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St/BA 폴리머 시멘트 모르타르의 물리적 특성 및 내구성

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Physical Properties and Durability of Polymer Modified Mortar Using Styrene and Butyl Acrylate Latexes

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초록: 본 연구에서는 스티렌(styrene; St)과 부틸아크릴레이트(butyl acrylate; BA)를 단량체 비에 따라 합성 제조하고, 합성제조된 시멘트 혼화용 폴리머를 혼입한 폴리머 시멘트 모르타르의 물리적 성질과 내구성에 대한 특성을 보통 시멘트 모르타르와 기존에 생산되어 현장에 적용되고 있는 St/BA계 폴리머 시멘트 모르타르를 비교 분석하고자 하였다. 실험결과, St/BA의 단량체 비가 50:50, 60:40일 경우에는 시멘트 혼화용으로 사용하기에 가장 적합하였으며, 강도특성에서도 우수한 결과를 나타냈다. 또한, 방수성능과 염화물 이온에 대한 침투 저항성, 그리고 중성화 저항성도 St/BA의 단량체 비가 증가할수록, 폴리머 시멘트 비가 증가할수록 증진효과가 우수한 결과를 나타냈다. 따라서, 본 연구를 통해 합성제조된 St/BA 라텍스를 시멘트 모르타르에 혼입할 경우 우수한 성능개선 효과를 얻을 수 있었다.

Abstract: The effects of the monomer ratios on the typical properties of polymer modified mortars that contain styrene and butyl acrylate latexes was investigated. Basic data was also obtained that is necessary for the development of appropriate latexes for cement modifiers. Polymer modified mortars that contain styrene and butyl acrylate latexes polymerized with various monomer ratios were prepared for different polymer-cement ratios. They were then tested to obtain the particle size of the polymer latexes, air contents, water-cement ratios, flexural and compressive strengths, water absorption, and chloride-ion penetration. From the test results, the polymer modified mortars that have styrene and butyl acrylate latexes (with the mix proportions of synthesis having monomer ratios of between 40:60 to 60:40 for the appropriate mix proportions) could be recommended for practical applications. The basic properties of the polymer modified mortars were more affected by the polymer-cement ratio than by the monomer ratio, and were improved over unmodified mortar.

Keywords: polymer modified mortar, monomer ratio, polymerization.

Introduction

Polymer modified mortars have been largely used as paving materials, flooring, waterproofing material, adhesives, anti-corrosive linings, deck coverings, and other various materials.[1-3] The various types and properties of the mixed polymer largely affect the characteristics of polymer modified mortar that has been mixed with polymer latexes. Consequently, its application purposes are varied according to these properties. Polymer can be classified as either a natural polymer or a chemically synthesized polymer. Natural polymers were more limited in tailoring the property compared to the synthetic polymers which can be prepared via a much more variety of synthesizing techniques. Various differences are presented in the characteristics of chemically synthesized polymers, according to synthetic methods and mixture conditions, such as the types or amount of added monomer, emulsifier, or initiator.[4,5] The purpose of this study is to investigate the effects of these various synthetic conditions, such as the types of monomer [St/BA; styrene-butyl acrylate], and the monomer ratios, on the properties of polymer modified mortars. The aim of the study is also to obtain basic data necessary to develop appropriate polymers for cement modifiers.

In this paper, the polymer modified mortars that have St/BA

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latexes and are polymerized with various monomer ratios are prepared with various polymer−cement ratios, and tested for air contents, strengths, water absorption, chloride−ion penetration, and carbonation of St/BA−modified mortar. From the test results, the effects of monomer ratios and polymer−cement ratios on the properties of polymer modified mortars are discussed.

Experimental

Emulsion Polymerization of St/BA Latexes. The polymer latexes were synthesized by emulsion polymerization using different monomers of St/BA. Ratios for the St/BA monomer were selected as 40:60, 50:50, and 60:40. Firstly, the reactor was charged with the desired quantities of monomer, emulsifier, and de−ionized and distilled water, and an initiator solution was prepared by dissolving KPS in DI water. Subsequently, dissolved oxygen was purged out by bubbling nitrogen gas through the reaction mixture. The initiator solution, which had previously been deoxygenated with the nitrogen gas and stored in a dropping funnel, was poured into the reaction mixture for 12 to 24 hours, in order to begin the process of polymerization. For all experiments, the reaction temperature was maintained within 80 ℃. The basic properties of syntheszed polymer is represented in Table 1.

Materials and Mix Proportions. An ordinary Portland cement specified in KS −L5201 was used in all the mixes. Siliceous sand (sizes: 0.25−0.6 mm), as specified in KS−L5100, was prepared as fine aggregate. Table 2 and Table 3 represents the chemical and physical properties of ordinary portland cement and Table 4 represent the properties of fine aggregate. The mortar mix proportions used in this investigation are as follows: a cement–sand ratio of 1 : 3 (by weight); and polymer−cement ratios of 0, 5, 10, 15, and 20% (calculated on the basis of the total solids of emulsions). The degrees of flow for the mortars were maintained within 170±5 mm by controlling the water−cement ratio. An antifoaming agent was added at a proportion of 0.7% in order to prevent air entrainment. Table 5 represent the mix proportion of St/BA−modified mortars.

Experimental Methods. The degree of flow and the air content were tested according to KS−L5105, and KS−F2409 respectively. The flexural and compressive strengths were tested according to KS−F2477, and water absorption was tested according to KS−F 4916. The chloride−ion penetration depth was tested according to KS−F2476. The cured beam specimens 40×40×80 mm, whose top and bottom surfaces were coated with an epoxy resin paint, were immersed in a 2.5% NaCl solution at 20 ℃ for 28 days for chloride ion penetration. After immersion, the beam specimens were split, and the split cross sections were sprayed with a 0.1% sodium fluorescein and 0.1 N silver nitrate solutions. The depth of the rim of each cross section changed to white color was measured by using slide calipers as a chloride ion penetration depth as seen in Figure 1. For the accelerated carbonation test, the test

Table 1. Properties of Polymer Dispersions for Cement Modifiers

Styrene content(%)	Monomer ratio (St/BA), by weight	Specific gravity(20℃)	pH (20℃)	Total solid (%)
SBP*		1.04	7.7	56.0
40	40:60	1.04	6.0	47.5
50	50:50	1.04	6.0	47.7
60	60:40	1.04	7.0	47.6

* Ready−made St/BA dispersion for cement modifier.

Table 2. Chemical Compositions of Ordinary Portland Cement

SiO_2	Al_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	Fe_2O_3
21.09	4.84	63.85	3.32	3.09	1.13	0.29	2.39

Table 3. Physical Properties of Ordinary Portland Cement

Specific gravity (20 ℃)	Blainess specific surface(cm^2/g)	Setting time		Compressive strength of mortar(kgf/cm^2)		
		Initial set (min)	Final set (h)	3d	7d	28d
3.15	3300	240	7:00	196	228	378

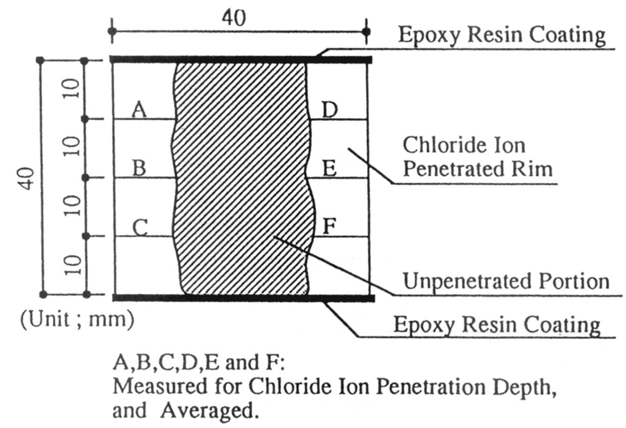
Table 4. The Properties of Fine Aggregate

Max. size (mm)	Unit weight (kg/L)	Specific gravity (20 ℃)	Water absorption (%)	Solid volume percentage(%)
<1.2	1.5	2.62	0.40	58.1

Table 5. Mix Proportions of Polymer Modified Mortars

Type of mortar	Cement : Sand	P/C (%)	W/C (%)	Air content (%)	Flow
Un−modified	1 : 3	0	67	3.6	167
SBP−modified	1 : 3	5	68	5.4	169
		10	63	8.0	169
		15	59	9.2	170
		20	56	10.9	171
SB40−modified	1 : 3	5	61	7.9	169
		10	54	8.8	170
		15	51	10.9	169
		20	47	13.0	172
SB50−modified	1 : 3	5	60	8.0	171
		10	55	9.9	172
		15	49	12.1	170
		20	45	12.8	169
SB60−modified	1 : 3	5	62	9.2	173
		10	56	11.2	169
		15	54	13.5	170
		20	49	14.1	171

*Bound styrene content.



$$\mathrm{Depth\,(mm)} = \frac{A+B+C+D+E+F}{6}$$

Figure 1. Cross section of specimen after chloride ion penetration test.

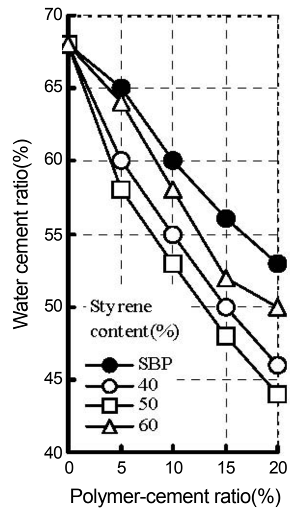


Figure 2. W/C of PMM.

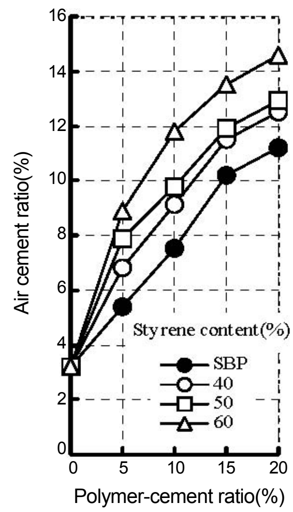


Figure 3. A/C of PMM.

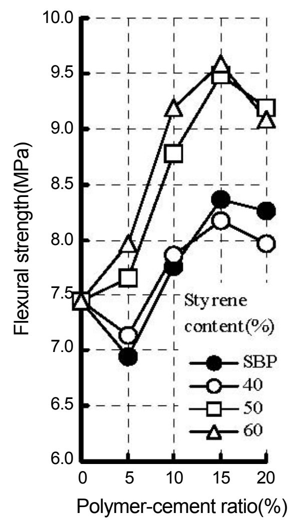


Figure 4. Flexural strength of PMM.

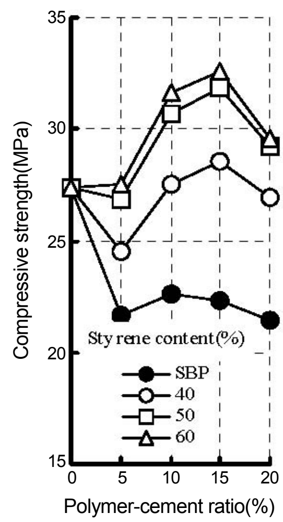


Figure 5. Compressive strength of PMM.

specimen that had been cured for 28 days was stored in a carbonation accelerator (temperature: 25 ℃, relative humidity: 40%, CO_2 concentration:15%) for 14 days. Then it was equally divided in to two, and the part that did not turn red when 1% phenolphthalein solution was sprayed on its cross-section was used to measure the carbonation depth.

Results and Discussion

Properties of the Fresh Polymer Modified Mortars that Contain St/BA Latexes. Figure 2 shows the water-cement ratios of polymer modified mortars that have St/BA latexes. The water-cement ratio of St/BA polymer modified mortars decreases markedly with an increase in the polymer-cement ratio. It is assumed that this is the result of an improved workability due to the ball bearing action of the entrained air and the dispersing effect of surfactants in the latexes. The water-cement ratios of the St/BA-modified mortars noticeably decrease at a styrene content of 50%.

Figure 3 shows the air content of polymer modified mortars that contain St/BA latexes. In general, the air content of the polymer modified mortars that have St/BA latexes increases more significantly with an increase in the polymer-cement ratio than it does with an increase in the monomer ratios. St/BA-modified mortars represent a considerably large air content than the unmodified mortar because of air entrainment. In this study, the air content of the St/BA-modified mortars ranges from 5.4 to 14.6%.

Strength Properties of Polymer Modified Mortars Using St/BA Latexes. Figure 4 shows the flexural strength of polymer modified mortars using St/BA latexes. The flexural strength of polymer modified mortars that have polymer-cement ratios of 5 to 15 percent increase with an increase in the bound styrene content, and reaches a maximum at a bound styrene content of 60 percent. However, the polymer modified mortars that have a bound styrene content of 40 percent and the polymer modified mortars that have a polymer-cement ratio of 5 percent, have a lower flexural strength than the unmodified mortar. It seems that a reduction in the flexural strength of the polymer modified mortars that have a bound styrene content of 40 percent depends on the lower strength of the polymer films in the mortars, and a continuous polymer film is not properly formed. The flexural strength of polymer modified mortars that have a bound styrene content of 50 and 60 percent increases markedly with an increase in the polymer-cement ratio. The highest flexural strength is obtained at a bound styrene content of 60 percent and a polymer−cement ratio of 15 percent.

Figure 5 illustrates the effect of the bound styrene content and the polymer−cement ratio on the compressive strength of the polymer modified mortars that contain St/BA latexes. The compressive strength of the polymer modified mortars increases with an increase in the bound styrene content and a maximum compressive strength is reached at a bound styrene content of 60 percent. Similarly to the flexural strength, the highest compressive strength is obtained at a bound styrene content of 60 percent and at a polymer−cement ratio of 15 percent. However, polymer modified mortars that have a bound styrene content of 40 percent, and the polymer modified mortars that have a polymer−cement ratio of 5 percent, and SBP−modified mortar, show a lower compressive strength than the unmodified mortar.

Commonly, the most excellent flexural strength property has been reported when the polymer to cement (P/C) ratio is 10 or 15%. But if the polymer to cement ratio is continuously increased, the excessive formation of polymer film causes the reduction of the strength. At the current study, the most excellent flexural strength property was also observed when the polymer to cement ratio was 15% and the strength was reduced at the P/C ratio of 20%.[6]

Water Absorption of the Polymer Modified Mortars that Contain St/BA Latexes. Figure 6 shows the 48−hour water absorption of polymer modified mortars that contain St/BA latexes. The water absorption of polymer modified mortars that have St/BA latexes is less than that of unmodified mortar, and tends to decrease considerably with an increase in both the polymer−cement ratio and the bound styrene content. An excellent waterproofing quality is achieved for the polymer modified mortars that contain St/BA latexes in the polymer modified mortar at a bound styrene content of 60 percent and a polymer−cement ratio of 20 percent. In general, the water absorption of polymer modified mortars decreases with an increase in the polymer−cement ratio.[7]

Chloride Ion Penetration of the Polymer Modified Mortars that have St/BA Latexes. Figure 7 presents the chloride ion penetration depth of polymer modified mortars that contain St/BA latexes. In a similar way to water absorption, the chloride ion penetration of the polymer modified mortars that have St/BA latexes is less than that of unmodified mortar, and tends to decrease steadily with an increasing polymer−cement ratio and an increasing bound styrene content. In particular, the resistance is relatively improved by approximately 3.1 to 1.3 times at the maximum and minimum level, compared to unmodified mortar. In addition, the resistance presents a greater difference for the polymer−cement ratio, than does the addition of bound styrene content. The highest resistance to the chloride ion penetration of polymer modified mortars that contain St/BA latexes is achieved in the polymer modified mortars at a bound styrene content of 60 percent and at a polymer−cement ratio of 20 percent, which is similar to the case of water absorption.

Carbonation of the Polymer Modified Mortars that Contain St/BA Latexes. Figure 8 presents the carbonation depth of the polymer modified mortars that contain St/BA latexes. The carbonation depth of the polymer modified mortars that contain St/BA latexes is less than that of unmodified mortar, and it tends to decrease with an increase in the polymer−cement ratio and an increase in the bound styrene content. The resistance to the carbonation of polymer modified mortars that have St/BA latexes presents a greater difference when the polymer−cement ratio is increased than when the bound styrene content

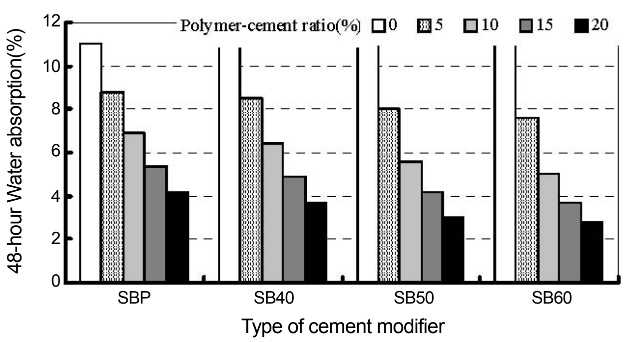


Figure 6. Water absorption of PMM.

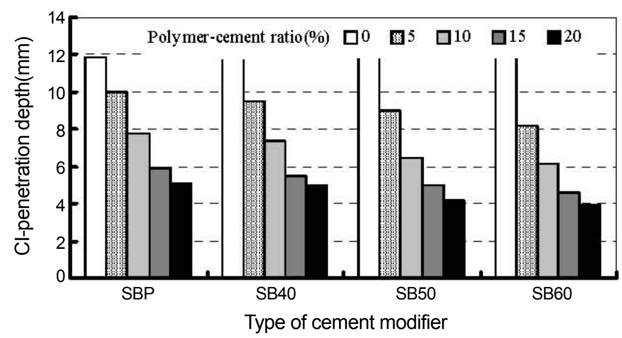


Figure 7. Chloride ion penetration of PMM.

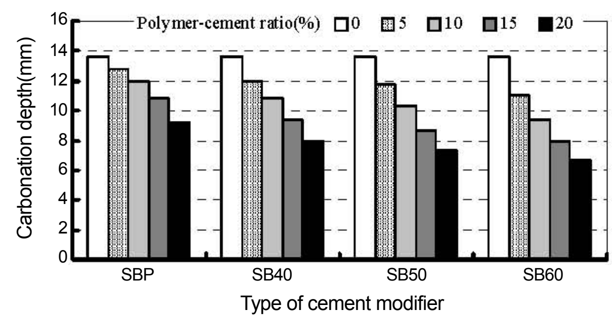


Figure 8. Carbonation depth of PMM.

is increased. The highest resistance to carbonation is achieved in the polymer modified mortars at a bound styrene content of 60 percent and a polymer−cement ratio of 20 percent. This is a similar result to that for water absorption and for the chloride ion penetration of polymer modified mortars that contain St/BA latexes. For the polymer modified mortars that have St/BA latexes at a bound styrene content of 60 percent and a polymer−cement ratio of 20 percent, the resistance to the carbonation is doubled.

Conclusions

The conclusions obtained from the test results for polymer modified mortars that contain St/BA latexes are summarized as follows:

1) The water−cement ratio of polymer modified mortars that contain St/BA latexes is markedly reduced with an increase in the polymer−cement ratio. This implies that an improved consistency is obtained from the ball bearing action between polymer particles and entrained air and from the dispersing effect of surfactants in the latexes.

2) In general, the polymer modified mortars that contain St/BA latexes show a considerably large air content compared to unmodified mortar because of air entrainment. The air content of the polymer modified mortars that have St/BA latexes is in the range of 6.8 to 14.6%.

3) The flexural and compressive strengths of polymer modified mortars that have St/BA latexes are generally improved over that of unmodified mortar, and increased when the styrene content was raised.

4) The water absorption, chloride ion penetration and carbonation of polymer modified mortars that contain St/BA latexes is less than that of unmodified mortar, and tends to decrease consistently when styrene contents are increased. However, the resistance presents a greater difference when the polymer−cement ratio is increased than when the monomer ratio is increased.

5) Consequently, it is concluded that, for practical applications, polymer modified mortars that contain St/BA latexes can be used in the same manner as ordinary polymer dispersion−modified mortars.

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