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Research on the mechanism of polymer latex modified cement

Min Wang [a], Rumin Wang [a,*], Hao Yao [a], Shameel Farhan [a], Shuirong Zheng [a,b], Zhujun Wang [a], Congcong Du [a], Hao Jiang [a]

[a] *The Key Laboratory of Space Applied Physics and Chemistry, Ministry of Education and Shaanxi Key Laboratory of Macromolecular Science and Technology, School of Science, Northwestern Polytechnical University, Xi'an 710072, PR China*
[b] *Northwestern Polytechnical University–East China University of Science and Technology Combined Research Institute of New High-Speed Railway Materials, PR China*

HIGHLIGHTS

- Divide the polymer latexes in modified cement field into two kinds.
- The mechanism contained physical and chemical aspects.
- The chemical reactions will build a 3D network structure.
- Provide a pathway to improve the flexural strength of cement composites.

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ABSTRACT

The mechanism of polymer latex modified cement was investigated by differential scanning calorimetry (DSC), Fourier transform infrared spectra (FTIR), X-ray photoelectron spectroscopy (XPS) and scanning electron microscope (SEM). Owing to the difference in polymer chains, most of the polymer latexes used in modified cement field can be classified into two kinds. Butyl benzene latex was used to represent the first kind polymer latex with no active groups in their polymer chains, the mechanism of these polymer latexes modified cement just contained physical modification mechanism. The latex film covered the surfaces of hydration crystals and filled the cracks and pores of cement, thus could able to give better performance to the modified cement. About the other, these polymer latexes with active groups which can react with hydration products to produce a 3D network structure in the modified cement system, such as carboxylic styrene butadiene latex. The mechanism of these polymer latexes included physical and chemical modification mechanisms. Meanwhile, the modification models of these mechanisms used in most polymer latexes have been put forward.

1. Introduction

Polymer modified cement mortars are widely used in civil infrastructures, bridges, external wall insulation mortar, self–leveling mortar and concrete repaired fields due to their excellent strength, environmental protection and workability [1]. In the earlier studies, the natural latex rubber modified cement mortar did not get the practical application because of its unsatisfactory compatibilities. Nowadays, the major latex includes butyl benzene latex (SBR latex) [2,3], neoprene emulsion (CR latex), polyvinyl chloride–vinylidene chloride emulsion (PVDC latex), styrene–acrylic emulsion (SAE latex) [4], carboxylic styrene butadiene latex (XSBRI) and polyacrylate (PA) latex [5], etc. In particular, SBR latex and XSBRI modified cement mortar exhibited the excellent toughness and water reduction, which have already been widely used as the adhesive, finishing materials and repairing materials for reinforced concrete structures [6,7].

With the addition of SBR latex and XSBRI; the tenacity, water retention, water reduction, fluidity and permeability resistance of modified cement mortars increase at different degrees. It is worth noting that the XSBRI (terpolymer of styrene, butadiene and carboxylic acid) latex modified cement mortar has more excellent performance compared with SBR (binary copolymer of styrene and butadiene) latex. SBR latex is a binary copolymer of styrene and butadiene and there are no active groups in the polymer chains. However, a large number of carboxyl groups exist in the XSBRI chains. Therefore, it is necessary to investigate the difference of mechanism between SBR latex and XSBRI in the modified system. These works will not only provide the theoretical basis

* Corresponding author.
E-mail address: wangmin19@mail.nwpu.edu.cn (R. Wang).

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for further application of polymer latex in the modified cement field, but will also bring a new train of thought for the development of new type polymer latex modified cement materials.

In the 1980s, Ohama [8] and Konietzko's [9] mechanism divided the process of polymer latex modified cement mortars into three and four phases, respectively. The characteristic of these two theories was based on the physical action of latex film in the modified system, hydration products and cement particles. In the view of Ohama, hardened cement paste was wrapped in polymer film, but Konietzko regarded that polymer and cement paste as a net structure; interpenetrate on each other to get the shape of network structure. Since then, there are two viewpoints about the polymer latex modified cement mortar. The first one was based on the physical behaviors of polymer latex in the cement hydration process [10]. Along with the hydration, polymer covered the surface of cement particles and hydration products, or filled in the cracks of cement hydration system. These physical functions could improve the porosity of cement. Another one considered that except the physical action between polymer latex and cement, there also contained chemical reactions. The chemical reaction obtained the chelation, which was linked by chemical bond to increase the property of cement [11–13]. In our previous researches, the mechanism of polyacrylate (PA) latex modified cement has been studied. The results showed that carboxyl groups of PA polymer chains participated the chemical reaction during the process. These chemical reactions between PA latex and cement generated a network structure, in which Ca^{2+} served as the cross-link point and linked different PA polymer chains together [14].

Here, we used SBR latex and XSBRI as typical cases to research the mechanism of polymer latex modified cement. The chemical interactions and physical configuration in polymer latex modified cement system were researched by means of DSC, FTIR, XPS and SEM. The polymer latex can be divided into two types, the first kind was represented by SBR latex which just contained physical modification mechanism in the modified system, and another kind was represented by XSBRI, which contained physical and chemical modification mechanism in the modified process. Based on the experimental results, an advanced model of physical and chemical modification mechanism has been established.

2. Experimental sections

2.1. Materials

The materials used in this research were Portland cement type 52.5R, ISO (International Standardization Organization) standard sand, SBR latex and XSBRI. The chemical composition of the cement is shown in Table 1, and the properties of the SBR latex and XSBRI are followed in Tables 2 and 3, respectively. Also, the deionized water was used in this study.

2.2. Sample preparation

In this research, the cement paste (cement, water and polymer latex) was used to investigate the physical and chemical modification mechanism in the polymer latex modified cement system. Then, the cement mortar (cement, sand, water and polymer latex) was mainly employed to study the influence of polymer latex on the mechanical properties of cement mortar. The ratio of water and cement was regularly kept at 0.5, and the ratio of sand and cement was kept at 3.0. The polymer cement ratio ranged from 0 to 20% (in solid content) in polymer latex modified cement.

Table 2
Properties of the SBR latex[a].

pH value	Particle size/nm	Glass transition temp/°C	Solid content/%	Viscosity/mPa s
9.8	700	−63	71.36	440

[a] The SBR latex in this research was produced by Kumho Petrochemical (KSL341).

Table 3
Properties of the XSBRI.[a]

pH value	Particle size/nm	Glass transition temp/°C	Solid content/%	Viscosity/mPa s
8.0	200	−20	50.00	470

[a] The XSBRI latex in this research was produced by Guangzhou Kaiju Chemical Company Ltd (BS–403).

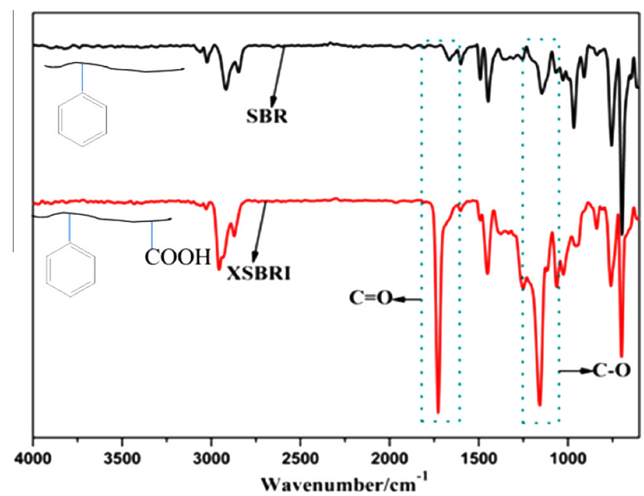

Fig. 1. The ATR–IR spectra of SBR latex and XSBRI.

Firstly, the polymer latex and water was added to a stainless steel container in turn and mixed well. Secondly, the mixture of polymer latex and water was divided into three equal parts. Finally, these three parts mixture were added into cement (or the cement and standard sand) in the time intervals of 3 min and mixed well. Three specimens for each test were immediately poured into the mold of 40 mm × 40 mm × 160 mm size. The specimens were allowed to cure in the mold for 24 h. During this period the specimens were covered with wet towel. After 24 h, the specimens were cured in water at 20 ± 2 °C for 6 days and then cured at 20 ± 2 °C/RH50 ± 5% in the next 21 days.

The paste samples for 28 days were firstly broken into pieces, then the fresh surfaces were selected and cleaned with anhydrous ethanol. After that, put them into the drying oven at 40 °C for 24 h in order to prepare the sheet samples. Finally, ground the sheet samples into powder and through a sieve (200 mesh), preparing the powder samples.

2.3. Characterization

The attenuated total reflection spectroscopy (ATR–IR) was used to analyze the different chemical structures of SBR latex and XSBRI. The latex was put into a drying oven at 120 °C for 48 h to build a film. This film was used to ATR–IR analyses.

Table 1
Chemical composition of the cement (%).

Composition	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	K_2O	Na_2O	LOI
Content	65.1	21.3	5.1	2.9	1.1	1.8	0.7	0.3	1.7