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

Abstract: Copolymer emulsion lattices based on styrene (St) and butyl acrylate (BuA) was synthesized with composition ratio (5/ 5) using potassium persulfate/ sodium metabisulfite (KPS/ NaMBS) as redox initiation in the presence of a coemulsifier dodecyl benzene sodium sulfonate/ polyoxyethylene glycol monomethyl ether (DBSS/ POE). The effect of concentration of copolymer lattices on the physico-mechanical properties of mortar was investigated. The results showed that, as concentration of copolymer lattices increased, W/C ratio, setting time as well as water absorption decrease, while compressive strength increases.

Key words: copolymer, lattices, strength, workability

Introduction

Chemical admixtures are chemicals that add to cement, mortar as well as concrete to improve the physical and mechanical properties including W/C ratio, setting time, water absorption, chemically combined water, compressive strength,...etc [1-10]. Admixtures can be classified by functions as air-entraining, water-reducing, plasticizers, accelerating, retarding, hydration-control, corrosion inhibitors, shrinkage reducers, alkali-silica reactivity inhibitors, and miscellaneous [10-20]. Admixtures modified mortars and concrete such as polymer lattices, water-soluble resins, surfactants, epoxy and polyurethane have been widely used in the world [21-30]. In our laboratory, it is of particular interest to study the effect of polymers on the physico-mechanical properties of cement, mortar and concrete. Our previous work reported the copolymer latexes based on molar ratio of 2-hydroxy ethyl acrylate and 2-hydroxy ethylmethacrylate [31], acrylic acid and butymethacrylate [32], 2-hydroxy ethyl acrylate and 2-hydroxymethacrylic acid [33], and styrene and methacrylate [34, 35]. The results indicate that the latexes cause improvement in mortar properties compared with control samples without latexes. Negim et al [3] 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 polyoxyethylene glycol monomethyl ether (DBSS/ POE). The effect of copolymer lattices on physico-mechanical properties of cement pastes was investigated. 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

Materials

Dodecyl benzene sodium sulfonate (DBSS) was used as anionic surfactant with a molecular weight of 348.48g/mole. The nonionic surfactants used were polyoxyethylene glycol monomethyl ether [POE) with a molecular weight of 5000.00. 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

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complete homogeneity of the cement. The Blaine surface area of the cement sample was 3350 cm^2/g [35].

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

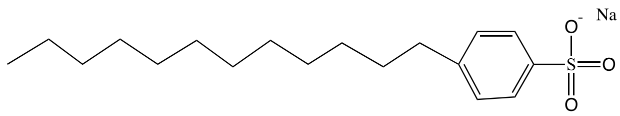
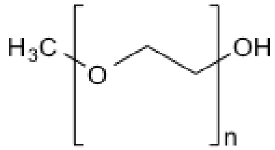
Surfactants	Symbol	Structure
Dodecyl benzene sodium sulfonate	DBSS	
Polyoxyethylene glycol monomethyl ether	POF	

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% Polyoxyethylene glycol monomethyl ether (DBSS/POE) The preparation of copolymers and the methods of analysis (^{1}H NMR, rheological and morphological techniques) have been previously described in a previous investigation [3].

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 [36, 37].

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[38], compressive strength, water absorption and combined water were described in a previous investigation by the authors [39].

Results and discussion

Water/Cement Ratio

The water / cement (W/C) ratio for cement pastes, concretes and mortars has a major on their properties including water absorption, workability and compressive [15, 2]. The effect of copolymer lattices dosages on W/C ratio of mortar mixes is shown in Figure 1. The results showed that W/C ratio of mortars is decreased with increasing dosage of copolymer lattices. Mortar mixed with M1, 0.25% gave lower W/C ratio, 0.32 while mortar mixed with M3, 1.0% showed higher W/C ratio, 0.48. W/C ratio of mortars depends on many factors, such as type monomers, surfactants, type and dosage of lattices [5, 9, 22]. Furthermore, the W/C ratio of mortar mixed with St/ BuA lattices in presence of DBSS/POE is lower than those premixed with St/ BuA lattices in presence of DBSS/PVA [34].

Workability

The addition of St/BuA lattices in presence of DBSS/POE to mortar mixes, improved the workability of mortar as shown in Figure 2. However, workability increased with increasing dosage of lattices. As expected, and in agreement with previously reported results by authors [30-34], workability increases with increasing dosage of lattices. in addition, the use of anionic surfactant in the preparation of lattices is highly detrimental to the workability of mortars and concretes. however, using lattices with nonionic surfactant improved the workability due to the steric repulsion forces [40].

Compressive strength

The results of compressive strength of mortars mixed with different dosages of St/BuA lattices are represented as a function of curing time in Figure 3. The results showed that the compressive strength increases for up to 28 days. However, the compressive strength of mortars increased with decreasing dosage of lattices. Mortar mixed with 0.25% lattice M1 gave highest compressive strength, while mortar mixed with 1% lattice M3 gave lowest compressive strength. The same behavior was reported by Negim et al. [35] when they studied the effect of lattices dosage in presence of DBSS/PVA on compressive strength of mortar. However, the compressive strength of mortar mixed with lattices in presences of DBSS/POE is higher than those premixed with lattices in presence of DBSS/PVA. This is attributed the formation of ether linkage between lattices and particles of cement and fine aggregate.

Water absorption

Water absorption of mortars mixed with lattices at different curing times is shown in Figure 4. The results showed that, the absorption reduces with the increase in curing time for all mixes. However, the water absorption increased with increasing dosage of lattice from 0.25%, M1 to 1.0%, M3. The decrease in water absorption is due to the formation of new linkage inside the pore structure of the hardened cement as in the study reported in Refs. [30-35].

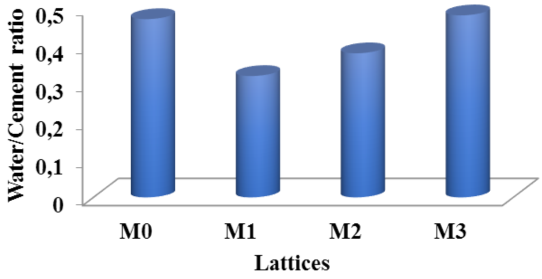


Figure 1 – The effect of St/BuA lattices on the water/cement ratio of mortar

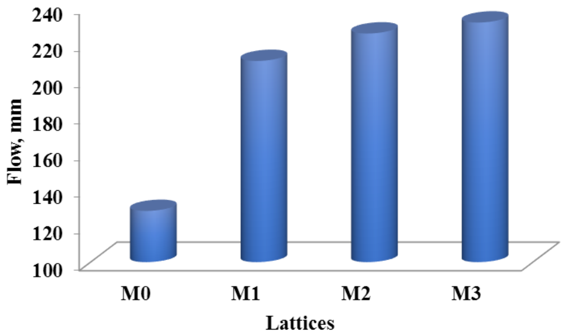


Figure 2 – The effect of St/BuA lattices on the workability of mortar

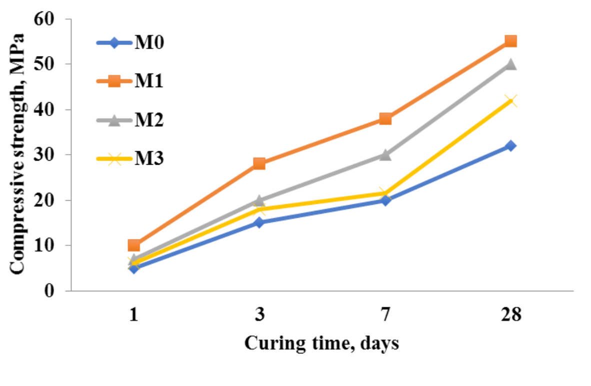


Figure 3 – The effect of St/BuA lattices on the compressive strength of mortar

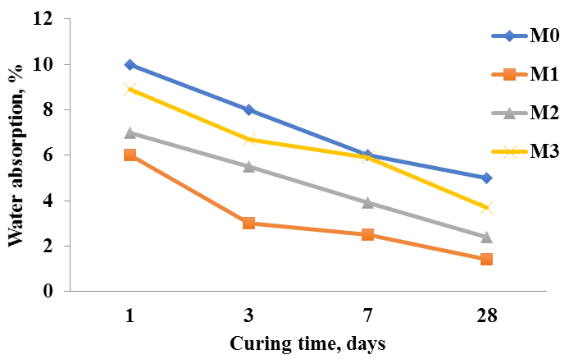


Figure 4 – The effect of St/BuA lattices on the water absorption of mortar

Conclusions

St/BuA lattices were prepared in presence of co-emulsifiers DBSS/POE and characterized by using FT-IR and ^{1}H NMR [3]. Mixing the mortar with different dosage of lattices decreased the water/cement ratio. Mixing the cement pastes with the copolymer lattices enhances the workability. The water absorption of the mortar premixed with the lattices decreases, while the compressive strength increases with decreasing dosage of lattices.

Acknowledgments

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