The Influence of Regenerate Styrene Acrylic Emulsion on Thin Layer of Toughening Cement Mortar used on an Expandable Polystyrene Panel

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Abstract: Studied the waste expandable polystyrene (EPS) foam to reproduce styrene-acrylate emulsion (SAE) latex and applied in cement mortar. The results showed that the increase content with regenerate SAE, the amount of water used in mortar was decreased and the water reducing rate was increased gradually, the pull-off strength was increased. When the regenerate SAE content is 3% by weight, the destruction formation of EPS panel and the SAE modified cement mortar showed cohesive destruction, confirmed the toughness and adhesion of the cement mortar and EPS panel was improved. The ratio of compression strength and flexural strength were decreased with the increase content with SAE, after that had a slight growth. The ratio of compression strength and flexural strength was minimum when the SAE content is 3.5% by weight which suggested the optimum regenerate SAE content in this study.

Introduction

Expandable polystyrene (EPS) foam has desirable properties such as low thermal conductivity, low density, low price, insulation sound and impact resistance. These properties making EPS foam to be widely used as packaging materials during transportation and handling, as thermal insulation materials for refrigerators, as external thermal insulation materials for architectures [1].

Due to the widely usage, the quantity of waste EPS has been increasing in the waste stream every year. The author explored recycling waste expandable polystyrene (EPS) foam to reproduce styrene-acrylate emulsion (SAE) latex. These including pyrolysis of the polystyrene into low molecule hydrocarbons and using it as a fuel [2], recycling it by dissolving the foam using organic solvents[3]. The waste EPS foam recycling were accomplished by means of simple and efficient ways[4], which reduced the white pollution. The emulsion Applied to the modified mortar, and got a good toughening effect.

Experimental

Materials Information

Materials included butyl acrylate (BA), styrene (St), acrylic acid (AA), waste EPS foam, polyvinylalcohol, sodium bicarbonate, ammonium hydroxide and ammonium persulfate. The emulsifier was sodium dodecyl sulfate (SDS) and polyethylene glycol mono-p-nonylphenyl (OP-10) with a mix weight ratio of 1:1. Above mentioned chemical agents are analytic grade. The

cement was ordinary Portland cement P•O42.5 produced by Ya Dong company in China. chemical composition is as showed in Table 1. Quartz sand that the particle size is 0.03~0.08 mm.

Table 1 Chemical compositions of ordinary Portland cement.

SiO_2	CaO	Al_2O_3	FeO	SO_3	MgO	K_2O	Na_2O	Loss
21.3	58.2	9.4	2.63	3.51	0.98	0.41	0.397	3.18

Performance Evaluation Methods

The compressive strength and flexural strength test samples were prepared and cured according to Chinese standard GB 17671-1999.The pull-off strength of the polymer-modified mortars on EPS surface was tested according to JG149-2003. XRD phase analysis and SEM morphology analysis were performed with the related standards. Cement and quartz sand ratio is 1:2.5 by weight. The polymer content of regenerate SAE is designed from 0~3.5% by weight with Solid content. Water quantity is determined by cone penetration test according to JGJ 70–2009 when the penetration depth is controlled at 80±5mm.

Sample Preparation

The hard (St+EPS) and soft (BA) molecular total weight was 100g and kept at a weight ratio of 1:1. The content of waste EPS foam was from 0%~50% with a weight ratio of hard molecular. The weight of functional monomer total AA and the water were 2g and 120g, the content of Emulsifier, Initiator, Protective colloid were 3%, 0.4%, 2% respectively. The preparation process followed Fig1.

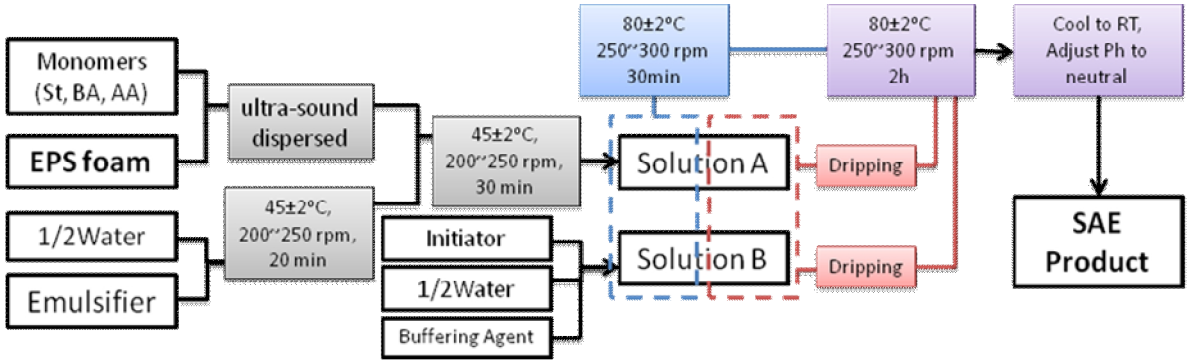


Fig 1 The preparation process of regenerate SAE

Fig.1 showed the SAE synthesis route. The measured waste EPS foam was dissolved in monomer solution and ultra-sound dispersed to prepare an EPS monomer mixture. Half of the deionized water, emulsifier were added into a 500ml flask with condenser, preheated at 45±2□ using an electric heater and agitated for 20 min at a speed of 200~250 rpm. The as prepared EPS/monomer mixture was all added into the flask and kept agitation at the same temperature for 30 min then a solution A which is a pre-emulsified liquid was prepared. The initiator and the buffering agent were prepared as solution with the rest de-ionized water, denoted solution B. Half of solution A and half of solution B were added into a four-neck flask and heated to 80±2 □ with agitation speed of 250~300 rpm and kept for 30 min. The rests of solution A and solution B were added drop wise with separate dripping funnels. The product was cooled downed to room

temperature in the air after reacting for 2h and used the buffering agent adjusted Ph to neutral Results showed the stable regenerate SAE can be produced with EPS <30%[5].

Results and Discussion

The relationship between regenerate SAE content and water quantity and water reducing rate were summarized in Fig.2. The amount of water used in mortar decreases gradually and the water reducing rate increases gradually with the increase of the regenerate SAE. The main reason is that the regenerate SAE can introduce bubble bearing effect and the dispersion of the surfactant[6].

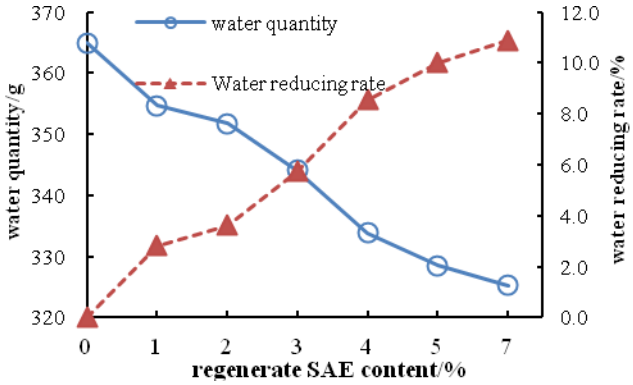


Fig.2 The water quantity and water reducing rate with different solid dosages of regenerate SAE

The 7d and 28d compression strength for mortars modified by regenerate SAE latex were summarized in Fig.3. The polymer content for regenerate SAE is the solid content of the emulsion. Accord to these curves, both compression and flexural strength showed a maximum peak followed by a sharp decrease in 7d and 28d results. For mortars modified by regenerate SAE, the maximum is at the polymer concentration of 0.5%. The ratio of compression strength and flexural strength of 7d and 28d were decreased with the increasing dosage of regenerate SAE, it was minimum when the SAE dosage is 3.0%~3.5%.

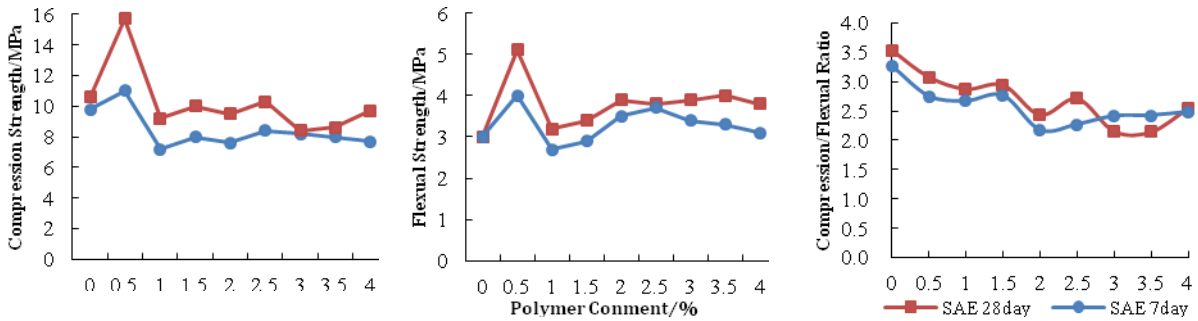


Fig.3 The compressive strength, flexural strength of 7d and 28d with different solid dosages of regenerate SAE

The cement particle can be dispersed better with bubble bearing effect and the dispersion of the surfactant, free water that can be wrapped by cement particle is fully released. Hence, less water was required in the same fluidity. When SAE content reaches a certain amount, this effect is not very significant. On the other hand, the continuous polymer film will gradually formed with the increase content of regenerate SAE, the continuous polymer film restrain the hydration of cement and fill the void of cement hydration. So, the compressive and flexural were decreased and the toughness was increased when the content continue to increase[7] .

Table 2 showed The pull-off strength and the cohesion destruction area with different contents of regenerate SAE. The pull-off strength of mortar and EPS panel was increased with content of regenerate SAE increasing, destruction formation was “I” Gradually transformed into “C”, destruction area was gradually increased. When the dosage was 3%, the destruction formation was “C”, destruction area was 90%. So the content of regenerate SAE was 3%, can meet the requirements of pull-off strength[8].

Table 2 The relation regenerate SAE and pull-off strength

dosages	0	0.5%	1%	1.5%	2%	2.5%	3%	3.5%
pull-off strength(MPa)	0.112	0.123	0.131	0.155	0.182	0.229	0.25	0.253
destruction formation	I	I	I	I	I+C	I+C	C	C
destruction area	0	0	0	0	15%	70%	90%	100%

“I”: interface destruction, “C”: cohesion destruction

Fig 4 showed the surfaces destruction formation of the pull-off strength. Cohesion destruction of sample showed in Fig. 4a had all EPS foam be pulled out. Fig. 4c showed destruction area was totally at the interface. Fig. 4b had partial EPS foam be pulled out.

Fig 4 a) Total b) Partial cohesion destruction c) destruction at the interface

Fig 5 showed the hydration cement mortar of 7d, the diffraction peak of $Ca(OH)_2$ was 18.1°and 28.5°, diffraction peak height was gradually reduced with the increasing content of regenerate SAE. At the same time, the content of $Ca(OH)_2$ in cement mortar was reduced. Moreover $Ca(OH)_2$ was the production of cement mortar hydration. Therefore, regenerate SAE had restrained the cement mortar hydration.

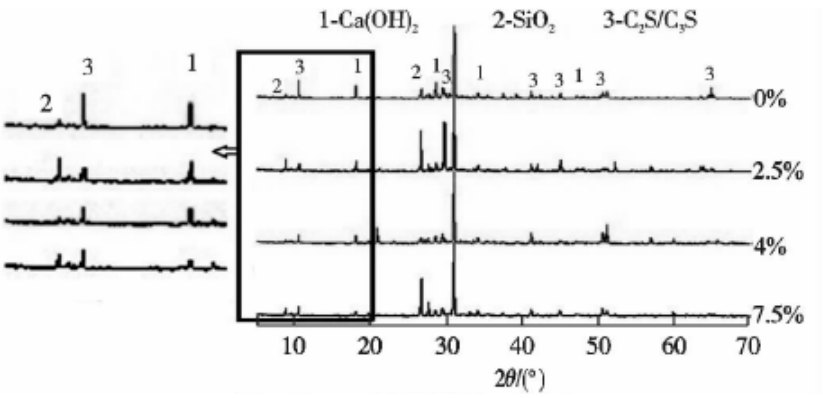
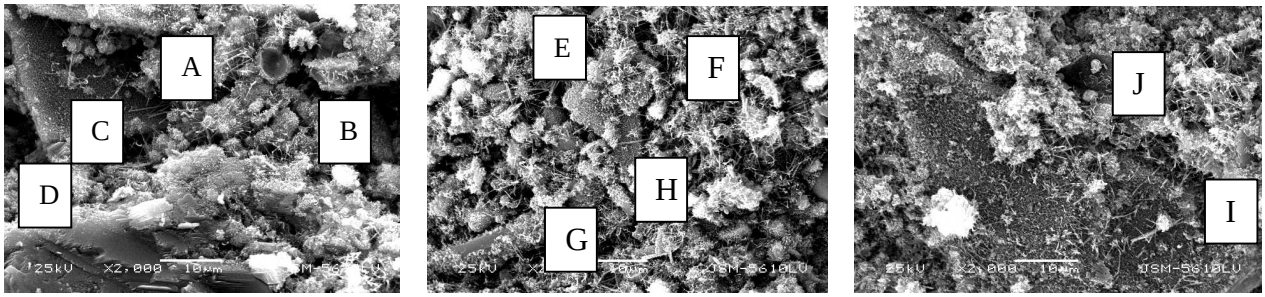


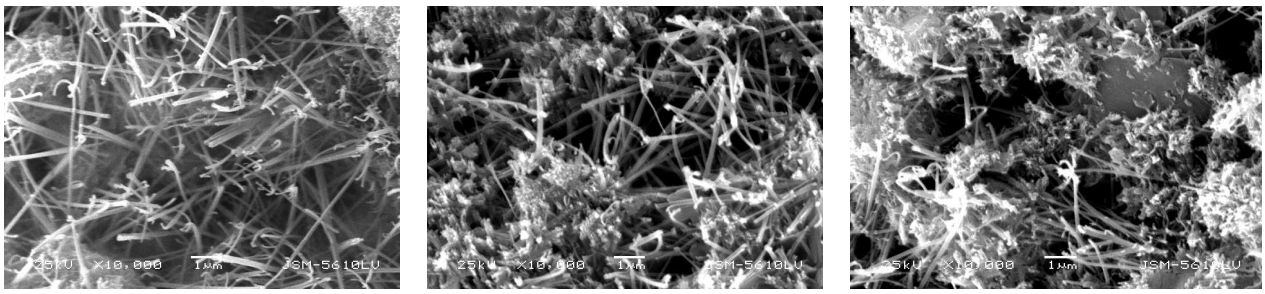
Fig 5 The XRD phase analysis of cement mortar with different dosage of regenerate SAE

Fig 6 showed the SEM morphology of the 7d hydration of cement mortar with different contents of regenerate SAE under the 2000 times. We can observe a little of acicular ettringite crystals in figure a. The sample surface of the B、C、D can be observed Obviously large pores after cement mortar solidification, and the quantity was largely, the structure was loosely. We cannot discover large pores in figure b, but the surface of E、F can be observed Obviously small pores, the sample structure was more densely in figure b than figure a, and flocculent material existed in G、H, wrapped in the surface of the sample, that may be formed by regenerate SAE. The sample surface structure was most densely in figure c. We cannot discover large pores and can observe a little of small pores, and mesh structure material can be observed in I、J. Because of regenerate SAE gradually formed a polymer film as the hydration of cement mortar, the polymer film adsorbed in the cement mortar surface or filling in the pores in the process of hydration cement mortar. So the structure of the cement mortar was more densely with the increase of dosage regenerate SAE.



a b c

Fig 6 The SEM morphology analysis in 2000 multiple of cement mortar with different dosage of regenerate SAE a) 0%, b) 4%, c) 7.5%



d e f

Fig 7 The SEM morphology analysis in 10000 multiple of cement mortar with different dosage of regenerate SAE d) 0%, e) 4%, f) 7.5%

Fig 7 showed the SEM morphology of the 7d hydration cement mortar with different dosage of regenerate SAE under the 10000 times. We can observe a large number of acicular ettringite crystals in figure d, but the sample structure was loosely. We can observe a large number of flocculent or mesh structure material wrapped in the surface of the ettringite crystals in figure e, the structure was more densely than sample in figure d. The flocculent and mesh material was increased in figure f, and bonded in together, formed a polymer film structure, firmly wrapped in the surface of the ettringite crystals, made the sample structure was most densely than sample in figure d and in

figure e. That showed regenerate SAE can form a polymer film in the process of cement mortar hydration, the polymer film wrapped the cement particle, delayed the hydration of the cement mortar.

Conclusions

The regenerate SAE latex added to cement mortar can disperse cement particle, free water that can be wrapped by cement particle is fully released. Hence, less water was required in the same fluidity. Can also form thin polymer film in the process of cement mortar hydration, that can delay the hydration of the cement mortar. Although the polymer film reduced the compressive strength greatly, increased the bonding strength and toughness of the mortar. The bonding strength of cement mortar and EPS panel was increasing with the increasing of regenerate SAE content. When the content was 3%, the destruction formation was cohesion destruction, the bonding strength was maximum. The ratio of compression strength and flexural strength of 7d and 28d were decreased with the increasing dosage of regenerate SAE, it was minimum when the SAE dosage is 3.5%, the toughness of cement Mortar had improved.

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