SYNERGISTIC EFFECT OF CHEMICAL ADMIXTURES ON WORKABILITY OF MORTAR CONTAINING ZEOLITE POWDER

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ABSTRACT

One of the most expensive component of concrete is a chemical additives used in the construction industry. Water reducing admixtures as one of the chemical additives used in the construction industry. Use of zeolite as a natural pozzolan in concrete due to the unique physical properties require larger amounts of water reducing admixtures in order to achieve specific workability. Hence, consumption and its impact on efficiency of chemical additives examined separately and together. Research results show that the simultaneous use of water reducing admixtures and Retarder not only reduces the amount of these chemical additives, but helps to compensate workability loss.

Keywords: Zeolite, Water reducing admixtures, Retarder, Workability retention

INTRODUCTION

Use of mineral admixtures as a partial replacement of Portland cements in concrete provides a channel to reduce CO_2 emission and energy of cement production. Due to low cost and low energy consuming, natural pozzolans such as zeolite has been widely used in the world. Utilization of zeolite as a pozzolans dates back to ancient times that the mixture of zeolites and lime was used as a hydraulic binder [1].

Natural zeolites are hydrated aluminosilicate minerals containing alkaline and alkaline-earth metals, formed by the alteration of volcanic. Several papers described that sufficient mechanical and durability properties obtained by substitution of ordinary

Portland cement with different kinds of zeolites. Yilmaz et al. showed that 10 percent replacement as an optimum value of zeolite blended cement can significantly improve mechanical properties of concrete [2]. These results were confirmed by other authors [3-5]. Najimi et al. showed that the use of Iranian zeolite from Semnan province as a substitution of Portland cement can effectively reduce rebar corrosion rate in chloride environment [6]. They also showed that replacement of zeolite with Portland cement can reduce drying shrinkage. Ahmadi and Shekarchi explained that pozzolanic reaction of zeolite with free lime leads to a strong microstructure in paste against chemical attacks [3]. They explained that durability properties of concrete such as permeability, water absorption and alkali-silica reaction can be improved by replacing 5 to 10 percent of zeolite. Due to high specific area, zeolites can influence rheological parameters of concrete. Research results show that use of zeolite can enhance stability of self compacting concrete and it could be a suitable choice for using zeolite as a viscosity modifying admixture in concrete [7]. It was reported that using higher replacement levels of natural zeolite (up to 30%) led to improved segregation resistance and therefore improve fresh properties of flowability, passing ability and stability [8]. However some authors observed that for a constant slump flow, superplasticizer demand of natural zeolite blended cement dramatically increased [9]. Uzal and Turnali reported that SP demand of zeolite-blended cements is 2 to 3 times higher than control mixture with naphthalene based and melamine based superplasticizers [10]. Polycarboxylate based demand of self compacting concrete with zeolite blended cement was investigated by Libre et al. [9]. They showed that in SCC, by 10% substitution of zeolite with OPC, the SP demand is about two times of control mixture. To the practical experience of the authors, the main concern of Iranian contractors that involve zeolite in their projects is severe workability loss of concrete containing zeolite.

Slump loss involves chemical and physical processes. The loss of consistency in cement paste during the dormant stage is mainly attributed to the physical coagulation of cement particles rather than to chemical processes. In the period during which the slump loss is occurring, the tricalcium aluminate reacts with gypsum. The product develops into a crystalline structure and is distributed in the mass of paste. But in zeolite blended cement, physical and chemical characteristics changedue to ion exchange capacity and high surface area of zeolite. Hence, it is necessary to investigate compatibility of different superplasticizers with zeolite blended cement.

 In this study, three different chemical based superplasticizers: Sodium Lignosulfonate(LS), Naphtalene Sulfonated Formaldehyde(NSF) and Polycaboxylate Ether (PCE)lonely and also combination of superplasticizers with phosphonate based retarder were used to achieve optimum SP demand and best workability retention.

EXPERIMENTAL PROGRAM

Materials
The design of mortar to evaluate slump loss and SP demand was based on recommendation found in literature [11]. The material selected was cement type II according to ASTM C150 and local zeolite (clinoptilolite type) powder from Semnan

province, Iran. The characteristics of these are shown in table 1. Moreover, the granulometry of the powders are shown in figure 1.

Table 1. Chemical Composition and physical properties of cementitious materials

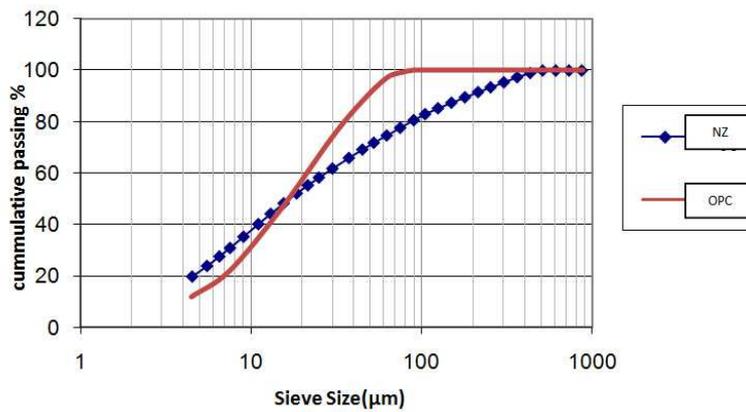| Oxide composition % by mass	OPC	NZ
CaO	63.10	1.68
SiO_2	21.25	67.79
Al_2O_3	3.38	13.66
Fe_2O_3	3.56	1.44
MgO	1.96	1.20
Na_2O	0.22	2.04
K_2O	0.54	1.42
SO_3	1.71	0.50
Loss on ignition	1.87	10.23
Specific gravity(Kg/m^3)	3140	2200
Specific Surface Area(m^2/gr)	3200	20000

Figure 1. Granulometry of Cementitious Materials

Three different chemical based superplasticizers and one chemical based retarder were used. Properties of chemical admixtures are shown in Table 2.

149

Table 2. Properties of Chemical Admixtures

Chemical base	Specific Gravity(gr/cm³)	PH	Solid Content %wt	Color	Viscosity(cPs)	Chloride Content % wt
Sodium Lignosulfonate(LS)	1.17	6.1	40	Dark Brown	-	Below 0.01
Naphtalene Sulfonated Formaldehyde (NSF)	1.20	7.2	40	Light Brown	-	Below 0.01
Polycarboxylate Ether(PCE)	1.14	6.3	30	Amber	180	Below 0.01
Phosphonate Retarder (P)	1.05	9.2	40	Colorless	-	-

The fine aggregate used for mortar mixtures were from the Karaj River region. The fine aggregate had a specific gravity of 2.67, absorption of 2.8%, and a fineness modulus of 3.06.

Mixing Procedure and Testing Method Mortar composition
In the zeolite blended cement, 10% wt of cement was replaced by zeolite in order to choose a suitable superplasticizer for optimum percentage of zeolite usage. In addition, with respect to the ability of superplasticizer to reduce water content, three water to binder ratios of 38% for polycarboxylate, sulfonated naphthalene formaldehyde, 42% for basic and 46% for sodium lignosulfonate were chosen. The mortars were made with 1:3 cement-to-sand ratios. First, the sand and cementitious materials were mixed for one minute in a Hobart mixer. After that, 90% of water was added to dry mixture and mixing was continued for another one minute. The Amount of added superplasticizers was chosen in order to reach a flow of 195±15 mm after 15 strokes in the flow table test. However, in superplasticizer-retarder combination, SP dosage was kept constant. Therefore, the effect of retarder on initial workability could be observed. Remaining water and superplasticizer were added to mixture and mixing was continued for two minutes. This procedure was done in low speed mixing. After one minute resting, high speed mixing was done for one minute. Immediately after mixing, flowability of mortar mixture was measured by the flow table. This measurement was repeated at 15, 30, 45 and 60 minutes after adding water to the mixture. The Mixture proportions are given in table 3.

Table 3. Mixture Proportions of Mortars

Type of superplasticizer	Code	W/B ratio %wt	SP Dosage (% wt cement)	Retarder Dosage (% wt cement)	Slump flow (mm)
LS	CLS	0.46	0.5	-	196.7
	ZLS	0.46	1	-	186.2
	ZLSR1	0.46	1	0.1	Flash setting
	ZLSR2	0.46	1	0.2	Flash Setting
NSF	CNS	0.42	0.8	-	180.6
	ZNS	0.42	1.2	-	187.8
	ZNSR1	0.42	1.2	0.1	183.3
	ZNSR2	0.42	1.2	0.2	185.8
	ZNSR3	0.42	1.2	0.3	195.8
PCE	CPC	0.38	0.4	-	177
	ZPC	0.38	0.6	-	179.1
	ZPCR3	0.38	0.6	0.3	199.7
	ZPCR5	0.38	0.6	0.5	217.5

RESULTS AND DISCUSSION

Figure 4, 5 and 6 shows the effect of different superplasticizers on 1 hour slump loss in ordinary Portland cement and zeolite blended cement mortars.
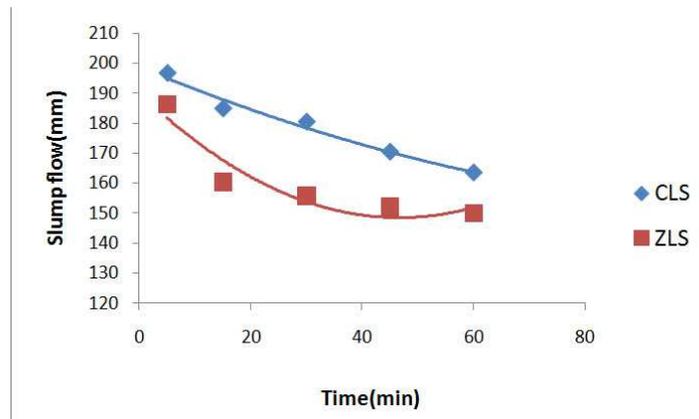

Figure 2. LS effect on slump loss (0.5% dosage CLS- 1.0% dosage ZLS) W/C=0.46

SP demand in all three superplasticizers increased significantly and also major part of slump loss occurs in first 30 minutes. In presence of lignosulfonate and after 30 minutes, slump loss linear slope decreased but in PCE and NSF slump loss slope was still sharp. It could be related to high SP adsorption when zeolite is substituted by cement. When high amount of superplasticizer exist in pore solution and W/B ratio is high, zeolite cannot adsorb all amount of superplasticizers and flow loss decreases.
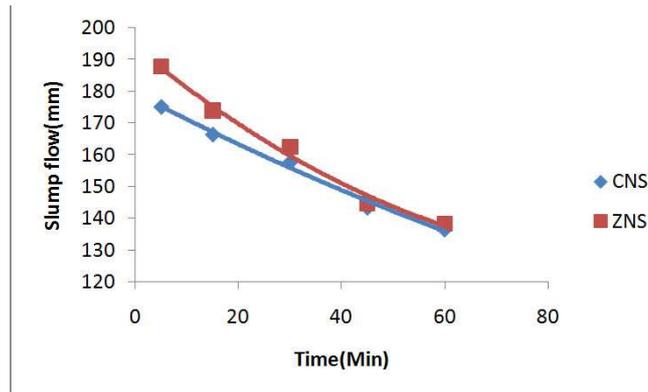
Figure 3. NSF effect on slump loss (0.8% dosage CNS- 1.2% dosage ZNS) W/C=0.42

Some authors expressed that slump loss in presence of NSF is higher than other chemical base. But figure 3 shows that more slump loss was observed in zeolite blended cement. It could be due to reduction of alkalis in zeolite blended cement. Kim et al. showed that cements with low alkalis are more incompatible with Naphtalene based superplasticizers [12]. Due to ion exchange and alkalis absorption by zeolite powder, content of Na^+ and K^+ ions reduced. And it could be the reason of NSF incompatibility with Zeolite blended cement.
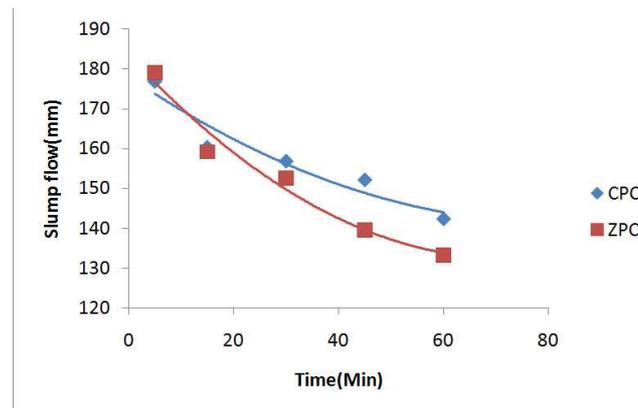

Figure 4. PCE effect on slump loss (0.4% dosage CPC- 1.2% dosage ZCP) W/C=0.38

Result of synergistic effect of superplasticizers and retarder are shown in figure 5 and 6. Use of LS and retarder led to flash setting. Ramachandran et al expressed that high dosage of non-modified lignosulfonate could results flash setting but phosphonates and modified lignosulfonate incompatibility should be further studied for validating [13].
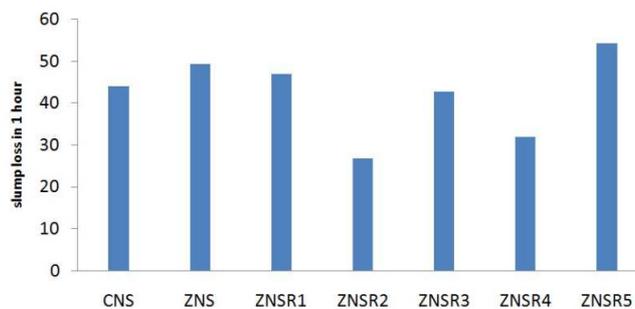

Figure 5. NSF and Phosphonate based retarder on 1 hour slump loss of zeolite blended cement mortar W/C=0.42

152

Figure 5 shows that adding retarder in rate of 0.1 to 0.4% wt of cementitious material can reduce workability loss. It was also observed that use of 0.2% wt cement phosphonate based retarder can reduce flow loss up to 50% of that doesn't have retarder. The reason could be related to high alkali properties of phosphonate based retarder. It can compensate content of alkalis in pore solution. Hence workability retention improved. It also observed from table 3 that by addition of Phosphonate retarder initial slump flow slightly increased.
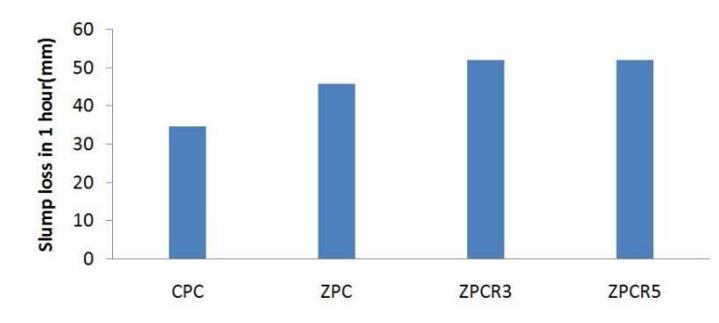

Figure 6. PCE and Phosphonate based retarder on 1 hour slump loss of zeolite blended cement mortar W/C=0.38

Figure 6 shows that by adding phosphonate slump loss increased slightly and slump loss in presence of PCE and phosphonate is more than PCE. Therefore combination of Polycarboxylate based polymer and phosphonate based retarder does not meet better workability retention.

CONCLUSION

In this paper compatibility of superplasticizers and zeolite blended cement from workability loss and superplasticizer demand points weres investigated:

1. Incompatibility of sodium lignosulfonate and phosphonate based retarder led to flash setting. More studies are needed to validate this phenomenon.
2. Use of phosphonate to a 0.2% by weight of cement and naphthalene based superplasticizer in mortar containing zeolite have a positive impact on the workability retention and reduce 50% of flow loss. It was also observed that up to 0.4% Retarder adding increases initial slump flow.
3. Although initial slump flow by addition of phosphonate based retarder to PCE mixtures increased, but there was approximately no changes in slump retention of mixtures.
4. Due to relationship between alkali content of mixtures and compatibility of NSF with cement, capacity of zeolite for ion exchange reduces alkali content in pore solution. Therefore slump loss with NSF in zeolite blended cement increased significantly.

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