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Research paper

Evaluation of the superplasticizer effect on the workability and strength of concrete

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Abstract

The adverse effects of temperature on the properties of fresh concrete include increased water demand, shorter setting time and increased slump loss. Superplasticizer (SP) is important for enhancing the workability and setting time of concrete in hot weather. Hence, an experi-mental investigation was conducted to determine the optimum dosage of an admixture and to study the effect of over dosing this admixture. Concrete mixes with SP dosages of 0.8%, 1% and 1.2% by weight of cement were prepared along with a control mix (water/cement ratio of 0.55). After casting, the concrete samples underwent normal curing. Among the properties of fresh concrete determined were compressive strength as well as workability. The over dosage of SP appeared to degrade the properties of concrete with an indication of lower compres-sive strength. However, if the dosage levels are lower than the optimum dosage, raising the admixture dosage might help enhance the con-crete characteristics.

Keywords: *Concrete; Admixtures; Superplasticizers; Workability; Compressive Strength Semicolon.*

1. Introduction

Concrete is the most important material in civil engineering. In the world, about 90-95% of the construction materials on the market for both structural and non-structural applications are made of concrete in contrast to other materials used for similar functions [1]. Concrete is generally made of cement, water and aggregates besides an additional material known as an admixture that is sometimes added to modify certain properties of concrete. Cement is the chemically active constituent, the reactivity of which is only brought into effect upon mixing with water. The aggregate has no important role in the chemical reaction, but its usefulness arises because it is an economical filler material or hard composite material with good resistance to volume changes that take place within the concrete after mixing and it also improves the durability of concrete.

In hardened state, concrete is a rock-like material with high compressive strength. In its plastic state, concrete may be moulded into any form of shape for potential advantages architecturally or solely for decorative purposes. The low tensile strength of concrete is the reason it is used with steel bars to resist tensile forces in the reinforced concrete. Concrete is usually used in the building of foundations, columns, beams and slabs, shell structures, bridges, sewerage treatment plants, roads, cooling towers, railway sleepers and so on. In the precast concrete industry, concrete is widely used in the form of concrete blocks, cladding panels, pipes, piles and lamp posts [2, 3, 4].

Nowadays, more than 90% of in-situ concrete in the world is produced by the ready-mixed concrete industry. Producers of ready-mixed concrete use retarding and superplasticizing (SP) admixtures that various manufacturers make readily available [1]. Superplasticizer (SP) is applied to increase workability without changing the water/cement ratio. Or it can be used to increase the ultimate strength of concrete by reducing water content while maintaining adequate workability. This experimental work is carried out to study the effect of retarder and SP dosage on the properties of concrete. In some cases, it has been observed at job sites that the concrete remains unset for 2 to 3 days due to the over dosage of the retarding admixture. This is a serious issue that has become very common in the concrete practice. Superplasticizer is a type of water reducer that can significantly reduce the water required for concrete mixing [5]. There are generally four main categories of superplasticizer: sulfonated melamine formaldehyde condensates, sulfonated naphthalene formaldehyde condensates, modified lignosulfonates, and others (e.g. sulfonic acids and carbohydrate esters). The obvious desirable effects of superplasticizer are to produce concrete with very high workability and/or very high strength. Superplasticizer works by giving the cement particles a highly negative charge so they repel each other due to the same electrostatic charge. By deflocculating the cement particles, more water is provided for concrete mixing [5].

The term cement-SP compatibility is used to represent the ability to achieve a desired result from a cement-SP combination in a concrete mix, viz. improved workability for a given water/cement or reduction in free water for a target workability. Any failure in this respect is called incompatibility. This problem is faced on most construction sites and is one of the most burning issues for the construction industry. The strength property of mortar serves as a criterion for evaluating its performance. In the absence of proper quality control measures, the batch- to- batch variations in SP can also add to the problem. Complications arising from compatibility issues are often mistaken for problems with concrete mixture design because of the lack of awareness amongst practicing engineers. Admixture manufacturers try to overcome the problem by formulating project-specific chemicals, which is obviously only a short- term solution. For a more comprehensive approach, a thorough understanding of the causes and remedies of incompatibility is necessary. Since the problem is often region- and project - specific, it is necessary to identify possible sources of variability and address the problem of incompatibility. Chemical admixtures are very important components of modern concretes and mortars; they make it possible to modify certain properties of mortar in fresh or hardened state [6]. The reason admixtures are so widely used is that admixtures are able to impart considerable physical and economic benefits with respect to concrete. However, using admixtures is not a remedy for the poor quality of concrete due to the use of incorrect mix proportions, poor workmanship in concrete mixing and problems caused by selecting low-quality raw materials [7]. Before commencing the experimental work, the following objectives were clearly defined:

- To determine the optimum dosage of concrete superplasticizer for normal concrete.
- To investigate the effects of superplasticizer on the properties of concrete.

The significance of the study is in quantifying the effects of superplasticizer on the properties of concrete in fresh and hardened states. In fresh state, the effect of the admixture on workability is investigated. In the case of hardened concrete, the effect of the admixture on compressive strength is studied. In addition, the optimum dosage of admixture to enhance certain properties of concrete is determined.

2. Experimental details

The materials used in this study are cement, and fine and coarse aggregates. However, a chemical admixture (superplasticizer) was added in order to change the characteristics of concrete for certain applications. Since the materials are important in determining the quality of the concrete produced, they had to be selected properly before beginning the experiment.

a) Ordinary Portland cement

The cement used in this study is Ordinary Portland cement. The type-I cement complies strictly with Ordinary Portland Type-1 cement. The properties were illustrated in Table1.It is widely used in general construction in the world, for example buildings, bridges and other precast concrete products and is available in 50 kg bags.

Table 1: Chemical Compositions of OPC Cement

Oxide composition	Oxide content %
CaO	63.24
SiO_2	20.13
Al_2O_3	4.59
Fe_2O_3	4.26
MgO	2.42
SO_3	1.12
C_3S	63.83
C_2S	9.55
C_3A	4.34
C_4AF	14.05

b) Fine and coarse aggregates

An aggregate is significant because it occupies about three- quarters of the volume of concrete. Usually there are two types of aggregate used in concrete, which are fine and coarse aggregates. Many parameters need to be considered in selecting an aggregate, for instance the type of aggregate, size and shape of the particles, and the strength of the aggregate. All aggregates must be free from dust, as dust may affect the bonding between the aggregate and cement particles. The fine aggregate used in this investigation is sea sand, while the coarse aggregate is crashed stone with a maximum size of 20 mm. In addition, aggregates should be cleaned before mixing to wash away the fine particles that stick on the aggregate surface.

c) Superplasticizer

The superplasticizer used in this study is Sikament®-520. It is a high- range water reducing concrete admixture. One of its benefits is that it can improve both early and final strengths. In addition, the slump retention and workability of concrete is also enhanced by using Sikament®-520 superplasticizer. The Table 2 showed the physical and chemical properties of Sikament®-520 as supplied by the manufacturer.

Table 2: Physical and Chemical Properties of Superplasticizer

Physical state	Liquid
Colour	Brown
Odour	characteristic
Vapour pressure	23 hPa (17 mmHg)
Density	ca. 1.188 g/cm3 (25 °C (77 °F) ())
pH	ca. 8.38, (25 °C (77 °F))
Viscosity, Dynamic	10 - 25 mPa.s (25 °C)

3. Experimental program

This study focuses on normal-strength concrete with a characteristic strength of 30 Mpa at 28- days age and comprising, Ordinary Portland Cement (OPC) as binder, 20 mm crashed stone as coarse aggregate and sea sand as fine aggregate. Sikament®-520 (ASTM C-494 Type F) is the superplasticizer used in this study. One control mix was prepared without any admixture. To investigate the effects of the superplasticizer, three additional mixes were prepared using admixture dosages of 0.8%, 1% and 1.2% by weight of cement. The slump test was applied to assess the workability of the concrete mixes and compressive strength was determined for a concrete cube at age 28 days. All samples for the hardened concrete test were cured in water that was maintained at a temperature of 25 + 2ºC (ASTM C 192/C 192M. 2002). The 12 specimens with dimensions of 150 mm x 150 mm x 150 mm were fabricated in the Structural Engineering Laboratory of University. Details of the mixes are given in Table 3.

Table 3: Mix Design Details

Mix No	Concrete Mix Cement kg/m3	Fine aggregate kg/m3	Coarse aggregate kg/m3	Water kg/m3	SP
Mc-1	350	740	1105	192.5	%
MS-2	350	740	1105	192.5	0
MS-3	350	740	1105	192.5	0.8
MS-4	350	740	1105	192.5	1.0

4. Results and discussion

Several tests were performed on fresh and hardened concrete. The fresh concrete tests were for workability (slump), while the hardened concrete property measured was compressive strength. Concrete curing was carried out with the specimens immersed in water.

a) Effect of Superplasticizer on Workability

The effect of superplasticizer on the slump of the four concrete mixes is highlighted in Fig (1). It is noted that the inclusion of superplasticizer in concrete increased the workability for all dosage mixes, while a higher amount of superplasticizer produced higher workability. It was found that the effect of superplasticizer on both the flowing and working capacity was much higher than the reference concrete.

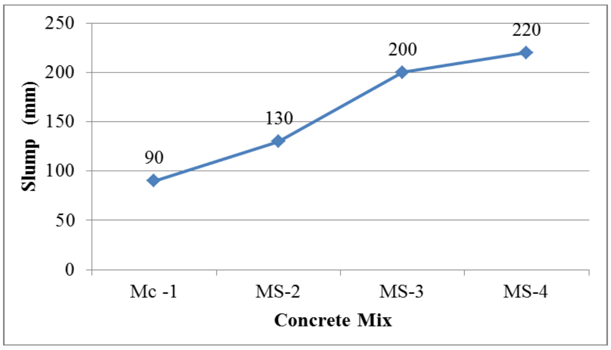

Fig. 1: The Workability Results for Concrete Mixes.

b) Effect of Superplasticizer on Compressive Strength

The compressive strengths of concrete with different superplasticizer dosages are listed in Table 4. This test was performed at 28 days. The compressive strength values for the different dosages of superplasticizer are then depicted in a chart in Fig 2.

Table 4: The Compressive Strength Results for Concrete Mixes

Concrete Mix	Sikament ®-520 %	Compressive strength (N/mm²)
Mc-1	0	30
MS-2	0.8	39
MS-3	1.0	33
MS-4	1.2	29

After conducting the experiment, a chart for compressive strength versus age of concrete was plotted. The chart illustrates the continuous strength gain of the superplasticizer concrete admixture with the increased admixture dosage. The superplasticizer concrete exhibited different behaviors in relation to the compressive strength of the concrete, whereby the increase in dosage increased the compressive strength. Since adding SP provides more water for concrete mixing, not only is the hydration process not disturbed, but it is also accelerated by the additional water from the deflocculation of cement particles. Hence, an increase in dosage will expand the entrapped water and promote cement hydration. Although incrementing the superplasticizer dosage will enhance the compressive strength, there is still an optimum admixture limit, beyond which, the compressive strength will only reduce. This phenomenon occurs because the over dosage of SP will cause bleeding and segregation, which will affect the cohesiveness and uniformity of the concrete. As a result, the compressive strength will reduce if the dosage applied is beyond optimum.

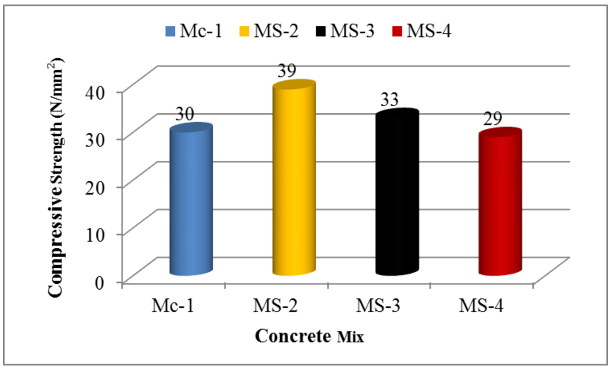

Fig. 2: Compressive Strength of Superplasticizer Concrete Mixes.

5. Conclusion

Based on the test results and observations, it can be stated that the properties of concrete in fresh and hardened states improved with the addition of superplasticizer. The properties of concrete containing Sikament ®-520 were subsequently studied. From the results of the present study, the following conclusions are drawn:

1) The workability of concrete can be increased by adding Sikament ®-520. However, very high dosages of superplasticizer tend to impair the cohesiveness of concrete.
2) The compressive strength is improved by Sikament ®-520. On the other hand, its ultimate strength is higher than the desired characteristic strength.

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