UDC 541.64 https://doi.org/10.26577/2218-7979-2016-9-2-27-31

[1,2*]El-Sayed Negim, [4]Bekbayeva L., [5]Irmukhametova G.S.,
[3]Kuzhantayeva A., [1]Sultanova D., [1]Suleimenova A., [4]Yeligbayeva G., [5]Mun G.A.

[1]School of Chemical Engineering, Kazakh-British Technical University, Almaty, Kazakhstan
[2]National Research Centre, Polymer & Pigment Department, Giza, Egypt
[3]Kazakhstan Maritime Academy, Kazakh-British Technical University, Almaty, Kazakhstan
[4]Kazakh National Research Technical University named after K.I. Satpayev, Almaty, Kazakhstan
[5]Department of Chemistry & Technology of Organic Materials, Polymers and Natural Compounds, al Faraby Kazakh National University, Almaty, Kazakhstan
[*]E-mail: elashmawi5@yahoo.com

Utilization of styrene copolymer lattices (DBSS/PVA) as chemical admixture for mortar

Abstract. The physical and mechanical properties of mortar containing copolymer lattices as chemical admixtures were investigated. Copolymer lattices used based on styrene and butyl acrylate were prepared in presence of potassium persulfate/sodium metabisulfite (KPS/NaMBS) as redox initiation system and a coemulsifier that consists of dodecyl benzene sodium sulfonate and polyvinyl alcohol (DBSS/ PVA). The results showed that the addition of copolymer lattices to mortar improves the physical and chemical properties of mortar. However, as the dosage of lattices increases, W/C ratio as well as workability increases while compressive strength and chemically combined water content decrease.

Key words: copolymer, lattices, strength, workability

Introduction

Dispersions lattices are important polymers which used as admixtures to modify physical and mechanical properties of cement, mortar and concrete [1-5]. Polymer lattices are water-soluble polymer particles suspended in an aqueous solution. Many of researchers have investigated the effects of polymer lattices including acrylic, epoxy and polyurethane on the properties of cement materials. In our laboratory, it is of interest to study the effect of acrylic lattices on the properties of cement pastes and mortar including water/cement ratio, workability, water absorption, porosity as well as strength. Negim et al prepared copolymer lattices based on 2-hydroxy ethyl acrylate & 2-hydroxy ethylmethacrylate [6-8], 2-hydroxy ethyl acrylate & vinyl butyl ether [9], acrylic acid & butymethacylate [10] and styrene & methacrylate [3, 11-13] using radical and redox initiators technique. The results showed that the acrylic lattices improved the physical and mechanical properties of cement pastes and mortar. Lattices modification of cement mortar is affected by cement hydration and polymer film formation processes in binder phase. This effect increases with increasing dosage of polymer lattices to mortar mixes. Barluenga and Olivares [14] studied the dosage of styrene-butadiene rubber latex on the properties of mortar including setting time, consistency, porosity and compressive strength. The results showed that water/cement ratio, setting time, porosity decrease and compressive strength increases with increasing the concentration of latexes. This is attributed to that styrene-butadiene-rubber has excellent bond strength in the concrete, higher flexural strength and lower permeability [15]. Alexandre et al [16] reported that as the concentration of ethyl vinyl laurate-chlorine polymer lattice increases from 2.5 to 5%, density, compressive strength of mortar decreased. Negim et al [11] prepared copolymer emulsion lattices based on styrene and butyl acrylate in presence of potassium persulfate/ sodium metabisulfite (KPS/ NaMBS) as redox initiator system and a coemulsifier dodecyl benzene sodium sulfonate and polyvinyl alcohol (DBSS/PVA). The effect of copolymer lattices on physico-mechanical properties of cement pastes was investigated. The results showed that as the concentration of copolymer increases, water/cement ratio, setting time and porosity decreases while compressive strength of cement pastes increases. The work was further extended to include the application of the obtained copolymer lattices with different dosages to modify the properties of mortar.

Materials and methods

Dodecyl benzene sodium sulfonate (DBSS) was used as anionic surfactant with a molecular weight of 348.48g/mole. The nonionic surfactants used were polyvinyl alcohol (PVA) with a molecular weight of 13,000. The chemical structure of the various surfactants is shown in Table 1.

The raw materials used in the present study are Portland cement clinker (PCC) and raw gypsum (G). Each of those raw materials was separately ground in a steel ball mill until the surface area of respectively 3650 and 2800 cm^2/g was achieved. The chemical composition of the raw materials is shown in Table 2. The mineralogical composition of the PCC sample is C_3S, 58.79 %; β- C_2S, 17.68 %; C_3A, 8.08 %; C_4AF, 9.72 %. The Portland Cement (PC) was prepared by mixing 96 % PCC and 4 % G (by weight) in a porcelain ball mill for one hour using 3 balls to ensure complete homogeneity of the cement. The Blaine surface area of the cement sample was 3350 cm^2/g [17].

The fine aggregate used was sand with particle size ranging from 0.21mm to 0.53 mm and is free from organic or clay-like materials.

Table 1 – The chemical structure of surfactants

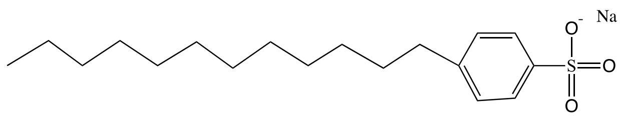
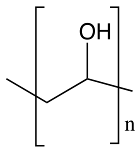
Surfactants	Symbol	Structure
Dodecyl benzene sodium sulfonate	DBSS	
Polyvinyl alcohol	PVA	

Table 2 – The chemical composition of the raw materials, mass %.

Oxides Materials	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	L.O.I
PCC	21.48	6.03	4.22	64.29	0.68	0.39	0.21	0.11	1.32
G	0.58	0.14	0.11	30.08	0.13	45.36	0.07	0.09	22.16

Synthesis and characterization of copolymers

Copolymer emulsion latexes based on styrene (St) with butyl acrylate (St/BuA) was synthesized with composition ratios (5: 5) using potassium persulfate/sodium metabisulfite (KPS/NaMBS) as redox initiation system in the presence of a co-emulsifier 2% dodecyl benzene sodium sulfonate with 1.5% polyvinyl alcohol (DBSS/PVA) The preparation of copolymers and the methods of analysis (^{1}H NMR, rheological and morphological techniques) have been previously described in a previous investigation [11].

Mixing and testing

Mortar specimens of size 70 mm cube were prepared in three groups. The control mix (M0) consists of Portland cement (PC), sand and water. The proportion of cement to sand was 1:3 (by weight). In mixes M1, M2 and M3, prepared lattices with dosage 0.25, 0.5 and 1.0 % was added. However, the mix M0 is the reference without lattices.

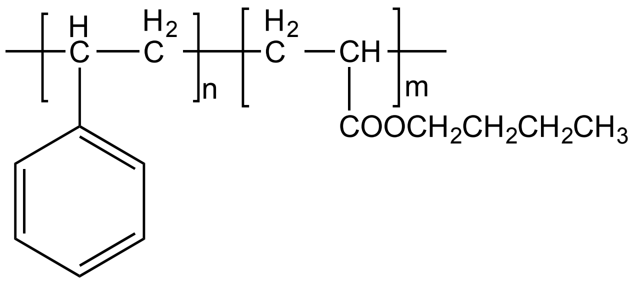
The cement and sand were intermixed until homogeneity was achieved. Then the prepared lattices were added to the mixing water. This was then added gradually to cement/sand mixture to determine the water of consistency using Vicat apparatus [18, 19].

The resulting mortar was directly placed into 70 mm cube stainless steel moulds. The moulds were manually agitated for 2 minutes and then on a vibrator for another 2 minutes. The moulds were kept in a humidity chamber at 100 % R. H and a constant room temperature overnight, then demoulded and cured under water till the time of testing. Testing included compressive strength, water absorption and combined water and was conducted at 1 day, 3, 7 and 28 days. The determination of water absorption as per the specifications of BS 1881: Part 122[20], compressive strength, water absorption and combined water were described in a previous investigation by the authors [21].

Results and discussion

Structure of Copolymers

The structure of the copolymers (St/BuA) is shown in Scheme 1 and further details about the synthesis and characterization have been previously reported by the authors [11].



Scheme 1 – The chemical structure of copolymer lattice [11].

W/C ratio

As shown in Fig. 1, styrene copolymer lattices reduce the W/C ratio of mortar compared to that of reference mix (M0). The reduction in W/C ratio is attributed to dispersion mechanism of styrene copolymer lattices on cement grain and coarse aggregate, this is in accordance with a previous study [6, 22]. However, the water /cement ratio of mortar increase with the addition of lattice (M3, 1%). Negim et al. [12, 13, 23, 5] found that styrene/methacrylate copolymers lattices reduced W/C ratio of mortar. Also, W/C ratio of mortar tends to change according to dosage of copolymer added to mortar during the mixing process (12, 13).

Workability

It is well known that the chemical admixtures have effective dispersing properties on the cement particles and improve the flow of mortar. Flow of mortar mixed with varied amount of styrene copolymer increased with increasing concentration from 0.25 to 1.0 %, as shown in Fig. 2. The increasing in workability of mortar is due to ball bearing action and dispersing effect of styrene copolymer particles among cement particles, there is a fluidity increase in the mortar mixture [12, 10]. In general, workability of mortar is affected by many factors such as composition, type, and functional groups of monomers in latexes [6]. When the concentrations of styrene copolymers are increased from 0.25 to 1.0%, the workability increased from 128 to 170 mm, due to the more water absorbed by the material. Negim et al., [6, 8, 10, 13] workability of the modified mortar increases with increasing latex concentration.

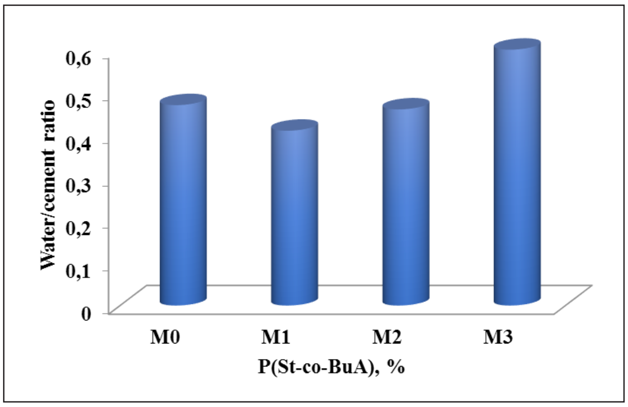


Figure 1 – The effect of copolymer lattices on the water/cement ratio of mortar.

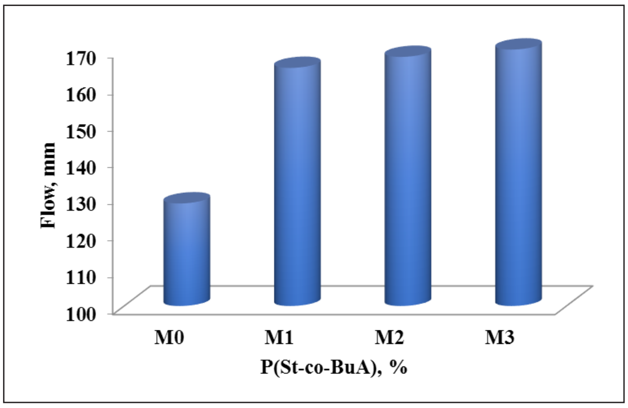


Figure 2 – The effect of copolymer lattices on the workability of mortar.

Compressive strength

Polymer lattices are admixtures that increased workability of mortar and produce high strength mortar. Fig. 3 shows the effect of dosage of copolymer lattices on the compressive strength of mortar. The compressive strength of mortar increases with curing time up to 28 days as shown in Fig. 3. This is attributed to the continual formation of hydration products, which tend to deposit into the pore structure of mortar cubes. The compressive strength of mortar tends to decrease with an increase in dosage of copolymer lattices. The highest compressive strength of mortar mixed with lattice (M1, 0.25%) while the lowest strength of mortar mixed with lattice (M3, 1.0%). It is well that the compressive strength of mortar is affected by dosage of the copolymer lattices [24, 25].

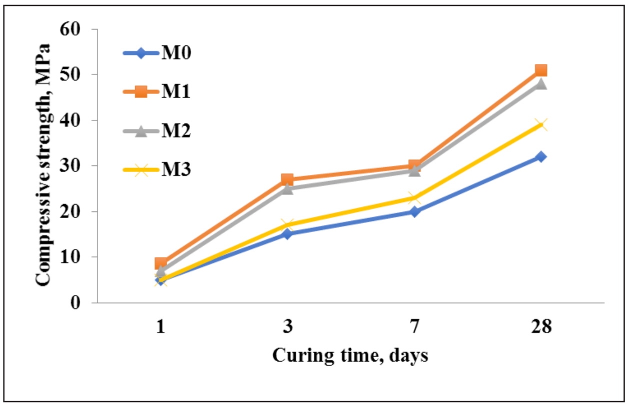


Figure 3 – The effect of copolymer lattices on the compressive strength of mortar.

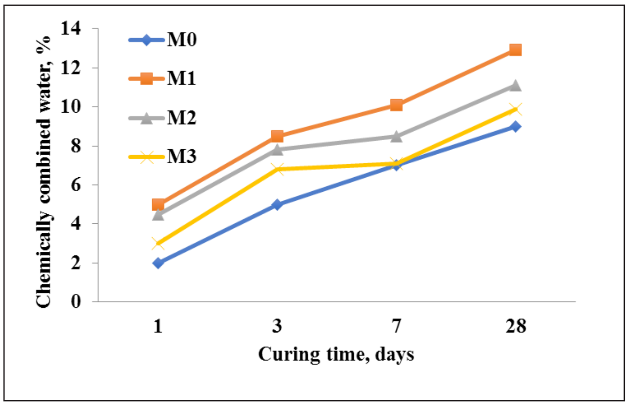


Figure 4 – The effect of copolymer lattices on the chemically combined water content of mortar.

Chemically combined water content

The chemically combined water contents of the mortar (M_0) and premixed with varying concentration of lattices are plotted as a function of curing time up to 28 days in Fig. 4. The results show that the combined water content of mortar increases with the increase of curing time. It is attributed to that the cement hydration process generally precedes the polymer film formation process by the coalescence of polymer particles in copolymer. As shown in Fig. 4, the addition of polymer lattices increases the chemically combined water content. However, the chemically combined water decreases with increasing dosage of lattices from 0.25 % to 1.0 %. The increasing in the chemically combined water content is attributed to the formation films of polymers around the cement grains or crystallizes inside the pore structure of the hardened cement pastes.

Conclusions

Mixing the mortar with the copolymers lattices enhance most of the specific characteristics of the mortar. The obtained results confirmed the important role of W/C-ratio on the effectiveness of the added copolymer so that their optimum values at W/C = 0.41. However, W/C ratio increased with increasing dosage of copolymer lattices in mortar mixes. There is evidently an improvement in the compressive strength of premixed mortar with copolymer for all experimentally at all curing ages of hydration compared with those of the pure cement pastes (M0) and good workability was achieved by mixing mortar with M3 (1% w/w lattices). There is an increase in the chemically combined water content of mortar premixed with 0.25% lattices (M1) compared with those mortar without polymer (M0), M2 (0.5 % lattices) and M3 (1.0 % lattices).

References

1. Y. Ohama, Handbook of Polymer-Modified Concrete and Mortars. Park Ridge, New Jersey, USA, 1995.
2. O. Xinping, G. Yongxia, Q. Xueqing, Constr. Build. Mater. – 2008. – 22. – P.1774–1779.
3. MMH Ayoub, MM El-Awady, HE Nasr, SM Negim, Polymer-Plastics Technology and Engineering. – 2003. – 42(5). – P.863-881.
4. MMH Ayoub, HE Nasr, MHH Darweesh, SM Negim, Polymer-Plastics Technology and Engineering. – 2005. – 44(2) – P.305-319.
5. ESM Negim, M Ramli, SE Mansour, B Saad, MI Saleh, Middle-East Journal of Scientific Research. – 2010. – 6(2). – P.99-107.
6. ESM Negim, J Khatib, MM Mohammed, SK Kerimbaevna, World Applied Sciences Journal. – 2012. – 19(6). – P.832-83.
7. ESM Negim, J Khatib, KA Mutairi, R Raikhan, MA Grigoriy, Middle- East Journal of Scientific Research. – 2012. – 11(8). P. 1131-1139.
8. ESM Negim, L Kozhamzharova, Y Gulzhakhan, J Khatib, L Bekbayeva, C Williams, The Scientific World Journal. – 2014. – 11. – P.235-241.
9. ESM Negim, J Khatib, M Ramli, B Saad, MI Saleh, World Applied Sciences Journal. 2010. – 10(6). – P.685-694.

10. ESM Negim, J Khatib, NO Inkarbekov, World Applied Sciences Journal. – 2013. – 23(4). – P.549-553.

11. SM Negim, MMH Ayoub, GM Enany, GA Mun, Eurasian ChemTech Journal. – 2006. -8(3). – P.243-252.

12. ESM Negim, M Ramli, B Saad, L Bekbayeva, MI Saleh, J. Polymer-Plastics Technology and Engineering. – 2011. – 50. – P.941 – 946.

13. ESM Negim, L Kozhamzharova, J Khatib, L Bekbayeva, C Williams, The Scientific World Journal. – 2014. – 10. – P.235-242.

14. G. Barluenga, F.H. Olivares, Cement and Concrete Research. – 2004. – 34. – P.527-535.

15. MA Bhutta, Y. Ohama, Concrete Research Letters. – 2010. – 1(4). – P.25-130.

16. M Alexandre, G Philippe, RR Humberto, Effect of EVLC latex polymer on masonry mortar properties and microstructure, 12th International BRICK/BLOCK Masonry Conference, Madrid-Spain, 25-28 June, 2000, – P.707-717.

17. ASTM C204-82, Standards Test Method, 1993.

18. ASTM C187-86, American Standard Test Method, 1993.

19. ASTM C191-92, American Standard Test Method, 1993.

20. BS 1881: Part 122 Testing concrete. Method for determination of water absorption, 1983.

21. ASTM C170-90, American Standard Test Method, 1993.

22. ESM Negim, N Rimma, L Bekbayeva, U Akmaral, BM Herki, N Merey, I Rinat, G Yeligbayeva. Oriental Journal of Chemistry. – 2017. – 33(1). P.450-457.

23. S.M. Negim, HY Cho, MMH Ayoub, SH Han, Effects of emulsifiers on the properties of styrene/methacrylate –type superplasticizer in cement paste. 4th International Symposium & Plasmo Chemistry. – Almaty, Kazakhstan, 12-14 September, 2007, P.135-139.

24. ESM Negim, G.Zh. Yeligbayeva, R. Niyazbekova, R. Rakhmetullayeva, A.A. Mamutova, R Iskakov, M Sakhy, GA Mun, International Journal of Basic and Applied Sciences. – 2015. – 4(3). – P.297-302.

25. ESM Negim, AMB Aisha, U. Yessimkanova , A. Kurmanbekova, K. Tyazhina, P.I. Urkimbaeva, R.K. Rakhmetullayeva, E. Shatabayeva, G. Irmukhametova, G.A. Mun, G.Zh. Yeligbayeva, JM Khatib, International Journal of Basic and Applied Sciences. – 2015. – 4(1). – P.10-18.