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Mix Design Selection for Old and New Generation of Supre Plasticizers

Navid Afshari[a], Seiyed Ali Haj Seiyed Taghia[*,b]

[a]*Master of Science in Construction Management, Department of civil Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran.*

[b]*Assistant professor, Department of Civil Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran.*

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Abstract

Determination the optimal mix design plays an important role in order to gain the maximum characteristic strength. This researchwas conducted as a case study for Manjil tunnel project located in Qazvin-Rasht highway. For this purpose, 18 concrete mix designs were prepared at the study phase of the project with specifications such as conventional water-to-cement ratios of 0.4, 0.5 and 0.6, the use of two generations of new and old conventional superplasticizer in Iran (naphthalene sulphonate and polycarboxylate ether types, respectively) with cement weight percentages of 0.2, 0.4 and 0.6. Superplasticizers are used to increase the fluidity of concrete without adding excess water. The naphthalene sulphonate is a polymeric molecule formed by condensation of naphthalene sulfonic acid and formaldehyde, in which the hydrophilic groups are mainly sulfonic groups. It has been demonstrated that polycarboxylate ether can mitigate plastic shrinkage of matrix because of the reduction of the build-up rate of capillary pressure by polycarboxylate ether. Finally, the optimal water-to-cement ratio and superplasticizer weight percentage were determined. Concrete mix designs with different ages of curing were made (0, 3, 7, 14 and 28 days).

Keywords z: *Polycarboxylate Ether, Naphthalene Sulphonate, Compressive Strength, Mix design*

1. Introduction

Choosing the optimal mix design by utilization of existing materials in construction site to reach maximum concrete strength is very important factor. These concerns were considered and planned in the study phase of the Manjil tunnel project (located in Qazvin-Rasht highway). In this project, the old and new generations of superplasticizer available in Iranian market were used to facilitate the implementation of concreting.

Superplasticizers help prevent concrete compressive strength reduction while providing concrete workability.

The next section introduces the Manjil tunnel project as well as the role of superplasticizer and specifically those used in this research.

1.1. Manjil tunnel Project (Qazvin-Rasht highway)

This project is located between Manjil and Rudbar cities in Gilan province of Iran.

The project is 7 km long, having two completely separated runways with 5 tunnels, two valley bridges, one ramp bridge (Zeytoun Bridge), and 4 km trench and open road, which started in 2015 and completed in March 2017.

This project had special importance due to its strategic location and its sensitivity in terms of reducing construction time (major concern of executive managers).

1.2. Superplasticizer

Nowadays, superplasticizers are used widely to produce flowable, strong, and durable Portland cement concretes and mortars. The hydration behaviors of Portland cement in the presence of superplasticizers have been investigated by a number of researchers. The dispersing effect of superplasticizers on cement particles can improve the workability of cement, thereby improving the

[*]Corresponding Author: Email address:ali.taghia@qiau.ac.ir

compactness, permeation resistance, and carbonation resistance of concrete [1–5]. There are various types of superplasticizers available:

1. Conventional superplasticizers based on naphthalene-sulphonate (PNS), melamine (PMS) or lignosulfonate (LS) disperse particles by means of electro steric.
2. New generation of superplasticizers such as polycarboxylate superplasticizers (PCEs) disperse particles by forming a steric obstacle.

Naphthalene (PNS) and polycarboxylate-ether (PCE) as conventional and new generation of superplasticizers were illustrated in this research respectively.

The effects of these kinds of superplasticizers on reducing water amount and increasing workability of concrete have already attracted many attentions so far. It has been reported that PCE has a good performance on improving workability of fresh concrete [6–16].

2. Experimental Procedure

In this section, the material properties, mix design, preparation and curing are described separately.

2.1. Material properties

The Portland cement type- II wasused in the entire specimens. The specimens were made according to ASTM C150 [17] and the gravel and sand aggregates are of river type in accordance with ASTM C33 [18]. The sand sizes ranged from 0 to 4.75 mm with apparent weight of 2700 kg/m3inSaturated Surface Dry (SSD) state.

In this study, two types of superplasticizers based on PNS and PCE have been used. One of the goals of this paper is to identify which superplasticizer is more applicable (comparison between old and new generation superplasticizers) and determine the optimal amount for concrete preparation.

The specifications of the used superplasticizers are given in Table 1.

Table 1. superplasticizers specifications

Properties	PNS	PCE
Ingredient	Naphthalene Sulphonate	polycarboxylate
Color	Dark green	Dark brown
State	Liquid	Liquid
Density g/ml (20˚C)	1.2 ± 0.02	1.1 ± 0.02
PH (20˚C)	8	7
Total chloride %	<0.1	<0.1
Ionic nature	Anion	Anion

2.2. Mix design

In this study, 18 mix designs were prepared which are summarized in Table 2. Each mix design includes three samples. Table 2 illustrates the abbreviation for entire specimens.

In the nomenclature of design, numbers 4, 5, and 6 after the letter W indicate the water-to-cement ratios of 0.4, 0.5, and 0.6 and the letters P and N, represent the polycarboxylate- ether and naphthalene sulphonate superplasticizers, respectively. Also numbers 2, 4, and 6 after P and N shows superplasticizers consumption as a fraction of cement weight (equal to 0.2, 0.4, and 0.6 percent, respectively).

In the preparation of concrete superplasticizer is usually used to compensate low water-to-cement ratio and increase concrete workability.

But in this study, the high water-to-cement ratio of 0.6 was also investigated to simulate the personal mistakes in construction site.

Table 2. Mix designs characteristics

Mixture code	Cement (kg/m^3)	Sand (kg/m^3)	Gravel (kg/m^3)	w/c	Plastisizers(%)
W4P2	400	910	1080	0.4	0.2
W4P4	400	910	1080	0.4	0.4
W4P6	400	910	1080	0.4	0.6
W5P2	400	910	1080	0.5	0.2
W5P4	400	910	1080	0.5	0.4
W5P6	400	910	1080	0.5	0.6
W6P2	400	910	1080	0.6	0.2
W6P4	400	910	1080	0.6	0.4
W6P6	400	910	1080	0.6	0.6
W4N2	400	910	1080	0.4	0.2
W4N4	400	910	1080	0.4	0.4
W4N6	400	910	1080	0.4	0.6
W5N2	400	910	1080	0.5	0.2
W5N4	400	910	1080	0.5	0.4
W5N6	400	910	1080	0.5	0.6
W6N2	400	910	1080	0.6	0.2
W6N4	400	910	1080	0.6	0.4
W6N6	400	910	1080	0.6	0.6

2.3. Sample preparation

The concrete was constructed in the beginning and it followed by inserting it into the pre-prepared molds and then samples were set to harden at constant temperature and humidity for 24 hours. Cubic mold shape was used with each length of 15 cm.

After 24 hours, the samples were taken out of the molds and were cured for 0, 3, 7, 14, and 28 days, differently to evaluate the effect of curing days on the concrete strength.

In order to match the maintenance conditions of the samples with real conditions in site, sample curing was done by covering them with gunny bags and daily watering (Figure 1).

Figure 1. Curing of Samples in site

3. Results and discussion

This section deals with the effect of curing days on concrete compressive strength after the 28-day.

It should be noted that the results of this section are valid for the ambient condition (i.e. temperature of 17˚c humidity of 65%).

3.1. The effect of curing time on concrete compressive strength at the age of 28-day

The compressive strength of cubical samples cured at different ages of 0, 3, 7, 14, and 28 days are reported in Table 3. The compressive strength tests were performed at the age of 28-days according to ASTM C39 [19].

As it can be seen from Table 3, samples W4P4 (with water-to-cement ratio of 0.4 and 0.4 percent of PCE) and W5N6 (with water-to-cement ratio of 0.5 and 0.6 percent of PNS) have the highest compressive strength. These samples are introduced as the optimal mix designs for two kind of superplasticizer in this project, separately.

Figures 2 to 7 report the 28-day concrete compressive strength for different weight percentages of two superplasticizers and different water-to-cement ratios.

The data presented in these figures were extracted from Table 3.

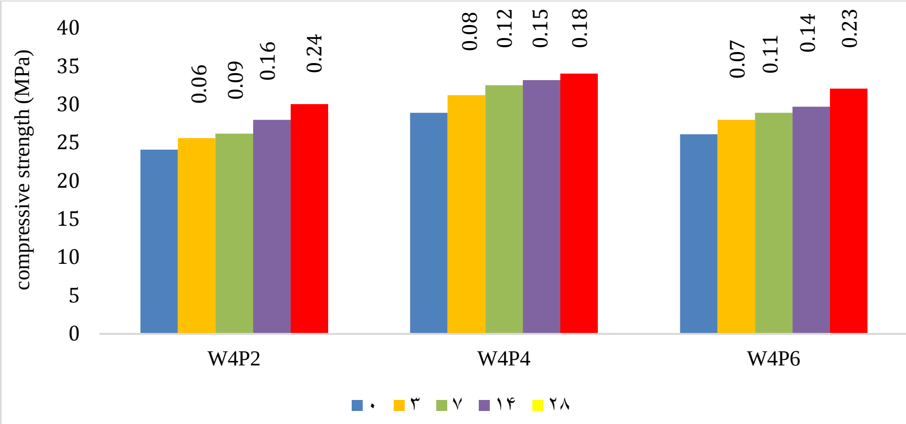

Figure 2. Compressive strength of mix designs at the age of 28 days for different curing periods (superplasticizer type: PCE and w/c=0.4)

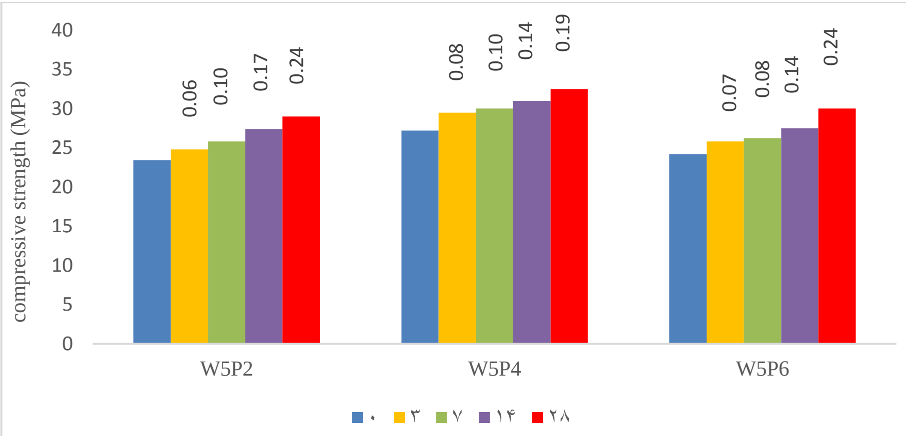

Figure 3. Compressive strength of mix designs at the age of 28 days for different curing periods. (superplasticizer type: PCE and w/c=0.5)

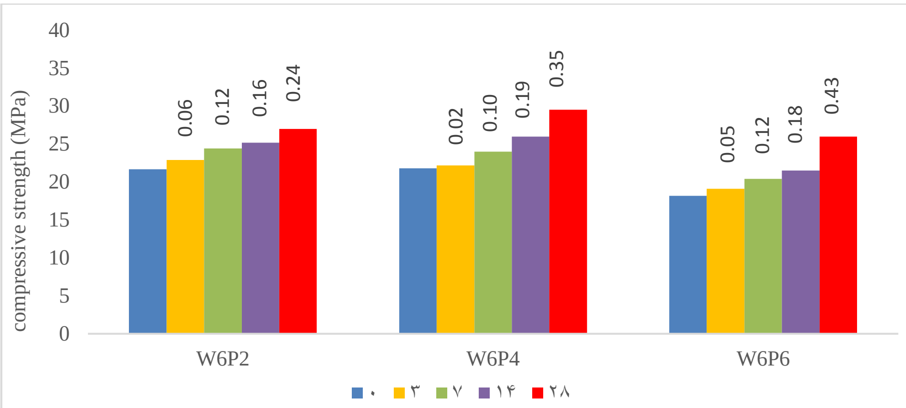

Figure 4. Compressive strength of mix designs at the age of 28 days for different curing periods. (superplasticizer type: PCE and w/c=0.6)

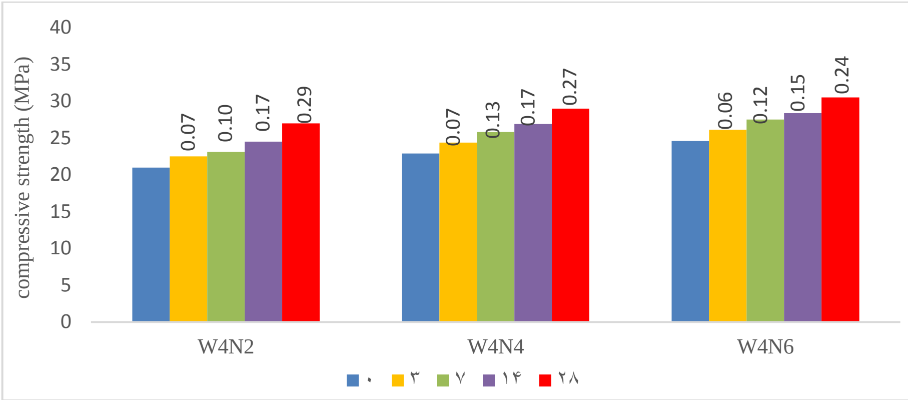

Figure 5. Compressive strength of mix designs at the age of 28 days for different curing periods.

(superplasticizer type: PNS and w/c=0.4)

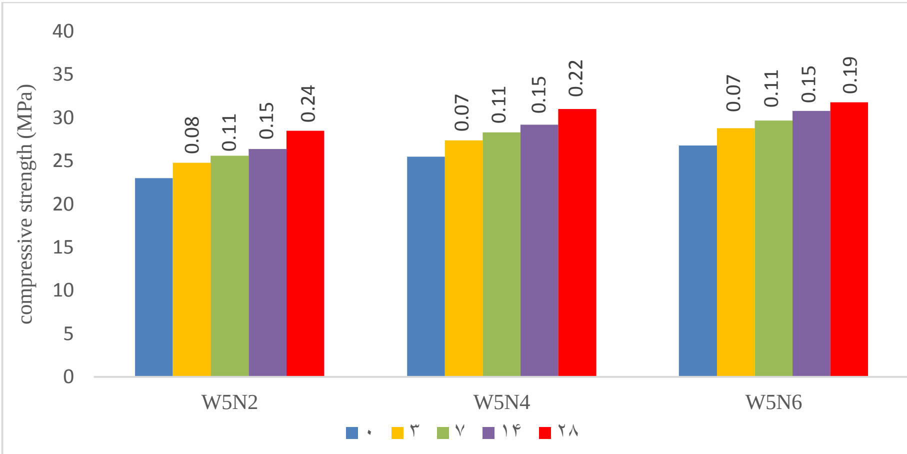

Figure 6. Compressive strength of mix designs at the age of 28 days for different curing periods.

(superplasticizer type: PNS and w/c=0.5)

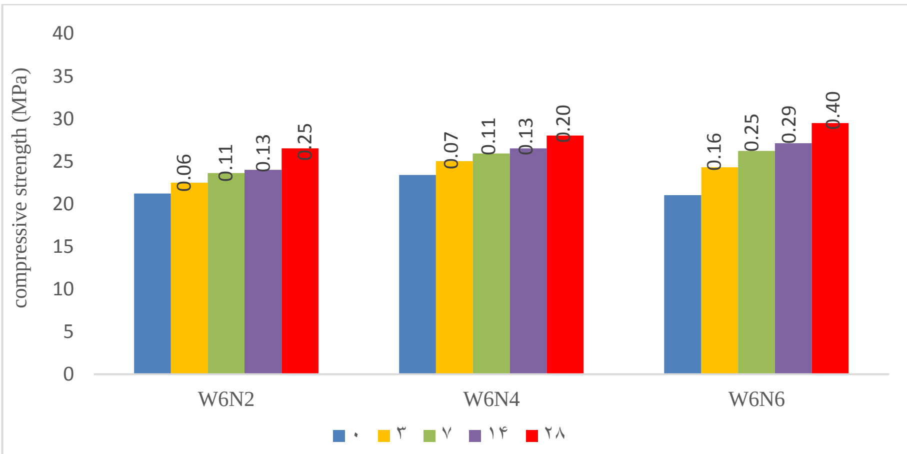

Figure 7. Compressive strength of mix designs at the age of 28 days for different curing periods.

(superplasticizer type: PNS and w/c=0.6)

As expected, in Figures 2 to 7, the 28-day compressive strength of the samples rises with increasing the curing time. However, the strength increase rate declines with increase in the curing time.

This means that the adequate strength of concrete can be gained in ages less than 28 days, without any significant reduction in ultimate strength.

4. Conclusions

This paper proposes appropriate mixing design for two kinds of superplasticizer. Based on the experimental results, the following conclusions are stated:

1. In the mix design containing superplasticizer of carboxylate type with cement weight percentage 0.4 and water-to-cement ratio 0.4, the maximum compressive strength was obtained and selected as the optimal mix design for this type of superplasticizer.
2. In the mix design containing superplasticizer of naphthalene type with cement weight percentage 0.5 and water-to-cement ratio 0.6, the maximum compressive strength was obtained and selected as the optimal mix design for this type of superplasticizer.

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