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EFFECT OF SUPERPLASTICIZERS ON PROPERTIES OF FRESH AND HARDENED CONCRETE

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ABSTRACT

In the world, about 90%-95% of the construction materials market for both structural and non-structural application is made of concrete compared with other materials used for similar functions. Concrete, generally, is a product made from cement, water and aggregates and an additional material known as Admixture, is sometimes added to modify certain properties of concrete. The present work is aimed at studying the effects of different superplasticizer dosages on the specific properties of fresh and hardened concrete (M30 at 0.35 w/c ratio) using Polycarboxylic Ether based (Auramix 400) as superplasticizer. The experimental tests for fresh and hardened properties of concrete for M30 grade are studied and the results are compared with normal concrete. The properties considered for study are Slump retention and Compressive strength. The slump retention has been obtained as the difference in the slump of concrete at initial and various intervals from the time of mixing. The compressive strength has been obtained as 7 day strength and 28 day strength. The optimum dosage is obtained as the dosage at highest compressive strength and at the highest slump retention. The project is divided into two phases: - Effect of Superplasticizer on concrete properties with variable water reduction and Effect of Superplasticizer on concrete properties with constant water reduction. It has been observed as the percentage of the admixture dosage is increased, the compressive strength also increases up to certain limit. The optimum dosage has been obtained as 0.8% for strength criteria and 0.9% for slump retention.

Keywords: Compressive Strength, Slump Retention, Superplasticizer, Workability.

I.INTRODUCTION

High-range water reducers (HRWR), commonly referred to as Superplasticizers, are chemical admixtures that can be added to ready-mix concrete to improve its plastic and hardened properties. They are also known as super fluidizers, or super water reducers. The first superplasticizer was developed in 1964 by Kenichi Hattori in Japan. It was based on formaldehyde condensates of beta-naphthalene sulphonates. Later that same year, a superplasticizer based on sulphonated melamine formaldehyde condensate was introduced in West Germany under the name Melment.

High-range water reducers are capable of reducing the water requirement for a given slump by about 30%, thus producing quality concrete having higher strength and lower permeability **[1]**. They present important advantages compared to conventional water reducers which only allow a reduction of up to 15%.

Superplasticizers significantly affect the rheological behavior of the cement paste. In general, the molecules of the superplasticizer align themselves around cement particles forming a watery shell as shown in Figure 1. These molecules are attracted to cement particles on one side and water molecules on the other. Thus they create a lubricating film around the cement particles, which reduces both the yield value and the plastic viscosity of the mix. These effects are more pronounced for higher concentrations of superplasticizer. Microscopic examination of cement particles suspended in water shows that large irregular agglomerates of cement particles are dispersed into small particles due to the effect of superplasticizers. As shown in Figure, the admixture forms needle-like hydration products instead of the large fibrous bundles found in normal concrete. At the age of six months, the concrete incorporating the admixture shows a tighter and more complete structure.

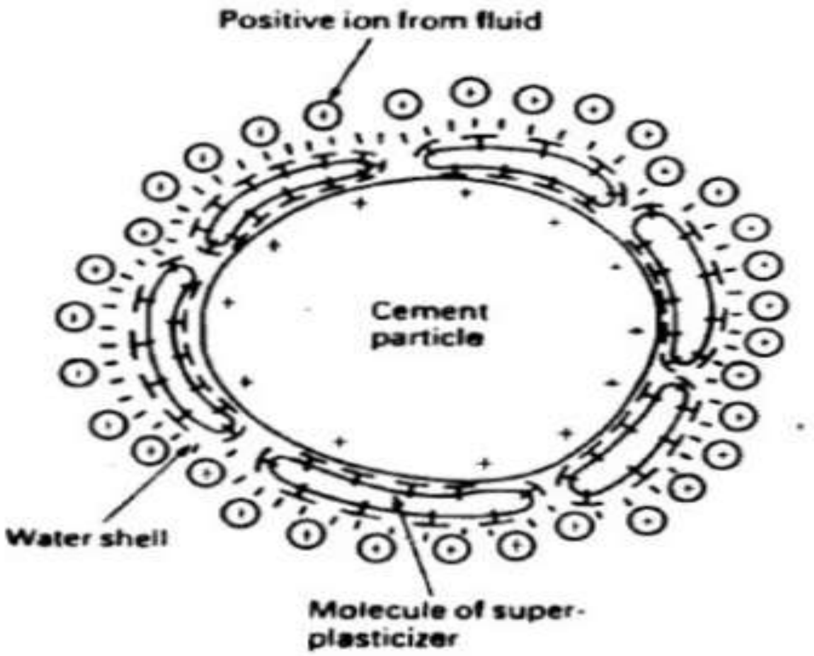

Figure 1: Mode of Action of Superplasticizers

Adsorption increases as the concentration of superplasticizer added is increased. Due to the adsorption of ions, particles develop charges. The repulsion between particles having identical charges prevents any agglomeration or precipitation, and decreases the viscosity of the system. The large negative potentials resulting from the addition of superplasticizer were found to decrease with time but remain high even after 1200 minutes. Soon after the initial contact between cement and water, cement particles increase in size and reaggregate, causing a reduction in fluidity almost immediately. Continuous mixing of the concrete shears off the hydration products formed on the surface of the cement particles. The combination of elevated temperature and the peeling action increases significantly both the hydration rate and the amount of hydration product formed thus causing a substantial reduction in fluidity. In order to reinstate the fluidity, the superplasticizer should act both on the cement particles and hydration products **[2]**. Therefore, a higher dosage of superplasticizer is required when the time of addition is delayed.

This research represents a complete study of high-range water reducers, their mode of action and their effects on plastic and hardened concrete properties. It also provides guidelines for engineers to follow in the field, including the time of addition and the dosage required to achieve the desired properties.

1.1. Effect of superplasticizer on properties of concrete (workability and compressive strength):

1.1.1. Workability

The workability of concrete depends on the following factors: initial slump, type and amount of cement, type and dosage of superplasticizer, time of addition of superplasticizer, temperature, relative humidity, mixing conditions (total mixing time, type of mixer, and mixer speed), and presence of other admixtures **[3]**. Mixes with lower initial slump require a higher dosage of superplasticizer. The opinions on the effect of initial slump on the rate of slump loss after the addition of superplasticizers are divided. Generally, mixes with higher initial slump were found to have a more gradual rate of slump loss. Workability is also affected by the cement type and cement content of the mix. It was found that to obtain the same workability, a higher dosage of superplasticizer is required for Type I than for Type V cement **[4]**. Mixes with higher cement content require smaller dosages of superplasticizer to achieve a certain slump. This is expected since mixes with higher cement content are known to be more fluid, even when no admixture is present. Moreover, mixes with higher cement content show a slower rate of slump loss. Superplasticizers differ depending on their type and manufacturer. It was reported that melamine based superplasticizers show a higher rate of slump loss compared to other types of superplasticizers. As the dosage of superplasticizer increases, workability increases and the rate of slump loss decrease. Overdosing the mixture will prolong workability even further, yielding an extremely high slump, but is likely to cause excessive segregation and bleeding. Another factor affecting workability is the time of addition of superplasticizers. The capacity of superplasticizers to improve workability decreases with time. It is, however, recommended to delay the addition for a few minutes until some of the C3A is removed from the mixture by hydration. This reduces slump loss considerably. At lower temperature, the loss in workability is reduced and the dosage required to achieve a desired slump is significantly increased, especially for temperatures below 68°F (20°C). Workability can be reinstated by repeated dosing with superplasticizers. Generally, repeated dosage does not deteriorate the concrete, but may result in loss of entrained air, and thus an increase in the plastic unit weight. Repeated dosage improves workability for an extra 25 to 45 minutes regardless of the slump achieved after the first dosage. The effectiveness of superplasticizers in improving workability decreases with the number of repeated dosages, and the rate of slump loss increases after each repeated dosage.

1.1.2. Compressive Strength

The strength of concrete with superplasticizer was found to be greater or at least equal to the strength of the same concrete made without the admixture. Since superplasticizers improve the workability, compatibility and facilitate reduction in water-cement ratio, and thereby increase the strength of concrete, it contributes to all-round improvement in the properties of hardened concrete. As a matter of fact, it is the use of superplasticizers, which is a pragmatic step to improve all-round properties of hardened concrete. The use of superplasticizer has become an unavoidable material in the modern High Performance concrete.

II.EXPERIMENTAL WORK

2.1. Raw materials

The cement used was commercially available ULTRATECH 43 grade Portland cement complying with the requirements of IS: 8112-2013. The coarse aggregates used were boulder crushed. Two types of coarse aggregates were used: 20 mm and 10 mm nominal size with specific gravity of 2.71. The fine aggregates used in all mixes was a natural sand conforming to grading zone 2 as per IS: 383-1970. Its bulk specific gravity at SSD was 2.65 and its fineness modulus ranged from 2.91 to 2.94. The superplasticizer used was AURAMIX 400 which is the advanced low viscosity high performance superplasticizer based on polycarboxylic ether.

2.2. Mix proportions

Tables 1 and 2 show the mix proportions of the concrete with w/c ratio of 0.35 with varying water reduction and constant water reduction respectively.

Table 1. Mix proportions of the concrete with w/c ratio 0.35 with variable water reduction:

Superplasticizer Dosage(%)	Water Reduction(%)	Composition of Concrete(kg/m^3)					
		Cement (kg)	Water (kg)	Coarse aggregate (kg)		Fine agg. (kg)	Superplasticizer dosage (kg)
				20 mm	10mm		
0	-	450	148.23	736	487.33	667	0
0.7	20	425	128	666.66	542	729.66	2.796
0.8	22	418	142	670.82	545.42	715	3.342
0.9	24	407	145	757.33	501.66	676	3.73
1.0	26	398	134	680	552.65	724	4.04
1.1	28	390	120	687	558.52	748	4.302

Table 2. Mix proportions of the concrete with w/c ratio 0.35 with constant water reduction@ 30%:

Superplasticizer Dosage(%)	**Composition of Concrete(kg/m^3)**					
	Cement (kg)	**Water (kg)**	**Coarse aggregate (kg)**		**Fine agg. (kg)**	**Superplasticizer dosage (kg)**
			20 mm	**10mm**		
0.7	372	120.27	776.13	514.18	734.26	2.604
0.8	372	111.71	775.84	513.95	742.51	2.976
0.9	372	129.93	775.52	513.73	723.95	3.348
1.0	372	121.58	775.18	513.51	731.96	3.720
1.1	372	125.29	774.87	513.31	727.94	4.092

2.3. Test method

Specimens of 150x150x150 mm were prepared for the compressive strength test. The specimens were cured in a room with 20 ± 1 ^{0}C and 95 ± 5% relative humidity. At the ages of 7 and 28 days, the compressive strength of the concrete cubes was measured.

III.RESULTS AND DISCUSSION

3.1. Effect of superplasticizers on properties of concrete with variable water reduction:

3.1.1. Compressive strength

The net results considering strength criteria can be summarized as:

S.No	Dosage (%)	28 day compressive strength
Trial 1	Nil	41.07
Trial 2	Nil	42.10
Trial 3	0.7	48.71
Trial 4	0.8	56.26
Trial 5	0.9	51.01
Trial 6	1.0	46.8
Trial 7	1.1	43.5

Figure 2 shows the plot between strength verses dosage of superplasticizer at 0.35 w/c ratio. It is evident that the compressive strength of concrete is maximum at 0.8% of superplasticizer dosage and is obtained as 56.26 MPa. Thus, it can be concluded that the optimum dosage of superplasticizer for strength criteria is 0.8%.

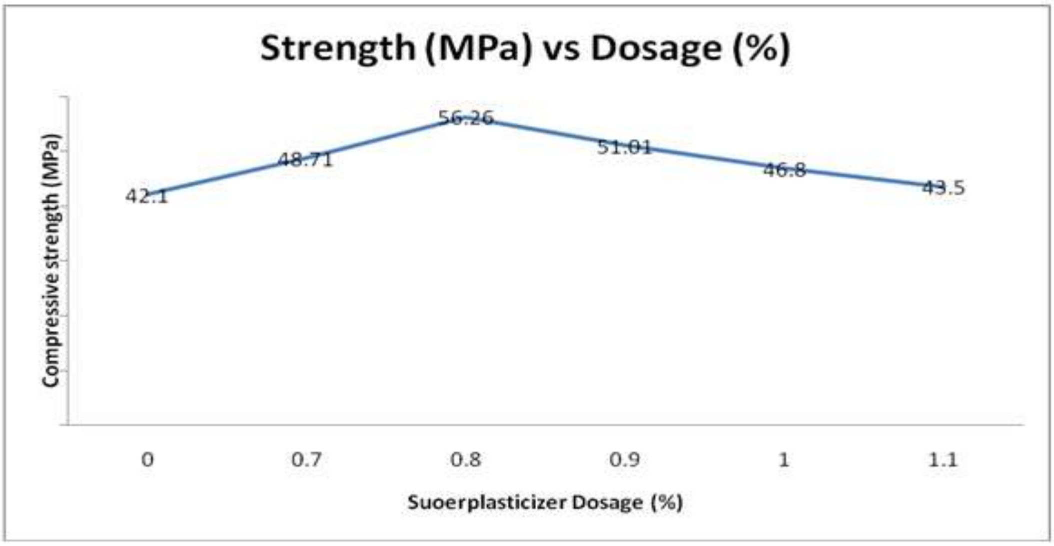

Figure 2: Compressive Strength Vs Dosage of Superplasticizer

3.1.2. Workability:

The net results considering workability criteria can be summarized as:

S.No	Dosage (%)	Slump loss(mm)		
		0 min	30 min	60 min
Trial 1	Nil	25	0	0
Trial 2	Nil	10	0	0
Trial 3	0.7	90	40	0
Trial 4	0.8	160	100	60
Trial 5	0.9	190	170	150
Trial 6	1.0	180	160	100
Trial 7	1.1	160	150	110

Figure 3 shows the plot between slump loss verses dosage of superplasticizer at 0.35 w/c ratio. It is evident that the minimum slump loss occurs at a dosage of 0.9%.Thus it can be concluded that the optimum dosage of superplasticizer for workability criteria is 0.9%.

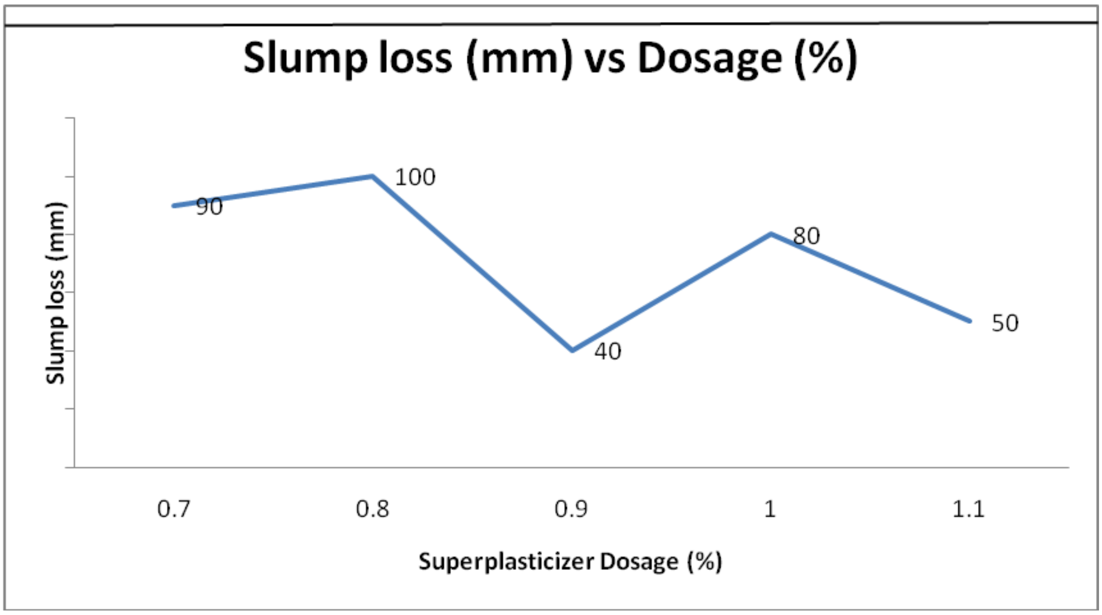

Figure 3: Workability Vs Dosage of Superplasticizer

3.2. Effect of superplasticizers on properties of concrete with constant water reduction:

3.2.1. Compressive strength

The net results considering strength criteria can be summarized as under:

S.No	Dosage (%)	28 day compressive strength
Trial 1	0.7	46.30
Trial 2	0.8	59.56
Trial 3	0.9	56.00
Trial 4	1.0	50.54
Trial 5	1.1	47.87

Figure 4 shows the plot between strength verses dosage of superplasticizer at 0.35 w/c ratio. It is evident that the compressive strength of concrete is maximum at 0.8% of superplasticizer dosage and is obtained as 56.56 MPa.thus it can be concluded that the optimum dosage of superplasticizer for strength criteria is 0.8%.

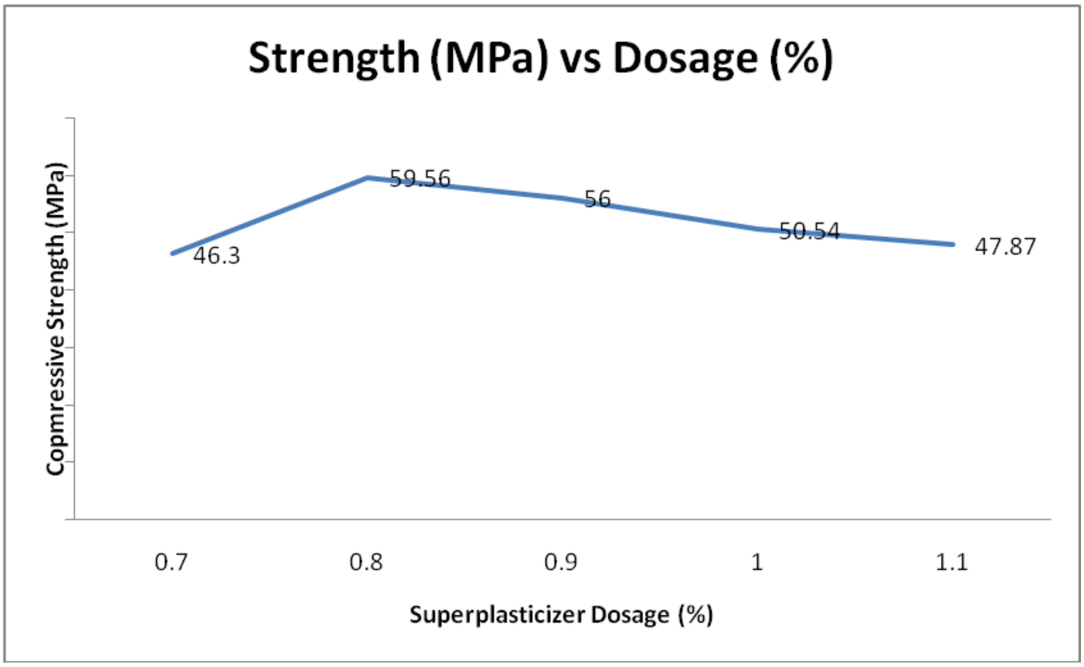

Figure 4: Compressive Strength Vs Dosage of Superplasticizer

3.2.2. Workability

The net results considering workability criteria can be summarized as**:**

S.No	Dosage (%)	Slump loss(mm)		
		0 min	30 min	60 min
Trial 1	0.7	6	0	0
Trial 2	0.8	40	0	0
Trial 3	0.9	100	60	40
Trial 4	1.0	120	105	90
Trial 5	1.1	140	115	60

Figure 5 shows the plot between slump loss verses dosage of superplasticizer at 0.35 w/c ratio. It is evident that the minimum slump loss occurs at a dosage of 1.0%.Thus it can be concluded that the optimum dosage of superplasticizer for workability criteria is 1.0%.

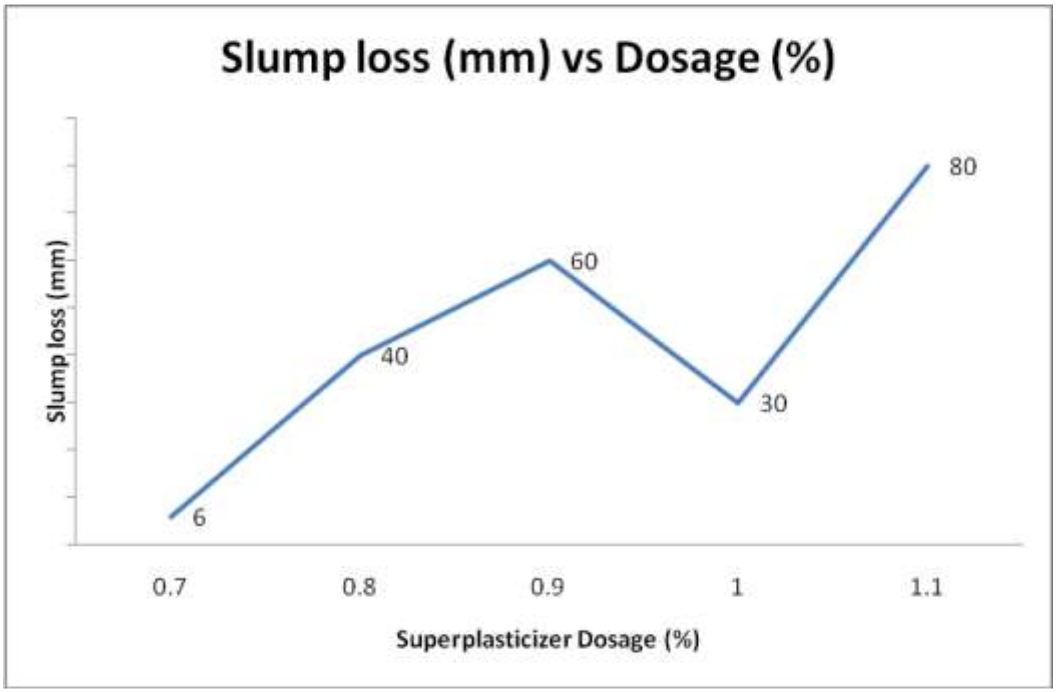

Figure 5: Workability Vs Dosage of Superplasticizer

IV.CONCLUSION

This study investigated the effect of superplasticizer on the properties of fresh and hardened concrete under two different conditions: variable water reduction and constant water reduction. The following conclusions are arrived at based on this study:

(a) The workability of concrete can be increased by addition of superplasticizer however very high dosage of superplasticizer tends to impair the cohesiveness property of concrete.

(b) Compressive strength is improved by superplasticizer; on the other hand its ultimate strength is higher than the desired characteristic strength.

(c) The strength of concrete without superplasticizer is found to be greater than the characteristic strength but the slump obtained is almost nil which means that though this concrete will fare well in terms of strength but it is not workable for major works.

(d) The optimum dosage for maximum compressive strength for both the cases of water reduction is found to be 0.8% of admixture quantity.

(e) The optimum dosage for max slump retention was found to be 0.9% of admixture quantity.

The decision of whether to use superplasticizers should be based on technical and construction considerations for each specific application. This type of admixture, if used properly, can be an advantageous component of the concrete mixture resulting in increased workability, increased strength and ease of placement. If not properly utilized, these admixtures can result in more problems than the situations that led to the consideration of their use. Because the effectiveness of superplasticizers is dependent upon many factors such as field conditions, production equipment, materials and environmental conditions, the Work Plan has to be developed using the same materials and equipment proposed to be used for the job. In addition, field trials must be conducted under similar conditions as those expected during the construction.

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