Influence of Chemical Admixtures on Fresh and Hardened Properties of Ready Mix Concrete

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Abstract

An experimental investigation was carried out to study the effects of types of chemical admixture on fresh and hardened properties of ready mix concrete. For conducting the investigation different concrete mixtures were prepared using six different types of chemical admixture (one water reducer based on lignosulfonate; and five superplasticizers based on organic polymer, second generation polycarboxylic ether polymer, polycarboxylic ether, sulfonated naphthalene polymer and synthetic polymer). Chemical admixtures were collected from the local market. Each mixture was subjected to prolonged mixing; slump tests were performed at 15 minutes intervals to assess the fresh behavior of concrete. Cylindrical specimens of diameter 100 mm and length 200 mm were made with the concrete mixtures for assessing the hardened properties of concrete. The specimens were tested for compressive strength, splitting tensile strength and Young's modulus at the age of 28 days.
Results indicate that sulfonated naphthalene polymer based superplasticizer and second generation polycarboxylic ether based superplasticizer show best performances in both fresh and hardened states of concrete. Lignosulfonate based water reducer exhibits poor performance in comparison to the superplasticizers.

Keywords: Chemical admixture, Compressive strength, Splitting tensile strength, Young's modulus.

1. INTRODUCTION

In the construction industry, the demand of ready mix concrete (RMC) is increasing rapidly day by day. The primary reasons behind this are: convenience of using RMC in high rise structures, shortage of space at construction site, saving of time related to the preparation of concrete on site and better quality of RMC. In cities like Dhaka, the time required to travel from RMC plant to construction site is very high, because of severe traffic congestions, especially during weekdays. To keep concrete workable for such a long time period is very challenging. Moreover, high ambient temperature in summer makes the situation worse, since high temperature adversely affects the workability of fresh concrete (Burg, 1996; Mehta and Monteiro, 2006). Therefore, high workability has become one of the most desired and essential properties of RMC in Dhaka city. A conventional practice to improve workability of concrete is to add water in the concrete mix. But with the increase of water to cement ratio (W/C), the compressive strength of concrete reduces significantly (Schulze, 1999; Dhir et al, 2004; Wassermann et al, 2009). So to overcome this problem, in recent years, RMC manufacturers in Dhaka city have started using chemical admixture as a fourth ingredient in concrete apart from cement, aggregates and water. Chemical admixtures allow RMC to achieve high workability without compromising its quality at hardened state (Devi and John, 2014).

In light of the above discussion, it is necessary to conduct a comparative analysis among the fresh and hardened properties of concretes made with different chemical admixtures in order to identify the best chemical admixture. Therefore, this study plans to investigate the effects of chemical admixtures available in the local market on workability of fresh concrete. The effects of chemical admixtures on compressive strength, splitting tensile strength and Young's modulus of concrete are also aimed to be evaluated.

2. EXPERIMENTAL METHOD

In this study six different types of chemical admixture were used. Among the admixtures, WR is water reducer and SP1, SP2, SP3, SP4, SP5 are superplasticizers. All the types of chemical admixture comply with ASTM C494. The chemical and physical properties of the chemical admixtures, and their dosage ranges as recommended by the manufacturers are mentioned in **Table 1**. Crushed stones were used as coarse aggregates. Natural river sand was used as fine aggregate. **Figure 1** shows the gradations of coarse and fine aggregates. Both the gradations of coarse and fine aggregates satisfy ASTM C33 requirements. The physical properties of coarse and fine aggregates are summarized in **Table 2** and **Table 3** respectively. CEM Type II/B-M cement (as per BDS EN 197–1:2000) was used as binding material. Tap water was used for mixing and curing of concrete.

Mixture proportions of the cases investigated in this study are summarized in **Table 4**. In this study, the maximum recommended dosages of the chemical admixtures were used to prepare the concrete mixtures. In all concrete mixtures, sand to total aggregate volume ratio (s/a), water to cement ratio (W/C) and cement content were kept constant to 0.40, 0.40 and 340 kg/m^3 respectively.

Slump tests of fresh concrete mixtures were done at 15 minutes intervals according to ASTM C143. 100 mm by 200 mm cylindrical concrete specimens were also prepared and tested for compressive strength, splitting tensile strength and Young's modulus according to ASTM C39, ASTM C496 and ASTM C469 respectively.

Table 1. Properties and recommended dosage ranges of chemical admixtures

Chemical admixture	Composition	Appearance	Specific gravity at 25 °C	Recommended dosage range (ml/100 kg of cement)
WR	Lignosulfonate based	Dark brown liquid	1.17	200 – 400
SP1	Sulfonated naphthalene polymer based	Dark brown liquid	1.24	700 – 1800
SP2	Polycarboxylic ether based	Light brown liquid	1.05	400 – 1200
SP3	Second generation polycarboxylic ether polymer based	Light brown liquid	1.10	500 – 1200
SP4	Synthetic polymer based	Dark brown liquid	1.22	500 – 1500
SP5	Organic polymer based	Dark brown liquid	1.19	600 – 1140

Table 2. Properties of coarse aggregate

Aggregate type	Specific gravity	Absorption capacity (%)	Abrasion (%)	SSD unit weight (kg/m^3)	Fineness modulus
Crushed stone	2.56	2.39	38.30	1549	6.95

Table 3. Properties of fine aggregate

Aggregate type	Specific gravity	Absorption capacity (%)	SSD unit weight (kg/m^3)	Fineness modulus
River sand	2.45	3.30	1520	2.52

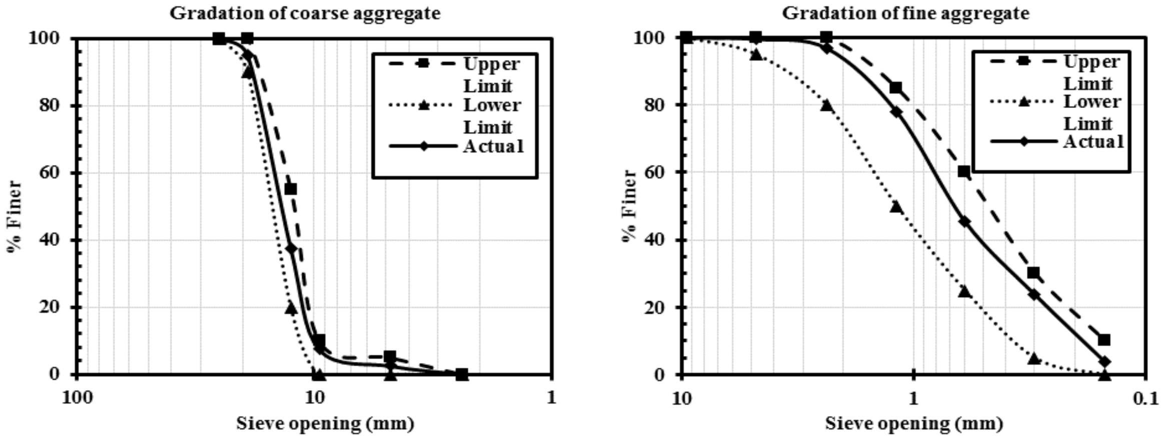

Figure 1. Gradation of coarse and fine aggregates

Table 4. Mixture proportion of concrete

Case ID	Chemical admixture	Dosage (ml/100 kg of cement)	W/C	s/a	Unit content (kg/m^3)			
					Cement	Sand	Aggregate	Water
C1	WR	400			340	743	1114	136
C2	SP1	1800			340	738	1107	136
C3	SP2	1200	0.40	0.40	340	740	1110	136
C4	SP3	1200			340	740	1110	136
C5	SP4	1500			340	739	1109	136
C6	SP5	1140			340	741	1111	136

3. RESULTS AND DISCUSSION

3.1. Effects of Chemical Admixtures on Fresh Properties of Concrete

Slump test results of fresh concrete mixtures prepared with different types of chemical admixtures are presented in **Figure 2**. It can be seen that concrete mixture prepared with sulfonated naphthalene polymer based admixture SP1 resulted maximum initial slump, it also remained workable for longest duration. The second best result was obtained for second generation polycarboxylic ether based admixture SP3. Concrete mixture made with synthetic polymer based SP4 resulted higher initial slump compared to concrete mixture with polycarboxylic ether based admixture SP2. However, concrete with SP2 remained workable for longer duration compared to concrete with SP4. Amongst the superplasticizers, organic polymer based SP5 imparted lowest workability to fresh concrete. Again, lignosulfonate based water reducer WR resulted poor workability compared to the superplasticizers.

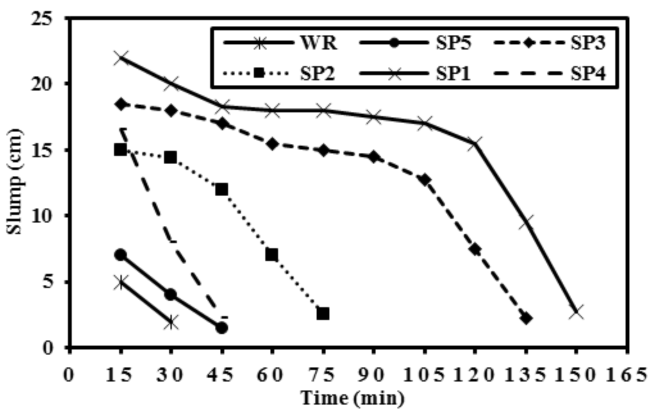

Figure 2. Slump test results of concrete mixtures made with different admixtures

3.2. Effects of Chemical Admixtures on Hardened Properties of Concrete

28 days compressive strengths of concretes made with different chemical admixtures are presented in **Figure 3**. It can be seen that concretes made with chemical admixtures exhibited better compressive strengths compared to the concrete made without admixture. The results therefore reapprove the findings of Mohammed and Hamada (2003), Papayianni et al (2005), Alsadey (2012), and Devi and John (2014) as opposed to the findings of Jerath and Yamane (1987) who concluded that the addition of superplasticizer in concrete mixture causes reduction in compressive strength. Papayianni et al (2005), and Devi and John (2014) attributed the reason of strength increase of superplasticized concrete to the improved workability of concrete in its fresh state which eventually leads to the formation of denser and less porous structure.

Figure 3 shows, second generation polycarboxylic ether based superplasticizer SP3 imparted the highest 28 days compressive strength to concrete. The second highest compressive strength was resulted by concrete with sulfonated naphthalene polymer based SP1. However, the compressive strengths of concrete with SP1 and concrete with SP3 were very close. Among the superplasticizers, organic polymer based SP5 imparted lowest compressive strength to concrete. Performances of the superplasticizers were better than that of the lignosulfonate based water reducer WR. The compressive strengths of concrete cylinders made with chemical admixtures were within the range of normal strength concrete specified by JSCE Guideline for Concrete (2007).

28 days splitting tensile strengths of concretes made with different chemical admixtures are shown in **Figure 4**. Concretes made with chemical admixtures resulted better splitting tensile strengths compared to the concrete made without chemical admixture. The results confirm the conclusions drawn by Shah et al (2014). Like compressive strength, the splitting tensile strength resulted by concrete with WR was less compared to the concretes made with superplasticizers. Concrete with second generation polycarboxylic ether based superplasticizer SP3 exhibited the highest splitting tensile strength. The second highest splitting tensile strength was resulted by concrete with sulfonated naphthalene polymer based SP1.

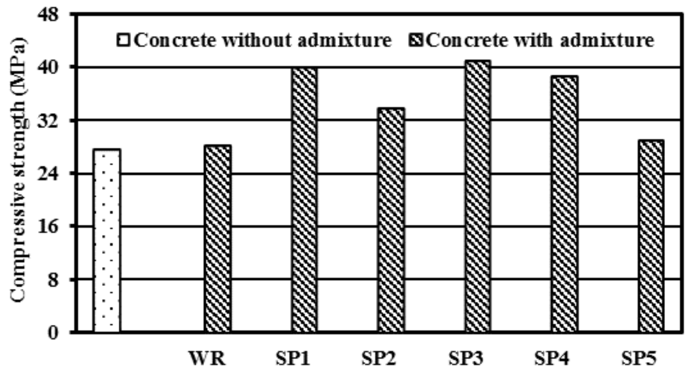

Figure 3. 28 days compressive strengths of concretes made with different admixtures

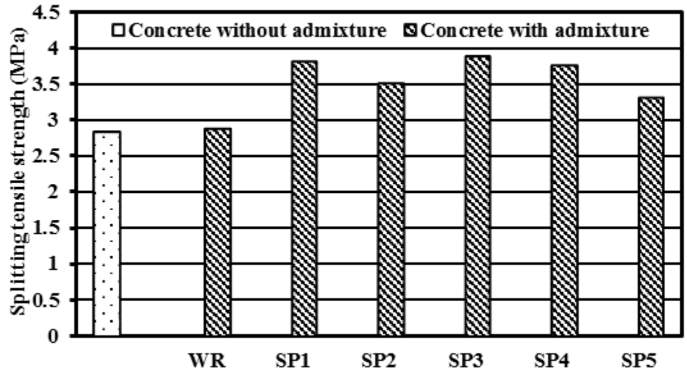

Figure 4. 28 days splitting tensile strengths of concretes made with different admixtures

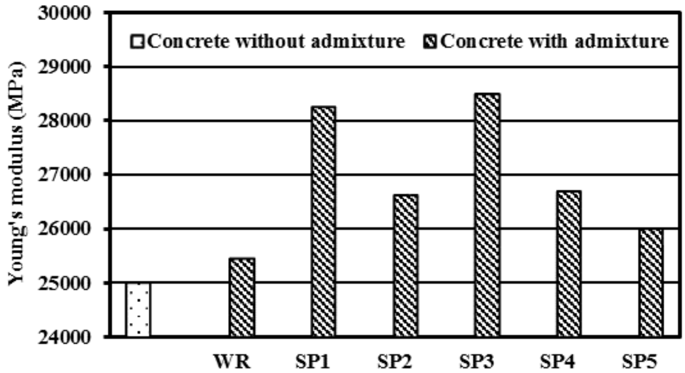

Figure 5. 28 days Young's moduli of concretes made with different admixtures

Young's moduli of concretes made with different chemical admixtures are shown in **Figure 5**. The results shown in **Figure 5** are similar to those presented in **Figure 3** and **Figure 4**. In this case also, concrete with second generation polycarboxylic ether based superplasticizer SP3 exhibited better performance compared to others. Concrete with lignosulfonate based water reducer WR resulted lower Young's modulus in comparison to the concretes made with superplasticizers.

Based on the results presented in **Figure 2**, **Figure 3**, **Figure 4** and **Figure 5**, it can be summarized that concrete with sulfonated naphthalene polymer based SP1 exhibited best performance in the fresh state of concrete. On the other hand, concrete with second generation polycarboxylic ether based SP3 showed best performance in the hardened state of concrete. However, in hardened state, the differences between the test results of concretes with SP1 and SP3 were insignificant.

4. CONCLUSIONS

Based on the results obtained from this experimental investigation, the following conclusions can be drawn:

- Sulfonated naphthalene polymer based superplasticizer shows best performance in improving workability of fresh concrete in comparison to other chemical admixtures. Sulfonated naphthalene polymer based superplasticizer also helps concrete to remain workable for longer time period in comparison to other admixtures. Second generation polycarboxylic ether based superplasticizer can be categorized as the second best chemical admixture in improving workability of fresh concrete.
- Concrete made with second generation polycarboxylic ether based superplasticizer exhibits higher compressive strength, splitting tensile strength and Young's modulus compared to concretes prepared with other admixtures. Concrete made with sulfonated naphthalene polymer based superplasticizer exhibits the second best performance in hardened state of concrete.
- Superplasticizers show better performance in improving fresh and hardened behaviors of concrete compared to lignosulfonate based water reducer.
- Concrete with chemical admixture results higher compressive strength, splitting tensile strength and Young's modulus compared to concrete without admixture, when the dosage of admixture is within the range recommended by manufacturer.

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