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# IMPACTS OF USE OF SUPER-PLASTICIZER ON PROPERTIES OF CONCRETE

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**Abstract -** A numerous studies have been conducted so far on cement paste, mortar and various concrete mixes with as well as without provision of super-plasticizers. This study presents the variation in the strength of concrete due to use of various super-plasticizers along with their variable concentrations. Three types of indigenous super plasticizers were taken from the different supply sources. The various super-plasticizers used for this study are CMC- Super Plast, sikament-600 and CICO-Super Plast. The concentration / dosage level of super-plasticizers are considered to be ranging from 0.5%, 1.0%, 1.5% and 2.0% and their behavior is studies in terms of standard consistency of cement paste, initial and final setting time of cement paste individually. The compressive strength of mortar and concrete mix is also calculated with the variation of concentration of super-plasticizer by the variation of concentration / dosage level of super-plasticizers. From the present study, it has been concluded that the setting of time of cement gets retarded by the addition of normal dosage of super-plasticizer without affecting other properties of fresh mortar and concrete. The increase in compressive strength of mortar and concrete takes place due to reduction in water requirements on increasing the dosage of super-plasticizers.

***Key Words***: Concrete, Super-Plasticizer, consistency, initial setting time, final setting time

## 1. INTRODUCTION

Strength, durability and workability of the concrete mixes are the prime concern to be considered during construction. These properties are predominantly achieved through many of the recent advancements in the concrete technology. Mineral additives and chemical additives are the part of the modern concrete. In order to improve the fresh stage and hardened stage properties of concrete, chemical admixtures are added to concrete. Super-plasticizers (SPs) are high range water reducers which can improve the workability of concrete without increasing the water- cement ratio or it can maintain the same workability at a reduced water-cement ratio. Cement plants are one of the major contributors of $CO_2$ to the atmosphere.

Flow behavior of concrete mix is mainly represented by the cement paste phase. Along with the recent advancement of fluid concrete such as pumpable concrete or self-compacting concrete, it has reasonably be mandatory to determine the flow properties of concrete which are studied under the core concepts of Rheology. Rheology represents the branch of science that deals with the study of flow and change in shapes of the matter even if it subjected to external force. Rheological studies of cementitious suspensions at different temperatures and super-plasticizer dosages help to understand the material behavior in fresh state. Presently, most of the researchers have been inclined towards the development of highly durable matrix of cemetitious properties. Durable concrete represents the capacity to resist or withstand with the possible deterioration conditions over which it may be supposed to be exposed. The attacks due to Sulphate, acid, penetration of excess of chlorides etc. are the major problems that are faced against the durability of concrete. The important method to improve the durability of concrete is to improve the microstructure of the concrete. Mineral admixture addition is one of the methods to improve the microstructure of the concrete and super-plasticizer addition is good for reducing the pore diameter. The effect of super-plasticizer addition in improving the strength and workability properties of concrete also deserves attention.

The effects of the normal water reducing admixtures can be studied in 3 ways:

(a) Addition of admixture, results reduction in w/c ratio and concrete having same workability as that control concrete can be obtained.
(b) Addition of admixture directly in concrete as part of gauging water, there is not other change to the mix properties. Concrete processing similar Strength developed characteristics is obtained and having grater workability than the control concrete.

A concrete can be obtained lower cement content and water than a control concrete without adversely affecting the durability or engineering properties of the concrete.

### 1.1 TYPES OF SUPER-PLASTICIZERS

There are many distinct types of super-plasticizers available, based on different chemicals, but in concrete they purport to have a similar purpose. These are all high molecular weight organic compounds, some of which are synthetic and others which are derived from natural products.

Super-plasticizer categories:

***A.) Sulphonated Melamine Formaldehyde Condensates:*** Polymers with a value of n (the number of condensation)usually in the range 50-60, giving a molecular weight of 20,000 in the area.
***B.) Sulphonated Napthalene-Formaldehyde Condensates:*** Polymers close to the previous group in several respects, with a simple repeat unit. Sodium salt is used again, because of the solubility of the sulphonate groups. In this case , the value of n usually lies in the range 5-10, giving a molecular weight of the 2000 order.
***C.) Modified Lignosulphonates:*** The crude wood-pulped lignosulphonates are commonly used as plasticizers and can be refined and modified to improve their effectiveness. The processing requires choosing a higher molecular weight fraction and, preferably, more sulphonation or partial polymerization to eliminate sugars and other impurities. In the admixture the calcium or alkali metal salt is used, the latter having superior water-unit has a complex phenyl-propane skeleton. Substituent groups vary, and may contain, in addition to sulphonate, phenolic, carboxylic and methoxylic compounds. The molecule coils in solution into a spherical shape, with groups anodized at or near the Surface. Examples are various chemicals or mixtures that are claimed to be super-plasticizers: amidealpolysaccharide acid mixtures and other hydroxylated polymers and poymers of higher molecular weight.

### 1.2 CHEMICAL COMPOSITION OFSUPER-PLASTICIZERS

***Category A:*** This type of chemical product was originally developed in 1950's foe applications in a variety of industries but after some years the possibility for application in the concrete field was recognized. It is prepared by normal resinification techniques. It has a molecular weight of about 30,000. Salts of sulphonates melamine formaldehyde come under this category. It is usually available as a 20% aqueous solution with a density of 10 kN/m3 approximately. It is clear to slightly turbid in appearance.
***Category B:*** This material is produced from naphthalene by oleum or sulphur trioxide sulphonation subsequent reaction with formaldehyde leads to polymerization, suphonic acid is normally neutralized with sodium hydroxide. Sulphonate naphthalene formaldehyde condensates fall in this category. Commercial products vary from 25 to 45 % (weight proportion) solid contents and the level required to produce concrete of almost self- compacting properties would be 1 – 3% by weight of cement content.
***Category C:*** Lignin is a complex material which forms approximately 20% of the composition of wood. During the production of paper making pulp from wood, a waste liquor is formed as a by-product containing a complex mixture of substances including decomposed products lignin and cellulose, sulphonation product of lignin, various carbohydrates and free sporous acids and or sulphates. Subsequent neutralization, precipitation and fermentation processes produce a range of lingo - subplate varying purity and composition depending upon a number of factors such as the neutralizing alkali, the pulping process used the degree of fermentation and even the type and age of wood used. Commercial lignosulphate used in admixture formulations are predominantly sodium or calcium based with sugar contents of 1- 30%. Its density is approximately 11kN/m3.

## 2. RESEARCH OBJECTIVE

The present research work deals with the following objectives-
1. To study the variation of Consistency of cement with the super-plasticizer dosage rate.
2. To study the variation of initial and final setting time of cement with the super-plasticizer dosage rate.
3. To perform the analysis of effect of dosage on compressive strength of mortar and concrete.

## 3. METHODOLOGY

The present investigation aim was to, study WRA property of the super-plasticizers which are locally present in India. Four samples of super–plasticizers were get from different sources which are listed in table 1. Test specimens were arranged with different type of concrete mixes at diff. dosage level of super-plasticizer. The trials were made by reducing the water – content and keeping workability the same as that of the cement compositions without the use of super-plasticizers. The practical work of trials, casting and testing is detailed below:
1. The SC (standard consistency), IST (initial setting time) and FST(final setting time) is compared with and without the use of super plasticizer.

2. The water reducing effect in cement sand mortar 1:3 has been worked out for different dosages of super plasticizers. The workability of the mortar was kept the same i.e. flow should be 110 ± 5. Using 50mm size cube specimens, the 7 – day and 28 – day compressive Strengths were determined.
3. The water – reducing effect in five different concrete mixes has been worked out for different dosages of super plasticizers. The compaction factor was kept the same i.e. 0.80 ± 0.05. Using 150 mm size cube specimens the 7 – day and 28 – day compressive Strength have been determined.

## 4. MATERIAL USED

Material used for testing like cement, fine aggregate, coarse aggregate, water, super plasticizer is as follows:

(a) ***Cement:*** Cement used was OPC (ordinary Portland cement) with properties shown in table 2. Same type of cement was used throughout the work.

(b) ***Fine Aggregate:*** Clean and fine natural sand from river bed as available I laboratory was used for the work. The fineness modulus of sand was found as 2.37 and its specific gravity as 2.70.

(c) ***Coarse Aggregate:*** Rounded, clean, free from any type of organic impurity, hard course aggregates were used for the work. The fineness modulus of coarse aggregate was found as 2.14 sand its specific gravity as 2.65.

(d) ***Water:*** Treated Water used for mixing.

(e) ***Super Plasticizers:*** Four super-plasticizers were collected from as per given table 1.

**Table 1:** Properties of Super-Plasticizers

| CODE DESIGNATION | Commercial Name | Color | State | Specific Gravity | Dose Level (% By Weight Of Cement) | Source Of Supply |
|---|---|---|---|---|---|---|
| A | CMC SuperPlast | Dark Amber | Liquid state | 1.138 | 1 to 2 | Constrction Material Corporation, Roorkee |
| B | Sikament 600 | Dark Brown | Liquid state | 1.22 | 0.5 to 3.0 | Sika-Qualcrete Pvt. Ltd. Culcutta. |
| C | CICO SuperPlast | Brown | Liquid state | 1.17 | 0.4 to 2.0 | The structural Water – proofing co. Pvt. Ltd., Culcutta |

**Table 2:** Physical Properties of Cement

| S. No. | Test Name | Result of test | Standard result as per IS269- 1976 |
|---|---|---|---|
| 1 | Cement Color | Grey (moderate) | |
| 2 | SC (Standard Consistency) | 25% | |
| 3 | SG (Specific Gravity) | 3.1 | |
| 4 | Setting Time | | |
| | (i) Initial | 69 Min. | > 30 Min. |
| | (ii) Final | 185 Min. | < 600 Min. |
| 5 | Compressive Strength of 1:3 standard mortar | | |
| | (i) 3 - day | 18Mpa | 16 Mpa |
| | (ii)7 - day | 27Mpa | 22 Mpa |
| 6 | Fineness modulus (By Sieve analysis on IS 90 micron sieve) | 8.50% | < 10 |
| 7 | Soundness | 2 | < 10 |

## 5. RESULTS AND DISCUSSIONS

The results of the testing done with super-plasticizers are summarized in table 3 for Standard Consistency, Initial and Final setting time. The results for the mortar are summarized in table 4 and the results for concrete mixes like summarized in table 5.

The results of the investigations done are discussed one by one for each super- plasticizer as under.

**Table 3:** Standard Consistency, Setting Time of Cement Paste with Different Super Plasticizers

| Types of Super plasticizers | Dose (% by weight of cement) | Standard Consistency in Percent | % Reduction of water - content | Setting Time | |
|---|---|---|---|---|---|
| | | | | Initial (Min) | Final (Min) |
| CMC Super – Plast (A) | 0.0 | 25.00 | 0 | 69 | 185 |
| | 0.5 | 23.75 | 5 | 121 | 215 |
| | 1.0 | 23.50 | 6 | 124 | 276 |
| | 1.5 | 23.25 | 7 | 126 | 281 |
| | 2.0 | 22.50 | 10 | 127 | 270 |
| Sikament - 600 (B) | 0.0 | 25.00 | 0 | 69 | 185 |
| | 0.5 | 23.00 | 8 | 182 | 300 |
| | 1.0 | 22.25 | 11 | 233 | 378 |
| | 1.5 | 21.50 | 14 | 256 | 492 |
| | 2.0 | 21.00 | 16 | 312 | 588 |
| CICO – Super Plast (C) | 0.0 | 25.00 | 0 | 69 | 185 |
| | 0.5 | 24.00 | 4 | 70 | 200 |
| | 1.0 | 23.75 | 5 | 216 | 286 |
| | 1.5 | 23.25 | 7 | 227 | 327 |
| | 2.0 | 22.00 | 12 | 225 | 328 |

**Table 4:** Super-Plastizers in Cement Mortar

| Super plasticizer type | Dose (percentage by weight of cement) | W/C Ratio | Percentage Reduction in Water Content | Compressive Strength (In MPa) | |
|---|---|---|---|---|---|
| | | | | 7-Day | 28-Day |
| CMC Super-Plast (A) | 0.0 | 0.7 | - | 9.1 | 18.2 |
| | 0.5 | 0.64 | 9 | 7.2 | 15.4 |
| | 1.0 | 0.63 | 10 | 9 | 16.5 |
| | 1.5 | 0.6 | 15 | 9.2 | 18.8 |
| | 2.0 | 0.58 | 18 | 9.4 | 19.6 |
| Sikament - 600 (B) | 0.0 | 0.7 | - | 9.1 | 18.2 |
| | 0.5 | 0.58 | 18 | 9.3 | 16.5 |
| | 1.0 | 0.54 | 23 | 11 | 17 |
| | 1.5 | 0.51 | 28 | 12.4 | 17.5 |
| | 2.0 | 0.46 | 35 | 12.2 | 19.8 |
| CICO – Super Plast (C) | 0.0 | 0.7 | - | 9.1 | 18.2 |
| | 0.5 | 0.62 | 12 | 9.7 | 15.8 |
| | 1.0 | 0.58 | 18 | 10.5 | 18 |
| | 1.5 | 0.54 | 23 | 11 | 24.4 |
| | 2.0 | 0.52 | 26 | 12.8 | 26.8 |

CEMENT: SAND is 1: 3 (By Weight); Cube Size = 50mm X 50mm X 50mm;

Flow = 110 ± 5 %; Area = 2500 $mm^2$

***Table 5:*** *Super-Plastizers in Concrete Mixes*

| Types of Super-plasticizers | Dose (percentage by weight of cement) | W/C Ratio | Percentage Reduction in Water Content | Compressive Strength in M Pa | |
|---|---|---|---|---|---|
| | | | | 7-Day | 28-Day |
| CMC Super – Plast (A) | 0 | 0.35 | - | 22 | 35.33 |
| | 1 | 0.33 | 6 | 21.8 | 38.4 |
| | 2 | 0.3 | 15 | 24.7 | 39.2 |
| Sikament - 600 (B) | 0 | 0.35 | - | 22 | 35.33 |
| | 1 | 0.33 | 6 | 24.6 | 36.2 |
| | 2 | 0.3 | 15 | - | - |
| CICO – Super Plast (C) | 0 | 0.35 | - | 22 | 35.33 |
| | 1 | 0.31 | 12 | 22.6 | 34.8 |
| | 2 | 0.3 | 15 | 24.9 | 37.1 |

Cement Content – 620 Kg/m$^3$, Aggregate / Cement = 2.8,

Constant Compaction Factor – 0.80 ± 0.05, Cube Size = 150 mm X 150 mm X 150 mm

The results of the investigations done are discussed one by one for each super- plasticizer as under.

### 5.1 TYPE 'A' SUPER PLASTICIZER – 'CMC SUPER PLAST'

The color, state, specific gravity and recommended dose of this super-plasticizer are listed in table 3.1.

***Cement Paste Results:*** The observed results of the Standard consistency, Initial and Final setting time of cement paste as affected with Use of this super plasticizer are Presented in table 4.1 with the following inferences:

- Standard consistency of cement decreases with an increase in dosage levels. The fall is about 10 % for the dose of 2 %.
- Initial Setting time and Final setting time are found to increase with an Increase in dosage levels.

***Cement Mortar Results:*** In case of cement sand mortar 1:3 the results are presented in table 4 and the following trends can be noticed from the table 4:

- This super-plasticizer acts as a water reducing agent. The %age of water reduction increases with the dosage levels for 2.0 % dose it is about 20%.
- In general it is seen that the 7-day and 28-day Compressive Strength get increased with the increase in the dosage level of this super-plasticizers.

***Concrete-Mixes Results:*** The results of various concrete mixes are presented in table 5 and the following trend is seen from the observed results:

- The %age of water reduction depends upon the type of mix and it increases with dosage level.
- In general it is seen that the 7-day and 28-day Compressive Strength increase with the increase in dosage levels of CMC SUPER PLAST. In case of mix M3 the compressive Strength increases up to 30 % for the dosage level 2%.

### 5.2 TYPE 'B' SUPER PLASTICIZER – 'SIKAMENT – 600'

The color, state, specific gravity and recommended dose of this super-plasticizer are listed in table 1. According to manufacturer it is high range water reducing and set retarding super-plasticizer.

***Cement Paste Results:*** The observed results of the standard consistency, initial and final setting time of cement paste as affected with the use of this super-plasticizer are presented in the same tables and Fig.which were referred in the case of CMC SUPER PLAST. From the close study of the table and the following inferences can be drawn and in the case of CMC SUPER PLAST. From the close study of the table, the following inference can be drawn:

- Standard consistency of cement paste decreases with the increase in the dosage levels.
- Initial and final setting time increase with increase in dosage levels of compound.

***Cement Mortar Results:*** The results for the cement mortar are presented in the table 4. The following trend can be noticed from the table and as referred above:

- The %age of water reduction increases with the increase in dosage level of this super- plasticizers. For 2.0% dose of this

super-plasticizer the %age of water reduction is 22 %.

- The results show a high early Strength development of the cement mortar with this super- plasticizer. The early compressive Strength in increased by 30% for 2% dosage levels.

***Concrete-Mixes Results:*** The results of various concrete mixes are presented in table 5 and the following trend is seen from the observed results:

- The percentage of water reduction depends upon the mix. For mix M3, The water reduction is more than the other mixes. The percentage of water reduction increases with the increase I the dosage levels. The 1 % and 2 % of this super-plasticizer reduces the water content up to 10% and 20% respectively.
- In general, the compressive Strength increases with the increase in the dosage levels of plastiment – BV /40. For the 25 of this super-plasticizer, in the case of mix M3, the compressive Strength increases 30 - 35%.

**5.3 TYPE 'C' SUPER PLASTICIZER – 'CICO - SUPER PLAST'**

The color, state, specific gravity and recommended dose of this super-plasticizer are listed in table 1

***Cement Paste Results:*** The observed results of the standard consistency, initial and final setting time of cement paste, as affected with the use of this super-plasticizer are presented in table 3 and the following inferences can be drawn:

- Standard consistency of cement-paste decreases with increase in dosage levels.
- Initial setting time and final setting time increase with an increase in dosage levels.

***Cement Mortar Results:*** The results for cement mortar are presented in table 4. The following trends can be noticed with the super - plasticizer:

- CICO-Super Plast works as a water-reducing admixture. The percentage of water-reduction increases with increase in dosage levels of compound. For the 2.0% dosage level of this super-plasticizer, the water-reduction is about 26%.
- For 2.0% percent of dosage level of this super-plasticizer, the compressive Strength increases by 35% to 40%. The results for the compressive Strength are very consistent.

***Concrete-Mixes Results:*** The results of various concrete mixes are presented in table 5. From the results and the plots following inferences can be drawn:

- The percentage of water – reduction depends upon the type of mix. For mix M3, The water reduction is more than in the other mixes. The percentage of water-reduction increases with the increase in the dosage level and 20% for 2.0% dosage level of this super-plasticizer.
- In general, the compressive Strength increases with the increase in the dosage levels of the CICO-SUPER PLAST. In case of mix M3 the compressive Strength increases up to 35-40 % for the dosage level 2%.

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