IJST, Transactions of Civil Engineering, Vol. 37, No. C+, pp 513-517
Printed in The Islamic Republic of Iran, 2013

"Research Note"

EFFECT OF HIGH RANGE WATER REDUCERS (HRWR) ON THE PROPERTIES AND STRENGTH DEVELOPMENT CHARACTERISTICS OF FRESH AND HARDENED CONCRETE*

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Abstract– Research is underway to increase the strength of concrete with the addition of chemical and mineral admixtures. The use of High Range Water Reducers (HRWR) has been increased many times in the last two decades. In this research the effect of two types of commercially available HRWR (Superplasticizers) are studied on the properties of concrete in fresh and hardened state. The strength development characteristics of concrete have been studied with the addition of the HRWR. The research has shown the selection of appropriate HRWR for the desired results of concrete in fresh and hardened state is a critical decision for the performance of the WRWR.

Keywords– Concrete, high range water reducers, mineral admixtures

1. INTRODUCTION

The High Range Water Reducers (HRWR) or Superplasticizers (SP) are commonly used in High Strength concrete, Precast/pre-stressed concrete, architectural concrete, etc. The detailed guidelines for the use of HRWR (Superplasticizers) are given by ACI 212.4R-06 [1]. SP are grouped under four major types namely, Sulfonated Naphthalene Formaldehyde Condensed (SNF), Sulfonated Melamine Formaldehyde Condensed (SMF), Modified Lignosulfonates (MLS) and Other types such as Polyarchylates, Polysterene Sulfonates, polymers etc [2].The SP affects the properties of fresh and hardened concrete by reduction in interfacial tension, multilayered adsorption of organic molecules, reducing its evaporation and wastage, release of water trapped amongst the cement particles, retarding effect of cement hydration and change in the morphology of hydrated cement [3]. Bjornstrom and Chandra [4] used three types of sulfonated superplasticizers to study their effect on the rheological properties of concrete. They showed that the mechanism by which these polymers disperse cement particles differs fundamentally. They proposed model for the adsorption of superplasticizer on a cement particle. The HRWR affect various properties of concrete in fresh and hardened states. The increase in slump due to SP depends on the type of cement, ambient temperature, dosage and type of HRWR [4]. An optimal dosage will produce a concrete with good workability maintained throughout the required amount of time, but without any major effect on setting time or initial mechanical properties [5]. In most cases, a high dosage of HRWR would lead to increase in the initial setting time, which may help in hot weather concrete [6]. The air voids are generally altered by the addition of HRWR [7]. In case of self compacting pump concrete using HRWR, the

*Received by the editors September 21, 2011; Accepted December 1, 2013.
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increase in slump may lead to segregation of concrete. This can be controlled by using a proper quantity of smaller particles. Due to imminent reduction in the water cement (Water binder) ratio, the strength of concrete in hardened state increases with the addition of HRWR in all cases for all dosages. Concrete with compressive strengths of 10,000psi (70MPa) or more can be developed on site. At the same time the tensile strength and modulus of elasticity of concrete is also increased with the addition of HRWR [8]. HRWR increase the drying shrinkage of concrete, if there is simultaneous reduction in the volume of cement [9, 10]. Concrete incorporating HRWR increases the freezing and thawing resistance. At the same time HRWR decrease the ingress of chlorides and increase the resistance to corrosion [11]. The reduction in the water binder ratio with the addition of HRWR reduces the permeability of concrete. The durability of concrete is increased as a result. The reduction of water also leads to increased sulfate resistance [12]. The use of SP in fly ash added concrete may reduce the effectiveness of SP as the contents may absorb the surface water [13]. Flatt [14] developed some models for predicting the rheology of superplasticized concrete. N.U.Kockal [15], while investigating the properties of cement mortars containing industrial wastes, used sulfonated polymer-based superplasticizer to adjust the consistency of the cement pastes. Similarly Sadrmomtazi and Fasihi [16] also used polycarboxylate ether based superplastisizer to regulate the fluidity of mortars.

This research attempts to investigate the effects of two major types of SP on the properties of concrete in fresh and hardened form.

2. MATERIALS AND METHODS

a) Material and mix proportioning

Ordinary Portland Cement (OPC) of Type-I, fine aggregates with specific gravity 2.75 and coarse aggregates of lime stone source and 18 mm down sizes were used. Two types of HRWR were used namely, SP-1 (Visco) conforming to ASTM C494 Type A and F of Carboxylic ether (CEE) group with long lateral chain and was SP-2 (Glenium), Conforming to ASTM C494 Type A and F of Polycarboxylates (PCO). Cement, fine aggregates and coarse aggregates were mixed in three nominal ratios of 1:1:2,1: 1.5:2.5 and 1:1.5:3 by weight. The nominal ratios were selected on the basis field practices. The dosage of the SP was kept at 0.8% by weight of the cement and the water cementitiuos material ratios were kept as 0.4, 0.35 and 0.30. For each w/c ratio, tests specimen with no SP, SP1 and SP2 were prepared. Concrete cylinders of size 150mmx300mm were tested at 3,7 and 28 days. Various tests such as workability test (slump cone test), Compressive strength i.e. cylinder crushing tests, split tensile tests and for flexural strength tests, plain cement concrete beams of sizes 100x100x300mm were tested under third point load. The test setup has been show in Fig.1.

Fig. 1. Testing setup for measuring the compressive strength of concerete

3. RESULTS AND DISCUSSION

a) Effect of SP on the slump and compressive strengths and modulus of rapture of concrete

The results are shown in Table 1. The increase in strength due to SP is the same for both cases, however the increase in workability is more pronounced in the case of SP-2. The price of Sp-2 is twice the SP-1 hence SP-2 can be preferred for cases where enhanced workability is required. Similarly, the cylinder tensile strength and flexural strength has also been increased for SP and the results are shown in Table 2 and Table 3. The increase in both properties of concrete is relatively more in case of SP-2. The increase in strength is pronounced at more age of concrete (56 and 90 days), hence initially there is little increase in the strength.

b) Effect of SP on water reduction of concrete

To achieve a constant slump of about 25 mm, the w/cm ratio was reduced and compensated with the increase in the SP dosage. The SP-2 has comparatively led to further decrease in the water cement ratio and increase in the compressive strength of concrete. The results are shown Table 4.

c) Strength development characteristics of concrete

To study the strength development characteristic of concrete, detailed investigation on various dosages of SP-2 for various mixes of concrete were used. The compressive and tensile strength was measured at 1 day, 3 day, 7 days, 14 days and 28 days and given in Table 6,expressed as % of 28 days strength. The early strength of concrete at one day has been increased from 35% for mix A at 0.5 Liter/100 Kg of cement to 61 % of 28 days strength for mix G with 1 lit/100 Kg of cement of SP. The very high early strength of concrete at 3 days more than 14 MPa, makes Very Early Strength (VES) concrete very suitable for use.

Table 1. Effect of superplasticizers on the workability and compressive strength

Concrete Mix	w/c ratio	SP Type	Slump (mm)	Compressive strength (MPa)		
				7 Days	14 Days	28 Days
A(1:1:2)	0.40	Nil	25	29.75	32.30	40.10
		SP-1	75	30.50	36.0	41.55
		SP-2	200	30.79	38.86	43.59
	0.35	Nil	15	25.17	36.21	41.50
		SP-1	50	28.38	37.55	43.60
		SP-2	175	29.30	37.60	45.17
	0.30	Nil	10	25.80	34.55	42.20
		SP-1	45	27.70	36.80	44.50
		SP-2	125	30.10	38.70	47.20
B(1:1.5:2.5)	0.40	Nil	35	20.30	28.30	35.90
		SP-1	95	20.90	30.40	37.30
		SP-2	150	21.70	36.70	39.55
	0.35	Nil	30	22.40	31.20	38.00
		SP-1	85	25.10	32.80	40.20
		SP-2	110	26.00	36.24	43.00
	0.30	Nil	05	22.50	32.00	35.50
		SP-1	50	24.50	33.90	37.0
		SP-2	80	24.90	34.90	43.60
C(1:1.5:3)	0.40	Nil	15	25.60	29.90	36.90
		SP-1	65	30.69	32.60	39.70
		SP-2	80	32.50	36.80	43.20
	0.35	Nil	50	21.40	23.25	36.25
		SP-1	95	23.80	31.85	38.65
		SP-2	250	25.20	32.00	41.00
	0.30	Nil	25	21.00	31.25	34.25
		SP-1	65	23.15	32.15	35.15
		SP-2	90	24.15	33.02	41.25

Table 2. Effect of supeplasticizers on the splitting tensile strength concrete

Mix ratio	w/c ratio	Slump (mm)			Cylinder Tensile Strength (MPa)		
		No SP	SP-1	SP-2	No SP	SP-1	SP-2
A(1:1:2)	0.35	15	50	175	3.94	6.93	7.21
B(1:1.5:2)	0.35	30	80	110	3.48	3.72	4.01
C(1:1.5:3)	0.35	50	90	250	3.52	3.66	3.95

Table 3. Effect of supeplasticizers on the flexural strength of concrete (Modulus of rapture)

Mix ratio	w/c ratio	Slump (mm)			Cylinder Tensile Strength (MPa)		
		No SP	SP-1	SP-2	No SP	SP-1	SP-2
A(1:1:2)	0.40	25	75	200	6.78	6.93	7.21
B(1:1.5:2)	0.40	35	92	150	5.86	6.14	6.38
C(1:1.5:3)	0.40	15	65	80	5.07	5.79	6.07

4. ONCLUSION

i. The increase in compressive strength, flexural strength and cylinder tensile strength is relatively greater in the case of Polycarboxylates group (SP-2).

ii. Substantial reduction in water demand has been observed with use of SP.

iii. With Polycarboxylates group (SP-2), more than 40% strength (14MPa) can be obtained after 3 days which makes it very suitable for Very Early Strength (VES) Concrete.

iv. The 28 days compressive strength of SP added concrete with Polycarboxylates group (SP-2), gives High Strength Concrete (HSC) having 28 days compressive strength in excess of 75 MPa (11000psi). Further research is required for cost optimization of the HRWR concrete.

Table 4. Details of strength development of different mixes expressed as % of 28 days strength

Mix Title	Nominal ratio of	Dosage of SP (Li/100Kg)	Compressive strength as % of 28 days compressive strength (MPa)				Compressive strength as % of 28 days tensile strength (MPa)			
			1	7	14da	28 days	1	7	14da	28 days
A	1:2:4	0.50	9.88	15.9	21.4	28.53	4.88	6.17	7.96	9.06
			35%	56%	75%	100%	54%	68%	87%	100%
B	1:1 ½: 3	0.70	16.7	23.7	27.3	40.05	5.63	7.41	11.2	15.58
			42%	60%	68%	100%	36%	47%	72%	100%
C	1:1 ½: 2 ½	0.90	17.4	24.1	29.0	42.79	6.17	12.0	12.9	14.27
			41%	56%	68%	100%	43%	84%	90%	100%
D	1:1:2	1.1	19.3	28.5	36.7	49.92	9.33	12.9	13.7	14.81
			39%	57%	74%	100%	63%	87%	92%	100%
E	1:1:1 ½	0.50	37.3	42.5	44.4	58.15	16.3	17.5	18.1	18.93
			64%	73%	76%	100%	86%	92%	95%	100%
F	1: 3/4: 1 ½	0.70	37.4	50.5	56.0	70.17	16.7	18.5	18.8	19.97
			53%	72%	80%	100%	83%	93%	94%	100%
G	1: ½:1	1	47.0	49.3	61.4	76.80	17.5	18.9	19.6	20.94
			61%	65%	80%	100%	83%	90%	93%	100%

***Acknowledgement*:** Authors are grateful to the Higher Education Commission of Pakistan for sponsoring the research.

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