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Studying effects of chemical admixtures on the workability retention of zeolitic Portland cement mortar

Hessam AzariJafari [a,*], Ali Kazemian [b], Babak Ahmadi [c,e], Javad Berenjian [d], Mohammad Shekarchi [e]

[a] Department of Civil Engineering, Université de Sherbrooke, 2500 Blvd. de l'Université, Sherbrooke, QC J1K 2R1, Canada
[b] The Sonny Astani Department of Civil & Environmental Engineering, University of Southern California, Los Angeles, CA, United States
[c] Department of Civil & Environmental Engineering, Amirkabir University of Technology, Tehran, Iran
[d] Department of Civil Engineering, Tabari Institute of Higher Education, Babol, Iran
[e] Construction Materials Institute, School of Civil Engineering, College of Engineering, University of Tehran, Tehran, Iran

HIGHLIGHTS

- Compatibility of zeolitic cement with three superplasticizers was studied.
- Workability retention of zeolitic cement incorporating superplasticizers and retarder were studied.
- Reduction in the amount of electrostatic charge occurred as a result of NZ inclusion.
- The influential mechanisms were recognized for the three superplasticizers.
- Workability loss of NZ mortars is highly dependent to the "free" admixture dosage.

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ABSTRACT

In this paper, the effects of three superplasticizers, namely, poly-carboxylate ether, calcium ligno-sulfonate, and Naphthalene Sulfonate Formaldehyde, on the workability retention of NZ blended mortars were investigated. In addition, simultaneous inclusion of either tripolyphosphate type retarder or Na_2SO_4 admixtures was examined as a measure to mitigate the workability loss of NZ blended mortars. Thereafter, the compatibility of zeolitic cement with three different superplasticizers was studied in more details by performing adsorption isotherm test, zeta potential test and also pH measurement of pastes at different time intervals. Obtained results indicated that for ligno-sulfonate and naphthalene sulfonate superplasticizers, reduction in the amount of electrostatic charge (which occurred by NZ inclusion) is an influential parameter contributing to the higher workability loss. On the other hand, for poly-carboxylate ether admixture, the results implied that the significantly high polymer adsorption is the major reason for the observed workability loss of NZ blended mortars.

1. Introduction

Natural pozzolans are considered as a major group of Supplementary Cementitious Materials (SCMs). Since ancient times, natural pozzolans such as zeolite have been broadly used in lime-based mixtures. Nowadays, zeolite is consumed as an SCM in many countries that have enough resources of zeolitic tuffs. Pozzolanic activity and effects of zeolite powder on the hardened properties of concrete have been widely investigated by researchers [1–8]. Earlier studies have shown that Portland cement replacement by NZ (5–55%, by mass) contributes to consumption of calcium hydroxide which is formed during hydration of Portland cement [9–11]. As a result of this, hardened properties of concrete made with NZ are improved. From a durability point of view, NZ can control Alkali Silica Reactions (ASR) in the presence of reactive aggregates and high alkali cements by mitigating alkaline ions in pore solution [4,12,13]. Other research works on NZ show that durability-related characteristics of concrete such as porosity of Interfacial Transition Zone (ITZ), pore structure of cement paste, permeability, sorptivity, and diffusivity are improved by use of NZ blended cement [7,14,6,15–18].

Fresh cement paste behavior is regarded to be closely associated with the development of mortar and concrete microstructure. Still, influence of NZ inclusion on the fresh state behavior of cementitious materials has been investigated only to a basic level. Some observations regarding the decreased workability, higher viscosity,

* Corresponding author.

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and accelerated workability loss (in the case of NZ incorporation) are reported by some researchers [1,2,5,9,19]. This is usually justified by the honeycomb like structure of NZ crystals which have extremely small pores and channels, varying in size from 3×10^4 to 4×10^4 μm. These characteristics enable NZ to absorb water by over 30% of its dry weight [1,20].

Şahmaran et al. [21] showed that combination of NZ and superplasticizer could lead to a suitable VMA for cement-based grouts. Furthermore, several studies were conducted on the use of NZ in powder-type Self-Compacting Concrete (SCC). Sabet et al. [19] reported that Portland cement partial replacement by NZ can improve fresh and hardened properties of self-compacting high performance concrete. Ramezanianpour et al. [2] reported that high NZ replacement level (30%) promotes segregation resistance of low Portland cement SCC mixtures, which was measured by sieve segregation test. A study by Ranjbar et al. [5] showed that use of NZ (up to 20%) contributes to satisfying the SF2 criteria for SCC mixtures (slump flow diameter of 660–750 mm). The criterion of SF2 is satisfactory for normal applications. Similar results were reported by Cioffi et al. [22] at 40% NZ replacement level.

From a technical point of view, it is widely known that a pozzolanic filler needs to be compatible with the chemical admixtures which will be used in a concrete mixture. This is highly important for both the conventionally vibrated and SCC mixtures. The powder-chemical admixture interactions determine how long the workability of fresh concrete is maintained (slump retention), which is definitely important for construction purposes. In some real-life projects, prolonged agitation and delay in concrete placement or finishing operations is inevitable [23]. As such, slump retention of fresh concrete becomes highly critical. Characteristics of the included superplasticizer are influential with regards to the slump retention of the fresh mixture.

An experimental research on comparison of three superplasticizers, namely LignoSulfonate (LS), Naphthalene Sulfonate Formaldehyde (NSF) and poly-carboxylate ether (PC) was conducted by Björnström and Chandra [24]. They measured slump loss of mixtures incorporating the superplasticizers with two different cements up to 45 min. The results demonstrated that at the same initial consistency level, the workability retention measured by flow diameter was lower with NSF compared to LS. They also noticed that the mixture containing polycarboxylate type admixture had the lowest slump loss. Superior performance of PC in terms of workability retention at constant dosage and *w*/*c* ratio was also observed by Tan et al. [25]. However, Gołaszewski and Szwabowski observed the same slump loss of mortars with PC and NSF superplasticizers [26].

While the compatibility issue has been investigated for various pozzolan-admixture combinations, it has not been carried out for NZ pozzolan. In fact, some observations with respect to the higher workability loss of NZ included materials are often reported, but detailed investigation on the involving parameters has been neglected by the researchers.

In this paper, the effects of three superplasticizers, namely, poly-carboxylate ether, calcium ligno-sulfonate, and Naphthalene Sulfonate Formaldehyde, on the workability retention of NZ blended mortars were investigated. In addition, simultaneous inclusion of two other admixtures was examined as a measure to mitigate the workability loss of NZ blended mortars. In the next step, compatibility of zeolitic cement with three different superplasticizers was studied in more detail. Evaluation of the compatibility was performed by adsorption isotherm test, zeta potential test and also pH measurement of pastes at different time intervals. The different test results for each of the admixtures were employed to recognize the influential mechanism with respect to the workability loss.

2. Experimental program

2.1. Materials

The cement used in this study was ASTM C150 [27] Type II Portland cement. The clinoptilolite type NZ was from the quarries in the north of Semnan, central region of Iran. The physical and chemical composition of the cementitious materials is listed in Table 1. Also, mineral composition of NZ, which was obtained from XRD quantitative analysis, is presented in Table 1. Moreover, particle size distribution of NZ is presented in Fig. 1. The results obtained from particle size analyzer apparatus indicated that, for the used NZ, X' (the particle size from which 63.2% of NZ particles are finer) is 33 μm.

Natural sand which was used in mortar mixtures had specific gravity of 2.67, water absorption of 2.8% and fineness modulus of 3.06. The sieve analysis of natural sand is presented in Fig. 2.

In order to investigate the effects of chemical admixtures on the workability retention of NZ incorporated mortars, three types of superplasticizer and a set retarder admixture were selected, all conforming to ASTM C494 [28]. Poly-carboxylate ether (PC), calcium LignoSulfonate (LS) and Naphthalene Sulfonate Formaldehyde (NSF) polymers were selected as target superplasticizers, while tripolyphosphate type (TP) retarder was the only set retarding admixture which was investigated herein. The selected superplasticizers are the most widespread chemical admixtures in three different generations [29–31]. As they performance are more effective in different *w*/*c* ranges, it might be a suitable choice to study the effect of NZ workability retention in different *w*/*c* ratios. The properties of the four commercially available admixtures are presented in Table 2.

2.2. Mixture proportions

Mixture proportions of mortars including different dosages and combinations of chemical admixtures are listed in Table 3. Based on the earlier research works on Iranian NZ [5,6,19], 10% was selected as the cement replacement level. Also, each of the chemical admixtures was employed within the concentration range recommended by the producer.

Three control mixtures (CPC, CNS, and CLS) were prepared for comparison purposes. These mixtures included Portland cement as the only binder. The initial flow diameter for these mixtures and also for the three NZ incorporated mixtures (ZPC,

Table 1
Properties of cementitious materials.

	Portland cement	NZ
Chemical composition (%)		
SiO_2	21.25	67.79
Al_2O_3	3.38	13.66
Fe_2O_3	3.56	1.44
CaO	63.1	1.68
MgO	1.96	1.20
SO_3	1.71	0.50
Na_2O	0.216	2.04
K_2O	0.56	1.42
L.O.I	1.87	10.23
Specific gravity	3.14	2.20
Blaine (m^2/kg)	320	320
Mineralogy of NZ (%)		
Clinoptilolite	–	70.6
Opal CT	–	18.8
Quartz	–	1.6
Plagioclase	–	2.4
K-feldspar	–	1.5
Smectite/illite (clay minerals)	–	5.2

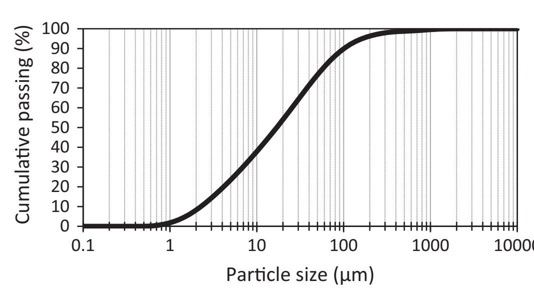

Fig. 1. Particle size distribution of natural zeolite.