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Compatibility of Sulphate Resisting Cement with Super and Hyper-Plasticizer

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Abstract – Use of superplasticing chemical admixtures in concrete production is widespread all over the world and has become almost inevitable. Super-plasticizers (SPA), extend the setting time of concrete by adsorbing onto cement particles and provide concrete to preserve its fresh state workability properties. Hyper-plasticizers (HPA), as a special type of superplasticizer, provide the production of qualified concretes by increasing the workability properties of concrete, effectively. However, compatibility of cement with super and hyper-plasticizers is quite important for achieving efficient workability in order to produce qualified concretes.

In 2011, the EN 197-1 standard is edited and cement classifications were updated. In this study, the compatibility of hyper-plasticizer and CEM I SR0 type sulphate resisting cement (SRC) that firstly classified in EN 197-1 is investigated. Within the scope of the experimental studies, a reference cement mortar was designed with a water/cement ratio of 0.50 confirming to EN 196-1. Spread diameters (at 0, 60, 120 min after mix preparation) and setting time of reference mortar were determined with flow table and Vicat tests, respectively. Three mortars were re-prepared with using both super and hyper-plasticizer confirming to ASTM C494 by 0.25, 0.50 and 0.75% of cement weight. Spread diameters and setting times of super and hyper plasticizer added mortars were determined. The flow table and Vicat tests were repeated to these mortars and results were compared. In conclusion, Both SPA and HPA increased the workability of mortar initially and workability maintained after 60 min of mixing. To achieve a longer workability, higher dosages of SPA is needed (0.75%). In terms of HPA, much longer workability can be obtained even at the lowest admixture dosages.

Keywords – CEM I SR0, hyper-plasticizer, setting time, sulphate resisting cement, super-plasticizer, workability.

I. Introduction

Use of plasticing chemical admixtures in concrete production is widespread all over the world and has become almost inevitable. These admixtures provide some benefits such as workability or controlling the setting time of concrete at fresh state [1]. Properties of a concrete mix in both fresh and hardened states can be improved by adding small dosages of chemical admixtures into the mix [2].

Plasticizers can be classified into three group by considering the water reducing ability; plasticizer (%10-15), super-plasticizers (%15-30) and hyper-plasticizers (>%30) [3]. However, this classification does not give any information about the chemical structure of plasticizers. In general, lignosulphonate based admixtures are named as normal plasticizers, naphthalene sulphonate formaldehite based ones are super-plasticizers and poly-carboxylate based admixtures are hyper-plasticizers [4]. Poly-carboxylate based super-plasticizers consist of a carbon main chain and a large number of side chains attached to this chain (Fig. 1) [5]. Owing to this multi-branched structure, they have unlimited modification possibilities [6]. Superplasticizers adsorb to the surface of the cement particles after the addition to the mix, negatively charge the surface of the cement particle and form electrostatic impulse. Besides, additional steric forces are generated in the poly-carboxylate based admixtures due to the poly-oxy ethylene side chains (Fig. 1). Recently, hyper-plasticizers, as special types of super-plasticizers, are the most important components in the production of cement based building materials [7].

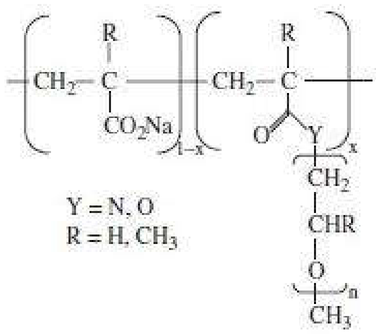

Fig.1. Example of poly-carboxylate based plasticizing admixture [5].

The dosage of the super or hyper-plasticizer is a critical parameter. It must be considered that the dosage of these admixtures is much lower when compared to other ingredients of concrete. Therefore, the use of excess amount plasticizing admixture due to the errors caused by factors of human and equipment during concrete production can cause increments in slump value of concrete. Additionally, concrete can lose its stability at fresh state and strength problems can be occurred due to air entraining side effect of plasticizing admixtures [8].

Compatibility of cement with super and hyper-plasticizers is another issue for achieving efficient workability in order to produce qualified concretes. Agarwal et al. [9] studied the compatibility of super-plasticizers with various cements. They showed that setting time of ordinary Portland cement increased with the addition of super-plasticizer while Portland slag cement has found fully compatible with super-plasticizer. Tang [10] investigated the compatibility of low alkali cement with naphthalene based super-pasticizer and proposed several measures for achieving compatilibity.

In 2011, the EN 197-1[11] standard was edited and cement classifications were updated. CEM I SR0 type sulphate resisting cement (SRC) is a special type of cement with different basic oxide ratios (zero C_3A or according to EN 197-1 can be below zero) from conventional cement and firstly classified in EN 197-1. There is a lack of information with this subject in the literature.

In this study, the compatibility of super and hyper-plasticizer with CEM I SR0 type sulphate resisting cement (SRC) was investigated. Within the scope of the experimental studies, the effects of super and hyper plasticizers (SPA and HPA) to the fresh state properties of sulphate resisting cement mortars (SRC) were examined. Optimum dosages of SPA and HPA were determined for providing the required workability and setting conditions of SRC mortars.

II. Materials and Method

A reference cement mortar (R) was designed with a cement:sand:water/cement ratio of 1:3:0.50 confirming to EN 196-1[12]. Standart sand and CEM I SR0 type cement was used in mortar preparation. The chemical, physical and mechanical properties of cement that obtained from the manufacturer were given in Table 1.

Three additional mortars were then re-prepared with using both super and hyper-plasticizer (SPA and HPA) by 0.25, 0.50 and 0.75% of cement weight. Physical and chemical properties of admixtures obtained from the manufacturer were presented in Table 2. Both SPA and HPA were classified as type F according to ASTM C494[13].

A laboratory type Hobart mixer was used for the mixing process. First, dry mix (cement and standard sand) were mixed for 1 min. Then water was added to the mixture and mixed for another 3 min. For plasticizer added mortars, after the water-mixing sequence, admixtures were added to the fresh mixture and mixed for another 3 min for ensuring the activation and dispersion of admixtures homogeneous to the mixture.

Table 1. The chemical, physical and mechanical properties of cement

Chemical Composition (%)	
SiO_2	19.47
Al_2O_3	3.99
Fe_2O_3	6.44
CaO	62.9
MgO	1.55
SO_3	2.47
Loss on inginiton	1.73
Na_2O	0.09
K_2O	0.32
Free CaO	1.02
Unsoluble Residue	0.34
Basic Oxides	
C_3S	62.95
C_2S	10.74
C_3A	-0.87
C_4AF	20.82
Physical Properties	
Blaine (cm^2/g)	4040
Specific weigth (g/cm^3)	3.27
Start time of setting	120 min
Finish time of setting	185 min
Volume stability	1.0 mm
Mechanical Properties	
1 day compressive strength (MPa)	13.7
2 day compressive strength (MPa)	19.2
7 day compressive strength (MPa)	33.5
28 day compressive strength (MPa)	55.0

Table 2. The chemical and physical properties of admixture

	SPA	HPA
Chemical Structure	Naphthalene Sulphonate based polymer	Poly-carboxylate based polymer
Solid content	%39.76	%27.13
Color	Dark brown	Dark brown
Density	1.192±0.015	1.08±0.015
Cl^-	<0.1	<0.1

Spread diameters and setting time of mortars were determined with flow table and Vicat tests, respectively. Tests setup for both Flow table and Vicat tests were given in Fig. 2 in accordance with the ASTM C230[14] and ASTM C191[15].

a b

Fig. 2. a) Flow table test, b) Vicat test.

For workability investigations, spread diameter tests had been performed at 0, 60, 120 min after mixture preparation. Maintenance and lost of workability of mortars were compared by using achieved spread diameter data.

Vicat tests were performed to the mortars for the investigating the effect of SPA and HPA to the setting times. Starting time of setting is excepted as the time when Vicat needle is started not to sink 1 mm from the base level. Finishing time of setting is determined as the time when the Vicat needle is sinking below the 1 mm of surface level. Measurement were taken by 15 min intervals just after the mixing sequence and finishing time of setting.

III. Results and Discussion

A. Spread Diameters of Mortars

Spread diameter results of mortars at 0, 60 and 120 min were given in Fig. 3.

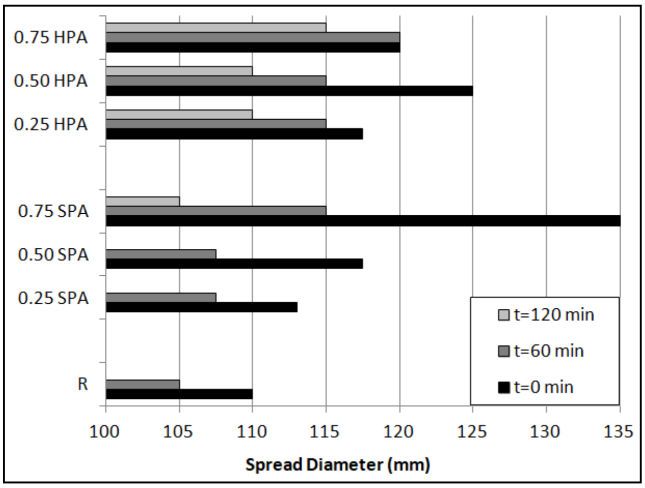

Fig. 3. Spread diameters of mortars

Initial spread diameter of reference mortar was measured as 110 mm. With the addition of both SPA and HPA initial spread diameters of mortars were increased gradually with the admixture dosage. HPA increased the spread diameters of mortars more than SPA at the dosages of 0.25% and 0.50%. However, the spread diameter value of SPA mortar was higher than HPA more at 0.75% admixture dosage. This situation can be explained with the lost of mixture stability at higher dosages of HPA. During the flow table test of 0.75HPA, bleeding and segregation was observed (Fig. 4). Due to the water being thrown out of the system with respect to bleeding side effect of high HPA dosage, spread diameter of mortar was decreased.

Fig. 4. a) 0.75SPA mortar (Stable), b) 0.75HPA mortar (Unstable and bleeding of mixture due to high HPA dosage)

After 60 min of mixing, spread diameter of R decreased to 105 mm. In SPA series, spread diameters of mortars decreased by 4%, 9% and 15% at dosages of 0.25%, 0.50% and 0.75%, respectively. However, in HPA added mortars spread diameters decreased by 2% and 8% at dosages of 0.25% and 0.50%, and spread diameter was remained at the same level at 0.75% dosage of HPA.

After another 60 min (at 120 min after mixing), R, 0.25SPA and 0.50SPA lost their workabilities. Spread diameter of 0.75SPA decreased to 105 mm. In all HPA series workabilities were maintained. It also had been observed that bleeding and segregation problem of 0.75HPA was solved within the time.

In both SPA and HPA, workability of mortars were relatively maintained at 60 min after mixing. In SPA series, 0.75% of SPA must be used for further maintaining the workability at 120 min after mixing. However, in HPA series, workability was successfully maintained even at the lowest admixture dosages (0.25% of HPA).

B. Setting Times of Mortars

Setting times of mortars (starting and finishing time of setting) were given in Fig. 5. No systematic change was observed in terms of starting time of setting. In general, setting time of mortars were increased with the addition of both SPA and HPA. Setting times of mortars were increased by 50%, 61% and 144% at 0.25%, 0.50% and 0.75% SPA dosages, respectively. HPA increased the setting times of mortars more when compared to the SPA series (except 0.75% admixture dosage). Setting times of mortars were increased by 78%, 89% and 100% with the addition to HPA by 0.25%, 0.50% and 0.75%, respectively.

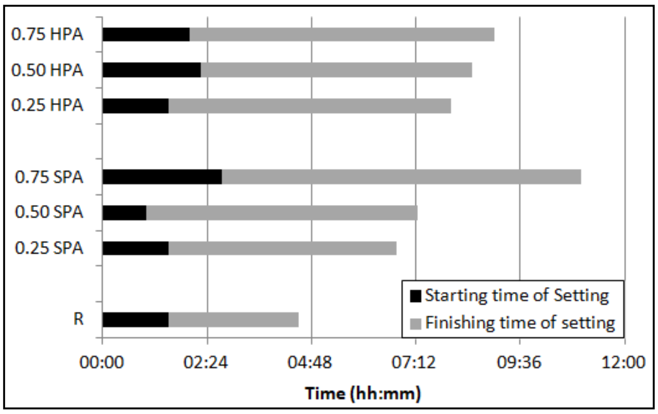

Fig. 5. Setting times of Mortars

By taking the test results into consideration, it can be said that both SPA and HPA increase the setting times of mortars. SPA ensures this behavior due to the adsorption of admixture to the cement surface and by electrostatically charging the the surface of cement. However in HPA, both electrostatic and steric forces are occurred after the adsorption of admixtures to the cement surface due to the poly-carboxylate based chemical structure of HPA. Therefore, HPA can prolong the setting times more than SPA. It must be noted that, owing to difference between the chemical structure of HPA and SPA, HPA must be used in attention in order to avoid of stability problems.

IV. CONCLUSION

In this study, compatibility of CEM I SR0 type cement with super and hyper-plasticizer was investigated at fresh state. Both SPA and HPA are found compatible with the CEM I SR0 type cement. The use of SPA and HPA increased the workability of mortar initially and maintained the workability after 60 min of mixing. To achieve a longer workability, higher dosages of SPA is needed (0.75%). In terms of HPA, much longer workability can be obtained even at the lowest admixture dosages. It must be considered that the use of both SPA and HPA increased the setting times of mortar. The use of HPA at higher dosages may cause stability problems such as segregation or bleeding owing to difference between the chemical structure of HPA and SPA. HPA must be used in attention in order to avoid of such stability problems.

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