Effect of Superplasticizers to Enhance the Properties of Concrete

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Abstract: This study aimed to study the effects of asuperplasticizing admixture, namely, Sikament-NN superplasticizer, on concrete properties, such as workability and compressive strength. Experiments were performed on different concrete mixes with water–cement ratios of 0.50, 0.55, and 0.60. The superplasticizer dosages by weight of cement were 0%, 0.8%, 1%, and 1.2%. The experiments were classified into two phases: the first phase focused on the effects of superplasticizer admixture on workability and compressive strength, and the second phase determined the influence of superplasticizer admixture on concrete quality by reducing the amount of mixing water. Results showed that the addition of superplasticizer admixture improved workability and compressive strength. The experiment program included tests on workability, slump test, and flow table. For hardened concrete's compressive strength test, we compared the properties of superplasticizer-based concrete with those of concrete without superplasticizer. The superplasticizer led to a significant water reduction but maintained workability.

Keywords: Superplasticizer, compressive strength, slump, workability, admixture.

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1. Introduction

Concrete is one of the most commonly used construction materials in the world. Concrete technology has made enormous strides in the past decade. Concrete is no longer a material consisting of cement, aggregates, water, and admixtures, but it is an engineered material with several new constituents. Admixtures are defined as materials other than cement, water, and aggregates that are used as an ingredient of concrete and added to the batch immediately before or during mixing. Admixtures are classified into two types: mineral and chemical admixtures. Water-reducing admixtures are chemical admixtures that provide a wide advantage for concrete in fresh and hardened states. Different water-reducing admixtures are available in the market; among them, high-range water-reducing admixtures are also known as superplasticizers. Numerous characteristics of concrete are influenced by the ratio of water to cementitious materials (w/cm) used in the mixture. By reducing the amount of water, the cement paste will have high density, which results in high paste quality. An increase in paste quality will yield high compressive strength. A superplasticizer is an admixture for concrete that is added to reduce the water content in a mixture or to slow the setting rate of concrete while retaining the flowing properties of a concrete mixture. The use of a superplasticizer will have positive effects on the properties of concrete both in the fresh and hardened states. In the fresh state, use of a superplasticizer can reduce bleeding due to the reduction in water–cement ratio or water content of concrete. If the water–cement ratio is maintained, then a superplasticizer can extend the setting time of concrete as more water is available to lubricate the mix. In the case of hardened concrete, the use of a superplasticizer will increase compressive strength by enhancing the effectiveness of compaction to produce dense concrete. In addition, the carbonation rate becomes slower when the water–cement ratio is decreased with the presence of a superplasticizer [1]. The slump of fresh concrete can be optimally controlled in all mix designs if reactive Liboment–163 is added. Given that the workability of concrete with low water–cement ratio is difficult to control, the addition of reactive Liboment–163 can maintain the initial slump of mixed concrete. Superplasticizers can produce good quality concrete by increasing the density of concrete through a significant reduction in water requirement and slump loss [2]. Water-reducing admixtures (superplasticizers) are generally used in concrete to increase strength with low water–cement ratios [3, 4]. However, the admixture dosage should be determined in the laboratory prior to its application as its excess might result in a slight improvement or adverse effects on the performance of roller-compacted concrete [5, 6]. Admixtures can provide considerable physical and economic benefits with respect to concrete. However, usage of admixture does not cure concrete's poor qualities due to the use of incorrect mix amounts, poor workmanship in concrete mixing, and problems caused by low-quality raw materials. Superplasticizers are used to increase workability without changing the water–cement ratio or increase the ultimate strength of concrete by reducing the water content while maintaining adequate workability. This work was carried out to study the effect of superplasticizer dosage on the properties of concrete with reducing water–cement ratios.

2. Experimental Program

This study aimed to compare the properties of concrete produced with and without using Sikament-NN-based superplasticizing admixture and investigative the effects of different dosages of Sikament-NN-based superplasticizing admixture on workability and strength of concrete.

2.1 Materials Used and Properties

The materials used in this study were cement, fine, coarse aggregates, and water. A chemical admixture (superplasticizer) was added to change the properties of concrete for certain applications. Materials are important in determining the quality of the produced concrete, so they should be properly selected and chosen before the beginning of the experiment.

2.1.1 Ordinary Portland cement

Ordinary Portland cement (50 kg) was used for the entire investigation. The cement used in this study was a product from A Zlitan Cement Industries, Libya, where it is widely used in general construction such as in buildings, bridges, and other precast concrete products. Ordinary Portland cement Type-I used in this experiment conformed to IS.

2.1.2 Fine and Coarse Aggregates

Aggregates are important because they occupy about 65%–75% of the volume of concrete. In general, two types of aggregates are used in concrete, namely,fine and coarse aggregates. Many parameters need to be considered in the selection of aggregates, such as types of aggregate, size and shape of particles, and strength of aggregates. All aggregates must be free from dust as dust may affect the bond between the aggregate and cement particles. Locally available sea sand was passed through a sieve of 6mm and used as fine aggregate in this study. By contrast, crashed stone with a maximum size of 20 mm was used as coarse aggregate. Aggregates were cleaned before mixing to wash away the fine particles on the surface of the aggregates.

2.1.3 Mixing Water

Water is important to ensure continuous hydration. Tap water was used for mixing and curing of concrete. Water must be free from reactive elements such as reactive ions and impurities to guarantee the quality of concrete.

2.1.4 Superplasticizer

The superplasticizer used in this study was Sikament-NN, which is a high-range water-reducing admixture. One of its benefits is its ability to develop both early and final strength. Slump retention and workability of concrete can also be improved by using Sikament-NN superplasticizer.

2.2 Proportions for Experimentation

To analyze performance, three design mixes of concrete with different water–cement ratios of 0.50, 0.55, and 0.60 and three superplasticizer dosages of 0.8%, 1%, and 1.2% of cement content required for mix of normal concrete were prepared. These mixes were cast in standard concrete cubes. Tests were conducted with three cubes for one batch, and the average strength of three cubes was considered for one proportion. The various quantities of materials are shown in Tables 1–3. These three mixes of concrete are abbreviated in Tables 4 and 5 for further discussion and interpretation with respect to normal concrete.

Table 1. Materials Proportion for w/c ratio 0.60

No. of Mix	Dimension (mm) L×B×H	Concrete Mix					
		Cement	Fine aggregate	Coarse aggregate	Water	SP	W/C
		kg/m^3	kg/m^3	kg/m^3	kg/m^3	%	
Mc-1	150×150×150	350	670	1200	210	0	0.60
MS-2	150×150×150	350	670	1200	210	0.8	0.60
MS-3	150×150×150	350	670	1200	210	1.0	0.60
MS-4	150×150×150	350	670	1200	210	1.2	0.60

Table 2. Materials Proportion for w/c ratio 0.55

No. of Mix	Dimension (mm) L×B×H	Concrete Mix					
		Cement	Fine aggregate	Coarse aggregate	Water	SP	W/C
		kg/m^3	kg/m^3	kg/m^3	kg/m^3	%	
Mc-1	150×150×150	350	670	1200	192.5	0	0.55
MS-2	150×150×150	350	670	1200	192.5	0.8	0.55
MS-3	150×150×150	350	670	1200	192.5	1.0	0.55
MS-4	150×150×150	350	670	1200	192.5	1.2	0.55

Table 3. Materials Proportion for w/c ratio 0.50

No. of Mix	Dimension (mm) L×B×H	Concrete Mix					
		Cement	Fine aggregate	Coarse aggregate	Water	SP	W/C
		kg/m^3	kg/m^3	kg/m^3	kg/m^3	%	
Mc-1	150×150×150	350	670	1200	175	0	0.50
MS-2	150×150×150	350	670	1200	175	0.8	0.50
MS-3	150×150×150	350	670	1200	175	1.0	0.50
MS-4	150×150×150	350	670	1200	175	1.2	0.50

3. Results and Discussions

This study analyzed the influence of increasing water reduction with different dosages of superplasticizer (Sikament-NN superplasticizer of the weight of cementitious material) on the characteristics of concrete with and without superplasticizer.

3.1 Effect of Superplasticizer with Reduced Water–Cement Ratio on Workability

The results for slump and flow of superplasticizer concrete are shown in Table 4. The data show the relation between dosages of superplasticizer and slump and flow. The values of slump and flow for different superplasticizer dosages were then plotted as a graph (Figures 1 and 2). The graph shows the slump and flow against different superplasticizer dosages. The slump and flow increased with increasing superplasticizer dosages. Moreover, increasing the dosage of superplasticizer increased the workability of concrete, because the superplasticizer helped retain the concrete in liquid state for a long time and reduced slump loss during the transportation of concrete to the site. However, overdosage of superplasticizer could lead to high workability, which would not yield the true expected and desired slump. The superplasticizer significantly increased the workability of concrete due to deflocculation and adsorption of highly negative charges on cement particles. Before adding the superplasticizer, the concrete was less cohesive and presented a small diameter (less than 500mm). According to BS 1881: Part 105: 1984, concrete can only be considered uniform and cohesive when it possesses a diameter between 500 and 650 mm. After adding the superplasticizer, this desired diameter was achieved. Hence, superplasticizer concrete was cohesive in accordance with BS 1881.

Table 4. Workability Obtained for various ratios during the experiment

No.	Proportions	Slump (mm)	Flow (mm)
1	Control Mix, For w/c -0.60	130	455
2	w/c-0.60 & SP-0.8	150	530
3	w/c-0.60 & SP-1.0	240	625
4	w/c-0.60 & SP-1.2	250	660
5	Control Mix, For w/c -0.55	90	365
6	w/c-0.55 & SP-0.8	130	480
7	w/c-0.55 & SP-1.0	200	540
8	w/c-0.55 & SP-1.2	220	575
9	Control Mix, For w/c -0.50	50	305
10	w/c-0.50 & SP-0.8	110	405
11	w/c-0.50 & SP-1.0	130	445
12	w/c-0.50 & SP-1.2	140	490

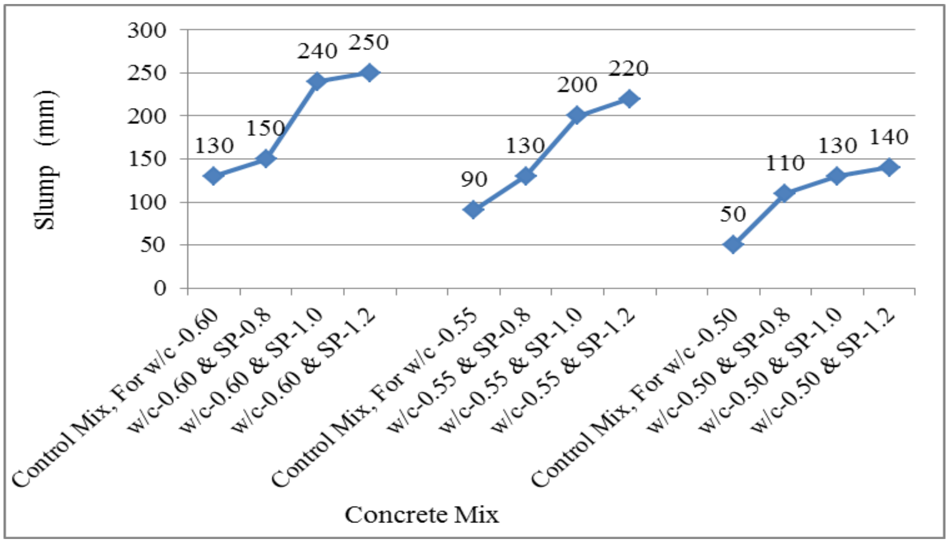

Fig. 1. Combination of graphs showing the results of slump at different w/c ratio of concrete by using three different dosages of superplasticizer and a conventional concrete

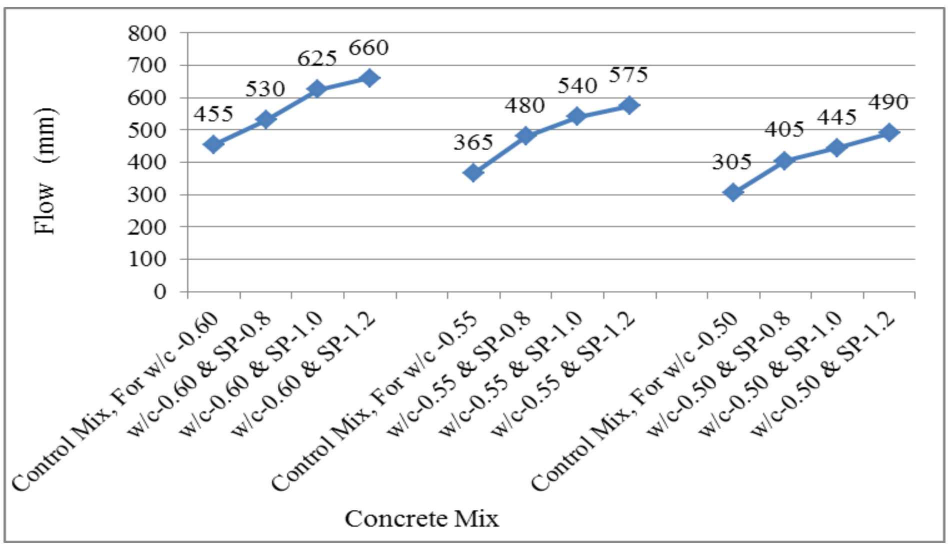

Fig. 2. Test result showing effect of superplasticizer on water reduction and flow table test at different w/c ratio of concrete

3.2 Effect of Superplasticizer with Reduced Water–Cement Ratio on Compressive Strength

The compressive strength of concrete with different superplasticizer dosages with reduced water–cement ratio is shown in Table 5. This test was performed for 28 days. The values of compressive strength for different superplasticizer dosages were plotted as a graph in Figure 3. The graph of compressive strength versus water–cement ratio of concrete revealed that the compressive strength of the chemical admixture increased with reducing water–cement ratio compared with that of the control mix. In terms of the influenceof the admixturedosage, the superplasticizer presented different effects on the compressive strength of concrete. Increasing superplasticizer dosage elevated the compressive strength for all mixes compared with the control mix. Theaddition of superplasticizer providedadditionalwater for concrete mixing, and the hydration process was accelerated by the additional water from deflocculation of cement particles. Hence, increase in dosage could increase the entrapped water and promote the hydration of cement. Although increasing the dosage of admixture couldenhance the compressive strength, an optimum limit was found for the usage of admixture. When the dosages exceeded this limit, an increase in dosage only reduced the compressive strength. This phenomenon occurred because overdosage of superplasticizer could cause bleeding and segregation, thereby affecting the cohessiveness and uniformity of concrete. Therefore, compressive strength decreasedwhenthe used dosage exceeded the optimum dosage. The optimum dosage of superplasticizer was based on the highest ultimate strength at 28 days. The graph demonstrated that the optimum dosage for the admixture was 0.8% by weight of cement. Any dosage higher than this optimum value couldreduce the compressive strength,which wasstill higher than that of the control mix. For accurate and precise results, additional dosages with small intervals should be investigated for a curve with the best fit.

Table 5. Compressive strength and Density

Sr No.	Proportions	Density g/cm^3	Compressive Strength (Map) 28 Days
1	Control Mix, For w/c -0.60	2.389	27.3
2	w/c-0.60 & SP-0.8	2.328	35.13
3	w/c-0.60 & SP-1.0	2.283	31.56
4	w/c-0.60 & SP-1.2	2.248	29.56
5	Control Mix, For w/c -0.55	2.397	30.6
6	w/c-0.55 & SP-0.8	2.289	38.76
7	w/c-0.55 & SP-1.0	2.277	33
8	w/c-0.55 & SP-1.2	2.266	31.9
9	Control Mix, For w/c -0.50	2.397	36.3
10	w/c-0.50 & SP-0.8	2.401	44.7
11	w/c-0.50 & SP-1.0	2.327	39.2
12	w/c-0.50 & SP-1.2	2.325	38.4

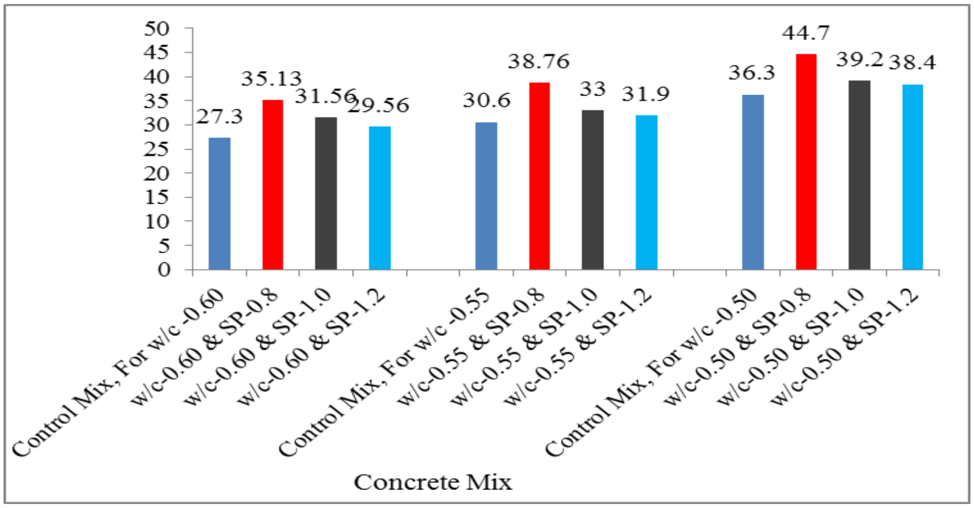

Fig. 3. Test result of the graph showing compressive strength at different w/c ratio of concrete with superplasticizer dosages

4. Conclusion

This study was conducted to study the effect of a superplasticizer on the properties of concrete. The properties examined were workability (slump) and compressive strength. Results demonstrated that the properties of concrete in fresh and hardened stages were enhanced with the addition of superplasticizer for all nominal mixes of concrete. Sikament-NN increased the compressive strength, workability, and water reduction requirements of concrete. Moreover, the workability of concrete increased with the addition of superplasticizer. However, high dosages of superplasticizer impaired the cohesiveness of concrete. Slump was increased by using the chemical admixture, but effectiveness was high for superplasticizer concrete.

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