Effects of Superplasticizers on Fresh And Hardened Portland Cement Concrete Characteristics

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Abstract— *Superplasticizer or high-range water reducer is a specific type of admixtures that is used to produce low water-cement ratio high-strength concrete with normal or enhanced workability. Therefore, by using superplasticizers, it became easier for contractors nowadays to place highly workable, durable, pumpable concrete with higher strength, and even with less cost than using other ways to produce concrete with such properties. The effects of superplasticizers on physical properties of hardened and fresh concrete have been studied in this paper by using different dosages of superplasticizer. The compressive strength tests were conducted for concrete samples of different dosages at 7 days and 28 days to determine the properties of hardened concrete, while the slump tests were conducted to determine the properties of fresh concrete as well. The results show that the highest compressive strength at 28 days was achieved at 3% dosage of superplasticizer, while the highest compressive strength at 7days achieved at 1% dosage. Whereas, using higher dosage of superplasticizer resulted in a lower compressive strength with very high slump value.*

Keywords—Characteristics of concrete, concrete compressive strength, superplasticizer, workability of concrete

I. Introduction

Concrete is the most widely used building material in the construction industry. It consists of rationally chosen mixture of blinding materials such as lime or cement, well graded fine and coarse aggregates, water, and admixtures. In a concrete mix, cement and water form a paste which in addition to filling the voids of the fine aggregate, coats the surfaces of fine and coarse aggregates and binds them together [1]. Concrete structures should be able to serve the purposes for which they were built throughout their service life [2]. Achieving durability in concrete therefore should be a very significant factor in the design and construction of new structures[3].

Recently, ready-mixed concrete is widely used. This concrete is prepared in a central plant, and delivered to the job site in mixing trucks ready for placing. Three mixing methods can be used for ready-mixed concrete: central-mixed concrete, shrink-mixed concrete, and truck mixed concrete [2]. By using ready-mixed concrete the contractors can save time, higher quality concrete can also be produced as well. Due to the wide use of ready-mixed concrete, it was very important to use admixtures to improve the quality of concrete, enhance workability, and to produce concrete that can sustain the severe environmental conditions. The function of each admixture focuses on a specific need, and each has been developed independently of the others. Some admixtures already have chemistry that affects more than one property of concrete and some have simply been combined for ease of addition during the batching process. Water reducers, or plasticizers, have allowed finishers to place the concrete with much less water, and thus produce higher strength and more durable concrete. High-range water reducers (HRWRs), or superplasticizers, were developed to adjust the plasticity of low-water concrete to a consistency that can easily be pumped up to higher elevations without compromising strength or durability [5]. Whereas, in the past, it was so difficult and expensive to produce a workable concrete with high strength, it becomes easier and cheaper for contractor to produce concrete with such properties by using superplasticizer. The superplasticizers can reduce water demand by 12% to 30%. The reduced water content and water-cement ratio can produce concrete with (1) ultimate compressive strengths in excess of 70 MPa, (2) increased early strength gain, (3) reduced chloride-ion penetration, and (4) other beneficial properties associated with low water-cement ratio concrete [5]. Superplasticizers are typically one of four chemical groups: sulfonated melamine-formaldehyde condensate (SMF), sulfonated naphthalene-formaldehyde condensate (SNF), modified lignosulfonate (MLS), and others that may include sulfonic acid esters or carbohydrate esters (carboxylates) [6].

II. Objectives of the Study

This study aims to:

- Determine the effect of superplasticizers on properties of hardened concrete, by testing the compressive strength of concrete at different dosages of superplasticizers.
- Determine the effect of superplasticizers on the workability of the concrete, which is one of the most important properties of fresh concrete.
- Find the optimum dosage of a specific superplasticizer (Conplast SP430) that can achieve the best compressive strength and workability for normal concrete.

III. Methodology and Tests

The prepared concrete is Portland cement concrete that composed of aggregates, water, cementing agent, and admixtures.

A. Cement

Portland cement type one was used in preparing the concrete samples, which is also known as normal Portland cement. This type of cement complies strictly with BS 12: 1991 where it is widely used in general construction, and it is the most used cement around the world [5]. The ingredients of this type of cement are Lime (60-65%), Silica, Alumina, and Iron Oxide.

B. Aggregates

Generally, aggregates composed of crushed stone, gravel and sand. Depend on the size, two aggregate sizes are used in concrete: coarse aggregates (aggregate particles that are retained on a 4.75 mm sieve) and fine aggregates (aggregate particles that pass a sieve 4.75 mm) [4].

The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy [5].

Aggregates must conform to certain standards for optimum engineering use: they must be clean, hard, strong, durable particles, free of absorbed chemicals, coatings of clay, and other fine materials, that could affect hydration and bond of the cement paste [5]. The coarse aggregates used in this study are mix of sedimentary and quartz aggregates with 19 mm maximum size. On the other hand sea sand is used as fine aggregates.

C. Water

Almost, any natural water that is drinkable and has no pronounced taste or odor can be used as mixing water for making concrete. Excessive impurities in mixing water not only may affect setting time and concrete strength, but also may cause efflorescence, staining, corrosion of reinforcement, volume instability, and reduced durability. In this study, potable municipal water was used in concrete mixtures.

D. Superplasticizer

The used superplasticizer in this study is Conplast SP430, which complies with BS 5075 Part 3 and with ASTM C494 as Type A and Type F, depending on dosage used. Conplast SP430 is a chloride free, superplasticizing admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water. Potable municipal water was used in concrete mixtures.

E. Concrete Mixing

Concrete samples were prepared by using a water cement ratio of 0.5, saturated surface dry aggregates and 1:2:4 (cement: fine aggregates: coarse aggregates) by mass proportions. Samples with different dosages of superplasticizer were prepared, while other samples were prepared without adding superplasticizer, in order to use as a control samples.

The dosages of superplasticizer that were used: 1%, 2%, 3%, 4%, and 5% by weight of cement. Details of the mixes are given in Table I.

TABLE I: MIX PROPORTION OF CONCRETE

Concrete mix	Water Cement Ratio	Superplasticizer Dosage (%)
1	0.5	0.0 %
2	0.5	1.0 %
3	0.5	2.0 %
4	0.5	3.0 %
5	0.5	4.0 %
6	0.5	5.0%

A. *Test Procedures*

To determine the compressive strength at 7 and 28 days, concrete cubes of 150 mm were used in these tests. As in BS 1881: Part 111:1983 code, with water curing temperature of 27± 2 C [8]. Some of the concrete cubes were broken at 7 days and others at 28 days, by using compression machine; failure loads were recorded and the compressive strengths were then calculated.

The slump test was conducted to determine the workability of the concrete, which is one of the most important properties of fresh concrete. Following the procedures of the ASTM Standard C143/C, 2003: (1) samples of freshly mixed concrete were placed and compacted by rodding in a mold shaped as the frustum of a cone, (2) the mold was raised, and the concrete allowed to subside, (3) the vertical distance between the original and displaced position of the center of the top surface of the concrete was measured and reported as the slump of the concrete [9].

I. RESULTS AND DISCUSSION

A. *Physical Properties of Fresh Concrete*

Workability is one of the main properties of fresh concrete; therefore, slump tests were conducted for varies concrete mixes with different superplasticizer dosages, in order to measure this property. The slump test results, which are illustrated in Table II and Fig.1, show the relation between dosages of superplasticizer and slump loss.

TABLE II: Slump Test Results at Different Superplasticizer Dosages

Concrete mix	Superplasticizer Dosage (%)	Slump loss (mm)
1	0.0	17
2	1.0	20
3	2.0	64
4	3.0	155
5	4.0	195
6	5.0	213

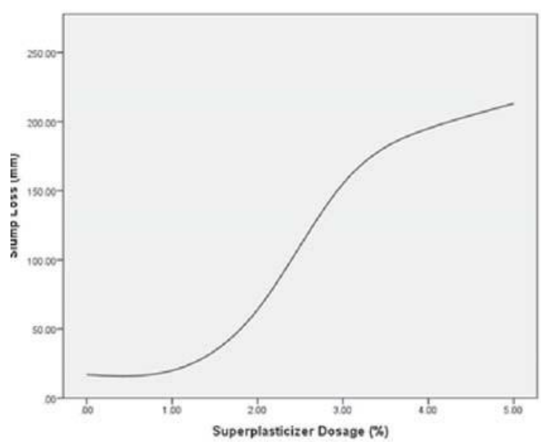

Fig. 1 Slump test results at different superplasticizer dosages

By increasing the dosage of superplasticizer the slump loss increases, since the superplasticizer helps to retain the concrete in plastic state for longer time, and thus the concrete can be transported for longer distances. However, over dosage of superplasticizer leads to very high slump loss, which is undesirable.

A. Physical Properties of Hardened Concrete

In order to study the effects of superplasticizer dosages on the properties of hardened concrete, compressive strength tests at 7 and 28 days were conducted for concrete mixes with different dosage of superplasticizers. Table III shows the results of compressive strength tests at different dosages of superplasticizer.

TABLE III: Compressive Strength Results at Different Superplasticizer Dosages

Concrete Mix	Super plasticizer dosage (%)	Compressive Strength at 7 Days (Kg/cm²)	Compressive Strength at 28 Days (Kg/cm²)
1	0.0	212.9	299
2	1.0	281.7	345.2
3	2.0	271	381
4	3.0	226.5	385.4
5	4.0	216.5	369.6
6	5.0	204.4	336.5

As a result of adding superplasticizer, the compressive strength at 7 and 28 days started to increase by increasing the dosage of superplasticizer to a specific limit, and then the compressive strength started to decrease after reaching the optimum dosage of superplasticizer, as shown in Fig. 2 and Fig. 3.

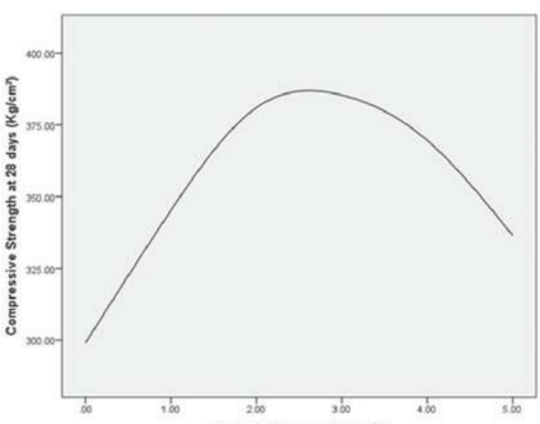

Fig. 2 Compressive strength at 28 days for different dosages of superplasticizer

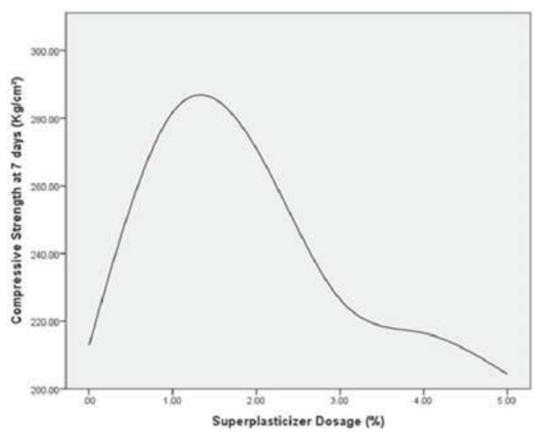

Fig. 3 Compressive strength at 7 days for different dosages of superplasticizer

For compressive strength at 28 days, the maximum achieved value was 385.4 Kg/cm² at superplasticizer dosage of 3%, while for compressive strength at 7 days, the maximum achieved value was 281.7 Kg/cm² at superplasticizer dosage of 1%. As a result, the optimum superplasticizer dosage is 3% when the main concern is the ultimate compressive strength, while the optimum superplasticizer dosage is 1 % when the main concern is the early compressive strength.

I. Conclusion

This study was conducted to determine the behavior of concrete at different dosages of superplasticizer as well as to determine the optimum dosage of superplasticizer (Conplast SP430) that can be added to concrete (with characteristic strength of 300 Kg/cm²). By analyzing the results of compressive and slump tests, the following conclusions are offered:

- The ultimate and early compressive strength can be increased by adding superplasticizer. By increasing the dosage of super plasticizer the strength increases. Thus until the optimum dosage limit is reached, after that the ultimate and early strength starts decreasing.
- Depending on the ACI method of mix design, the recommended slump for most types of construction is between 25 mm to 75 mm; therefore, the desirable dosage of superplasticizer that can achieve these values is between 1% to 2%.
- The workability of concrete increases with the increasing of superplasticizer dosage. However, over dosage of superplasticizer will lead to undesirable workability, which may not suitable for concrete construction.
- The optimum dosage of superplasticizer that can be added to normal concrete is around 1%, when the main concern is the early compressive strength.
- When the main concern is the ultimate compressive strength, the optimum dosage of superplasticizer that is desirable to use is 3%.

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References

[1] S. K. Duggal, Building Materials, 3rd ed. India: New Age International Publishers, 2008.

[2] V. Baroghel-Bouny, T. Q. Nguyen, and P. Dangla, “Assessment and prediction of RC structure service life by means of durability indicators and physical/chemical models”, Cement and Concrete Composites, Vol. 31, 2009, pp.522-534.

[3] W. Merretz, G. Smith, and J. Borget, “Achieving durability in construction”, CIA Concrete Durability Worksho, June 2009. [Online]. Available: http://www.sciaust.com.au.

[4] Michael S. Mamlouk and John P. Zaniewski, Materials for Civil and Construction Engineers, 3rd ed. United States of America: Prentice Hall,2011.

[5] M. L. Wilson and S. H. Kosmatka, Design and Control of Concrete Mixtures, 15th ed. United States of America: Portland Cement Assn, 2011.

[6] Edward G. Nawy, Concrete Construction Engineering Handbook, 4th ed. United States of America: CRC Press, 2008.

[7] Salahaldein Alsadey, “Effect of superplasticizer on fresh and hardened properties of concrete”, Journal of Agricultural Science and Engineering, Vol. 1, No. 2, 2015, pp. 70-74.

[8] I. B. Muhit, “Dosage Limit Detemination of Superplasticizing Admixture and Effect Evaluation on Properties of Concrete”, International Journal of Scientific and Engineering Research, Vol. 4, No. 3, 2013. [Online]. Available:http://www.ijser.org/researchpaper. ASTM Standard C143/C, 2003, “Slump of Hydralic Cement Concrete”, ASTM International, West Conshohocken, PA, 2003, DOI: 10.1520/C0033-03, www.astm.org.