student, School of Materials Science and Engineering, Chang’an University, Xi’an 710061, Shaanxi, China; wshuhua0506@126.com
³Professor, School of Materials Science and Engineering, Chang’an University, Xi’an 710061, Shaanxi, China; hxchen@chd.edu.cn
⁴Lecturer, School of Materials Science and Engineering, Chang’an University, Xi’an 710061, Shaanxi, China; lfs@chd.edu.cn.
⁵Master student, School of Materials Science and Engineering, Chang’an University, Xi’an 710061, Shaanxi, China; 1161393476@qq.com

ABSTRACT: Mechanical property of cement mortar is closely related to polymer modifier type. Four kinds of polymer latex including Chloroprene Rubber (CR), Styrene Butadiene (SBR), Styrene Acrylic (SA) and Polyvinyl Acetate (PVAc) were selected to prepare the modified cement mortar in this study. Mechanical behavior of modified cement mortar was evaluated by flexural strength, Compressive Strength and Tensile Strength, respectively. The micro-morphology of modified cement mortar was observed by scanning electron microscope (SEM), which was useful to analyze the modification mechanism. The results show that the SBR and PVAc latex can effectively improve the flexural strength of cement mortar, while the compressive strength is reduced slightly. Tensile strength of modified cement mortar was increased, especially the PVAc latex modified cement mortar.

INTRODUCTION

Cement mortar is one of the major construction materials throughout the world owing to its design versatility and cost efficiency. While ordinary cement mortar appearance some weak points, such as great brittleness, low flexural strength, easy crackness and low durability, which limit its widely use in construction practice. Adding polymer to modify the ordinary cement is one of useful measures to improve properties of mortar.

Now there is rich experience in polymer modified cement mortar at home and abroad. The most often used polymer latexes are chloroprene rubber (CR), styrene acrylic (SA) and polyvinyl acetate (PVAc), ethylene-vinyl acetate based polymer (EVA) and styrene Butadiene copolymer (SBR) types. Xu and Li investigated physical properties of SBR modified cement mortar, and results have shown that SBR latex would improve physical properties: such as increasing water production, delaying setting time, reducing capillary water adsorption and bulk density. Kong et al. studied the impact of styrene acrylic latex on properties of modified mortar, and analyzed the improvement function on flowability of fresh mortar and retardation.
effect on cement hydration by environment scanning electron microscope.

Moreover, mechanical behaviors are base measurement for cement mortar. So far in the literature, ample studies have been conducted theoretically and practically with respect to the mechanical properties of cement mortar. It has shown that the polymer emulsion reduces content of mixing water, effectively enhances both flexural strength and tensile bond strength, largely decreases the ratio of compressive strength to flexural strength, while improves the ratio of flexural strength to elastic modulus. Wang investigated mechanical properties of SBR modified cement mortar used for repair of bridge surface. Superior mechanical properties of combined slag and styrene butadiene rubber (SBR) modified concrete have also been reported by Joo et al. Shaikh Faiz Uddin Ahmed evaluated the mechanical properties of three types modified mortar through measuring compressive and flexural strength, whereas the water absorption and carbonation and chloride penetration tests were performed to evaluate their durability properties.

However, a little literature has verified the relationship between mechanical properties of modified cement mortar and different polymer type. Research on this issue in China needs to be further conducted to develop high performance of modified mortar.

This research aimed to compare the improvement effect of CR, SBR, SA and PVAc latex on mechanical behaviors of mortar through flexural strength, compressive strength and tensile strength test, and analyze the modified mechanism through scanning electron microscope (SEM).

MATERIALS AND METHODS

Materials

Type 42.5 ordinary Portland cement was used in this study, which was obtained from Jidong cement industry. The physical mechanical properties of the cement are listed in Table.1. Four kinds of polymer latex including CR, SBR and PVAc were used in this study, which physical property is presented in Table.2. The silica sand (40~80 mesh) was selected in the study. Water reducing ration of polycarboxylic series of water reducer is 25%, and its solid content is 18%. The defamer was obtained from Zhenpin chemical limited industry in Shanghai.

<table>
<thead>
<tr>
<th>Index</th>
<th>Flexural strength (MPa)</th>
<th>Compressive strength (MPa)</th>
<th>Setting time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3d</td>
<td>28d</td>
<td>3d</td>
</tr>
<tr>
<td>P.O 42.5</td>
<td>21.5</td>
<td>50.8</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Table 2. Physical property of polymer latex.

<table>
<thead>
<tr>
<th>Index</th>
<th>Appearance</th>
<th>Solid content(%)</th>
<th>Viscosity (Pa•s)(25°C)</th>
<th>Chemical stability</th>
<th>Mechanical stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR</td>
<td>Creamy white liquid</td>
<td>44</td>
<td>1.34</td>
<td>qualified</td>
<td>qualified</td>
</tr>
<tr>
<td>SBR</td>
<td>Creamy white</td>
<td>43</td>
<td>1.47</td>
<td>qualified</td>
<td>qualified</td>
</tr>
<tr>
<td>SA</td>
<td>Creamy white liquid with blue light</td>
<td>48</td>
<td>1.36</td>
<td>qualified</td>
<td>qualified</td>
</tr>
<tr>
<td>PVAc</td>
<td>Creamy white liquid</td>
<td>46</td>
<td>1.55</td>
<td>qualified</td>
<td>qualified</td>
</tr>
</tbody>
</table>

*Methods*

The following four test programs were carried in this study:

The determined water cement ratio was 0.42, and the cement sand ratio was 1:2. The polymer cement ratio varied from 0 to 25% by 5% intervals. The amount of the water reducer varied from 0 to 2% to ensure the mixtures had a similar flow and can be cast easily. Furthermore, the defoamer (0.2%) was added to reduce porosity and improve the mechanical strength. The content all mans effective component content in the later paper.

The mixing phase consisted of four steps: a. Dry particles were mixed (cement and sand) for 2 min at 140 rpm in a planetary Hobart mixer. b. The polymer was added to the water, then pouring into the bowl, and mixing continued for 2 min at 280 rpm. c. Water reducer was added to the mortar in the bow and mixing continued for 1 min. d. defoamer was mixed with the mortar 60 rpm for 4 min.

Immediately after mixing, the cement-based material was poured into $4 \times 4 \times 16 \text{cm}^3$ parallelepiped mould for flexural and compressive strength, and a 8-form parallelepiped moulds for tensile strength. Then, samples were conserved for 24h in a curing chamber (90% of relative humidity and $20 \pm 1 \degree C$). The samples were removed from the moulds and immersed in another curing chamber (65% of relative humidity and $20 \pm 1 \degree C$) until the testing deadline.

Flexural and compressive strength tests were performed following European Standards. For each mix, three samples were tested in flexural, which resulted in six samples available for compression strength measurements. Tensile strength tests were conducted through direct tensile method by universal testing machine. Three samples were tested for each group.
A scanning electron microscope (SEM) from Hitachi Instruments Ltd, Japan, was used to characterize the micro-morphology of mortar samples. The samples should soak in the ethyl alcohol to end the reaction, then be treated by the Gold sputtering.

RESULTS AND DISCUSSION

Flexural strength measurement

FIG.2 compares 7 days flexural strength of CR, SBS, SA and PVAc modified cement mortar with polymer content, and FIG.3 shows 28 days flexural strength. The results show that all kinds of latex can improve the flexural strength. 7 days flexural strength of all modified mortar increase with the polymer added. While 28 days flexural strength curve reach its highest level in 15% polymer content, and drops slightly above 15% content. It may relate to the flexible structure of polymer, which improve effectively anti-folded capability of cement mortar.

The CR modified mortar shows the lowest flexural strength below the 15% content compared with others, while its flexural strength is little bigger than that of SA modified mortar. The 7 days flexural strength of SA modified mortar increases steadily from 5.5MPa to 6.2MPa, while the 28 days flexural strength curve remains stable at 8.5MPa with SA emulsion content. The presence of SBR and PVAc latex promote both7days and 28days flexural strength obviously. The 7 days flexural strength of PVAc modified mortar grow from 5.3 to 7.7, with 45% increasing range, and the 28 days strength reach its peak at 12.5MPa in 15% polymer content.
**Figure 3. Relationship between 28 days flexural strength of mortar and polymer content.**

**Compressive strength measurement**

FIG.4 illustrate 7 days compressive strength curve with the polymer content change, and 28days compressive strength curve is shown in FIG.5. It can be seen obviously that presence of polymer lowered compressive strength, and compressive strength falls to its lowest point at polymer content below 5%. Almost compressive strength of modified mortar experience increase in the content of 5% to 15%, and see an opposite trend above 15%. 7 days compressive strength of SBR and SA modified mortar shows decrease above 20%, and the same is true of 28 days compressive strength of SA modified mortar. There are several possible explanations for this result. The porosity of mortar increases with the low content polymer adding, and cross-linked network may be formed at higher content polymer. However, the excess of polymer may adhere to surface of hydrated products, which may hinder ionic migration of hydrated products and delay the hydration process.

CR and SA modified mortar appearance lower compressive strength compared with that of SBR and PVAc. SA modified mortar experiences slight change in compressive strength. PVAc shows the best improvement in compressive strength of mortar, which is higher about 25% than CA mortar in the same content.

**Figure 4. Relationship between 7 days compressive strength of mortar and polymer content.**
Figure 5. Relationship between 28 days compressive strength of mortar and polymer content.

Tensile strength measurement

Relationship between 7 days and 28 days tensile strength of mortar with polymer content are shown in FIG.6 and FIG.7 respectively. The tensile strength curve is similar to flexural curve. From these results it can be seen that the presence of polymer emulsion increases the tensile strength. The improvement effect order of different polymer is PVAc>SBR>SA>CR. 7 days tensile strength of PVAc modified mortar reaches the highest level at 7.0MPa in 15% content, which is more 30% promotion than that of traditional mortar. After peaking at 9.2MPa in 20% content, 28 days tensile strength of PVAc modified mortar falls slightly.

Figure 6. Relationship between 7 days tensile strength of mortar and polymer content.

Figure 7. Relationship between 28 days tensile strength of mortar and polymer content.
SEM test analysis

This research selects PVAc (15% content) modified mortar to analyze micro-morphology comparing with traditional cement mortar. FIG.8 shows the scanning electron micrographs of ordinary cement mortar in 28 days. It can be seen that there are both more gel pores and capillary pores in the ordinary cement stones, so it performs worse compactness.

FIG.9 shows micrographs of PVAc modified cement mortar in 28 days. As a kind of high molecular material, PVAc almost combines with cement paste by physical function, while enrichment area of PVAc are appearance during the polymer content being added and overtaking the level. It may be caused by the different density of polymer, cement and sand, and it also can be explained through the assumption of Grosskurth that the polymer is pushed and concentrated by cement stone during hydration process. With water evaporating and observed by other base materials, the polymer particles interweaves with cement and hydration products through a condensation reaction. This conclusion can be proved by the result of FIG. 9. It can be seen that the presence of PVAc can reduce pores and increase the compactness of mortar. Crosslinking network structure of polymer with other materials can improve adhesion property of cement with sand, and toughness also can be increased.

CONCLUSIONS

Based on the laboratory test results and analysis of the modified mechanism, the following conclusions were drawn.

a. Four types of polymer emulsion can improve mechanical properties of cement mortar in a degree.
b. The SBR and PVAc latex can effectively increase the flexural strength of cement mortar.
c. The PVAc latex modified cement mortar. The tensile strength of all modified cement mortar were increased.
d. PVAc can interweave with cement and hydration products, and form crosslinking network structure, which is useful to improve toughness of mortar.

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