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The effect of blend copolymers on physico-mechanical properties of mortar

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Abstract. The present study investigates the effect of blend copolymers on the physico-mechanical properties of mortar mixes. Blend copolymers were synthesized based on poly vinyl alcohol (PVA) and urea (U) in aqueous solution with different blend ratios 65/35, 50/50 and 35/65 respectively, using glacial acetic acid as crosslinking. Physico-mechanical properties of mortar examined included water/cement ratio, setting time, workability, water absorption and compressive strength. The addition of blend copolymers to the mortar affected the physico-mechanical properties of mortar mixes. As the content of PVA increases in the blend copolymers, the water of consistency decrease, whereas the setting times (initial & final) were shortened. The compressive strength of the hardened cement pastes was increased at all ages of hydration while water absorption decreased.
Key words: Mortar, PVA, urea, cement, compressive strength, workability.

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Introduction

A number of researchers have studied the addition of chemical admixture to building materials based on polymeric compounds to improve the physical and mechanical properties of cement pastes, mortar and concrete [1-10, 30-31]. The main mechanism of improving properties of cement with addition of polymers is a thin film formed on the surface of grains of cement, aggregate, as well as pores which gave more adhesion [2-6].

Polyvinyl alcohol (PVA) is a water-soluble polymer and used in the industry as a modifier, as aggregate surface pre-treatment agent and as reinforcement in cement-based materials because of its chemical resistance and physical properties [3, 6]. Generally, PVA is added in the form of aqueous solution in small amounts (up to 2% based on the weight of cement during mixing) to improve the properties of cement mortar and concrete product [3, 8]. Negim *et al.* [11, 12] investigated the physical and mechanical properties of mortar containing PVA and dodecyl benzene sodium sulfonate as an air entraining agent. Additionally, PVA and dodecyl benzene sodium sulfonate were used to prepare copolymers latex: styrene/butyl methacrylate, styrene/methyl methacrylate, styrene/glycidyl methacrylate and styrene/ butyl acrylate. The results showed that PVA improved workability of mortar mixed as well as copolymer latex. Copolymer latexes based on 2-hydroxy ethyl acrylate and 2-hydroxy ethyl methacrylate. Different molar ratio of 2-hydroxy ethyl acrylate and 2-hydroxy ethyl methacrylate was designed to investigate the effect of latexes on the physico-mechanical properties of mortar. The copolymer latexes reduce water of consistency of mortar and increased workability [13]. The effect of concentration of styrene/butyl acrylate latexes on properties of mortars was investigated [14]. If the concentration of polymer is more than 5%, there is no significant influence on the properties of mortar mixes.

Negim et al. [15] prepared blend polymers based on polyvinyl alcohol (PVA) and urea (U) in different ratios, using glacial acid as catalysis. The addition of blend polymers to cement pastes improved the properties of cement pastes [16]. The work was extended to include the application of blend polymers to study physical and mechanical properties of mortar.

Experimental part

Materials: Polyvinyl alcohol (PVA) of molecular weight 14 x 10^3 g/mol purchased from Merck (Germany). Urea (U) and glacial acetic as catalysis purchased from Aldrich. 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 was 3650 and 2800 cm^2/g. 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 was sand with particle size ranging from 0.21mm to 0.53 mm and is free from organic or clay-like materials.

Synthesis and characterization of copolymers: Copolymer blend based on polyvinyl alcohol (PVA) with urea (U), were synthesized with composition ratios 65: 35 (M1), 50: 50 (M2) and 35: 65 (M3) glacial acetic acid as catalysis. The preparation of copolymers and the methods of analysis (^{1}H NMR, rheological and morphological techniques) have been previously described in a previous investigation [15].

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) (M0). In mixes M1-M3, prepared copolymers blends were added. The addition rate was 2% by weight of cement. The cement to sand ratio was kept constant. However, the water to cement ratio was changed so that the same consistency was achieved.

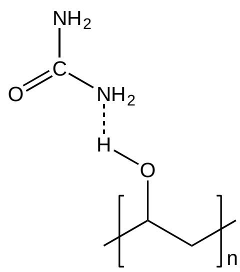
The cement and sand were intermixed until homogenity was achieved. Then the surfactants or prepared latexes were added to the mixing water. This was then added gradually to cement/sand mixture in order to determine the water of consistency and setting time using Vicat apparatus [18, 19].

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 blend P(PVA-b-U) is shown in Scheme 1 and further details about the synthesis and characterization have been previously reported by the authors [15].



Scheme 1 Structure of P(PVA-b-U).

Water/ cement ratio (W/C): The results of water consistency of mortar mixes are graphically illustrated in Figure 1. The water–to–cement ratio is one of the most important items in all tests because special failures associated with the cement structures are essentially due to either too much or too low water that is added during mixing [22]. The W/C ratio for mortar mix without polymer was 0.525. The premixed grafting polymer with mortar mixes decreases W/C ratio from 0.525 to 0.49 (M1). However, increasing the PVA content in the blend copolymer decreases the W/C ratio of the mortar mixes.

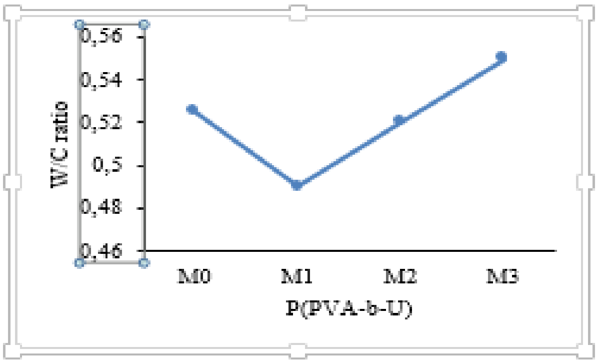


Figure 1 The effect of blend copolymer on W/C ratio of mortar.

Setting time: The setting time (initial and final) of mortar premixed with blend copolymers are given in Figure 2. The setting time of mortar extends with the addition of blend copolymers to mortar. From Figure 2, it is clear that, as the content of PVA in the blend copolymers increases, setting times decreased. This is fundamentally because of the water losing by evaporation from the external surfaces of the samples mixed with the blend copolymer is generally not as much as that of the control mortar mix [23].

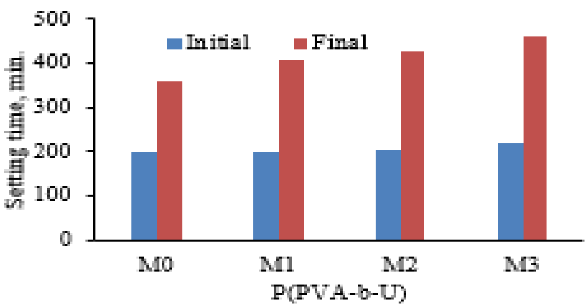


Figure 2 The effect of blend copolymer on setting time of mortar.

Workability: The results of the mortar workability tests are shown graphically in Figure 3. The outcomes demonstrate that the workability of mortar without polymer (M0) is 128 mm; but there was an expansion in workability estimation with the addition of blend copolymer. This expansion in workability was attributed to the blend copolymer being a surface-active agent. Figure 3 shows sharp increase in flow of mortar with increasing the content of PVA in the blend copolymer. Mortar mixed with 65% PVA gave the highest flow with 190.4 mm while mortar mixed with 35% PVA gave the lowest flow with 158.7 mm. Increasing of the mortar workability is principally determined as far as enhanced consistency because of both the 'ball bearing' activity and the dispersing impact of polymer [24].

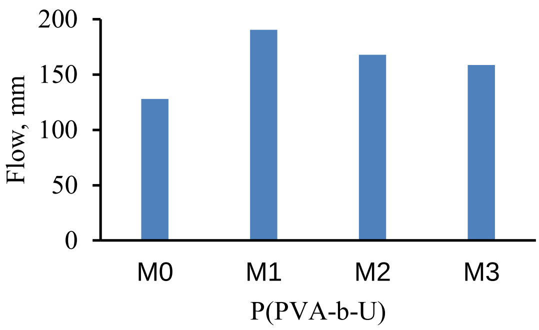


Figure 3 The effect of blend copolymer on workability of mortar.

Water absorption: For the most part, the contact of cement in mortar with water, cement retains water in view of its permeable microstructure. The lower the water absorption, the lower the porous pore volume [25].

The effect of blend copolymer with different content of PVA on water absorption of mortar is demonstrated graphically in Figure 4. It is clear that the water absorption of the mortar mixed with blend copolymer decreased with the increasing of PVA content in the blend copolymer. This is ascribed to the hydration procedure occurring. Different investigations additionally demonstrated that the polymer fills the voids in the cement grid [26, 27]. Polymer-modified mortars are therefore expected to be more resistant towards penetrating aggressive environments than control mix.

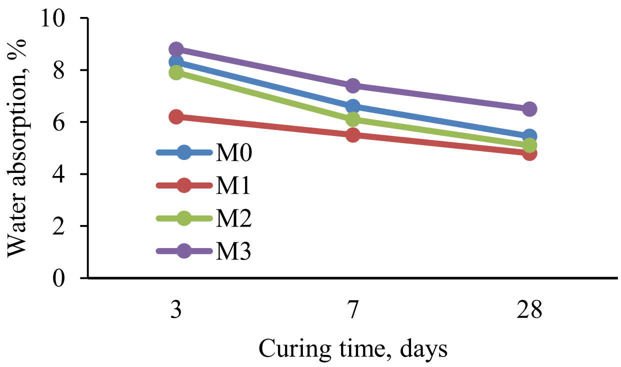


Figure 4 The effect of blend copolymer on water absorption of mortar.

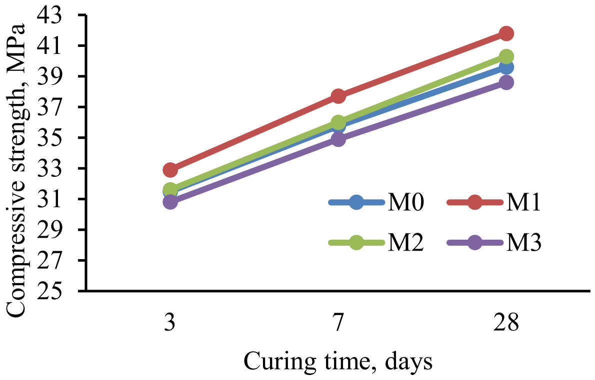


Figure 5 The effect of blend copolymer on compressive strength of mortar.

Compressive strength: Compressive strength of mortar increased with addition blend copolymer to mortar mixes as shown in Figure 5. As appeared from Figure 5, the compressive strength of mortar premixed with blend copolymer (M1, 65% PVA) is higher than that of mortar mixed with blend copolymer (M2, 50% PVA) and (M3, 35% PVA) at all curing periods. This is chiefly because of the adhesive activity due to polymerization or crystallization of the polymeric materials the excess of polymers deposits and polymerizes inside the pore arrangement of the solidified mortar cubes. The development of crystalline structure goes about as nuclei for different components. This may keep on enlarging precious crystals and solid arms-bearing high strength [28]. The consequences of compressive strength of mortar blended with united. This tends to enhance and upgrade the mechanical properties of the mortar cubes. Moreover, the higher level of polymerization and the higher powers between the particles of cement and those of the polymeric materials are the fundamental elements in charge of the generally higher compressive strength [29].

Conclusions

Based on the results of the conducted studies, it is possible to conclude the following:

- ➢The addition of blend copolymers (M1; 65% PVA & M2; 50% PVA) to the mortar mixes improves most of the specific characteristics of the mortar;
- ➢The addition of blend copolymer to mortar decreases water/ cement-ratio decreases, i.e. the blend copolymer acts as a water reducing agent when mixed with the mortar;
- ➢Setting time of mortars increased with increasing the content of PVA in the blend copolymers.
- ➢The flow table results showed that the blend copolymer enhances workability of mortars specially with 65% PVA.
- ➢Water absorption of the mortar premixed with the blend copolymers (65% & 50% PVA) decreased while with blend copolymer 35% PVA increased.
- ➢Compressive strength of mortar increased sharply compared with those of the reference mortar.
- ➢As the ratio of PVA in the blend copolymer increased, the properties of the mortar also improved.

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Аралас сополимерлердің цементті ерітіндінің физика-механикалық қасиеттеріне әсері

Л. Бекбаева, Эльсайд Негим, Г. Елигбаева, Е. Ганжиан

Түйіндеме. Бұл зерттеуде аралас сополимерлердің құрылыс ерітіндісінің қоспаларының физико-механикалық қасиеттеріне әсері карастырылды. Аралас сополимерлер 65/35, 50/50 және 35/65 қоспаларында әртүрлі қатынастағы поливинил спиртінің (ПВС) және мочевинаның (М) судағы ерітіндісі негізінде, мұзды сірке қышқылын тіккіш қосылыс ретінде пайдалана отырып синтезделді. Зерттелетін ерітіндінің физика-механикалық қасиеттеріне жататын: су / цемент қатынасы, қатаю уақыты, қозғалғыштығы, суды ұстағыштығы және қысуға беріктік күші белгіленді. Аралас сополимерлерді құрылыс ерітіндісіне қосу, ерітіндінің қоспаларының физико-механикалық қасиеттеріне әсер етті. Аралас сополимерлердегі ПВС құрамының артуы салдарынан судың құрамдылығы азайып, қатаю уақыты (бастапқы және соңғы) қысқарды. Қатайған цемент пасталарының су сіңіргіштігі төмендеп, беріктігі сығылу күшінің барлық гидратациясының ұлғаюымен бірге өсті.

Түйін сөздер: құрылыс ерітіндісі, ПВС, мочевина, цемент, сығылу күші, қозғалғыштығы.

Влияние смесевых сополимеров на физико-механические свойства цементного раствора

Л. Бекбаева, Эльсайд Негим, Г. Елигбаева, Е. Ганжиан

Аннотация. В настоящем исследовании исследуется влияние смешанных сополимеров на физико-механические свойства строительных растворных смесей. Смешанные сополимеры были синтезированы на основе поливинилового спирта (ПВС) и мочевины (М) в водном растворе с различными соотношениями смесей 65/35, 50/50 и 35/65 соответственно, с использованием ледяной уксусной кислоты в качестве сшивки. Физико-механические свойства исследуемого раствора включали соотношение вода / цемент, время схватывания, подвижность, водо-поглощение и прочность на сжатие. Добавление смешанных сополимеров в строительный раствор влияло на физико-механические свойства растворных смесей. По мере увеличения содержания ПВС в смешанных сополимерах консистенции воды снижалась, тогда как время схватывания (начальное и конечное) сокращалось. Прочность при сжатии затвердевших цементных паст увеличивалась при всех возрастании гидратации, тогда как водо-поглощаемость уменьшалось.
Ключевые слова: строительный раствор, ПВС, мочевина, цемент, прочность на сжатие, подвижность.

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