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EFFECT OF SUPER ABSORBENT POLYMER IN SILICA FUME CONCRTE

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Abstract - The use of Super Absorbent Polymer (SAP) in concrete leads to change in properties of concrete. The present study involves the use of SAP for internal Crack Sealing and self-curing of concrete when contacted in high exposure conditions. The addition of SAP changes the properties of concrete by increased workability, fire resistance and Shrinkage Resistance. Self-Curing helps in Better hydration of cement which leads to achieve higher lateral strength.. The SAP of different proportion of 0.1%, 0.3% and 0.5% of by the weight of cement is added to plain M20 grade of concrete with Silica fume. Silica Fume of constant proportion of 2% is replaced for cement to gain greater lateral strength. The main focus of this study is to compare results of fresh and hardened properties of M20 grade of silica fume added concrete incorporated with Super Absorbent Polymer. And Conventional M20 grade of concrete.

Key Words: Super Absorbent Polymer, internal curing, fresh and hardened concrete properties, silica fume

1. INTRODUCTION

In early stages Super Absorbent Polymer is most advantageous in field of agriculture due to this Water Entraining Properly. Later scholars initiate the use of SAP as an additive in concrete construction. The SAP used to block the water flow through cracks and voids. SAP is added to a dry mix of concrete materials. When water is added to mix SAP absorbs water and retains it thereby increase in volume by 250 times. The retained water is converted into the form of gel which fills the voids created due to hydration and freeze-thaw effect. Water from concrete evaporated by increased heat of hydration which leads to formation of voids. Expansion and contraction of concrete creates large number of voids which leads to Shrinkage cracks. Proper curing of concrete structure is necessary to meet best strength and durability requirements. Perfect curing cannot be done manually because of less availability of water and difficulty of height of curing at site. When water is needed for concrete is not readily available. The solution of this problem is Self-curing. Internal or self-curing is achieved by adding of SAP to concrete. Superabsorbent polymers can be used to improve and prolong soil water holding capacity, decrease drought stress, and increase time between irrigation events. There are results indicating SAPs can reduce compaction. A superabsorbent polymer (SAP) (also called slush powder) is a water-absorbing hydrophilic homopolymers or copolymers that can absorb and retain extremely large amounts of a liquid relative to its own mass.

2. SCOPE OF THE PROJECT

The scope of this project work involves

- Study on properties and industrial use of Super Absorbent Polymer
- Estimate the effective usage level of Super Absorbent Polymer in M20 grade concrete for construction purpose.

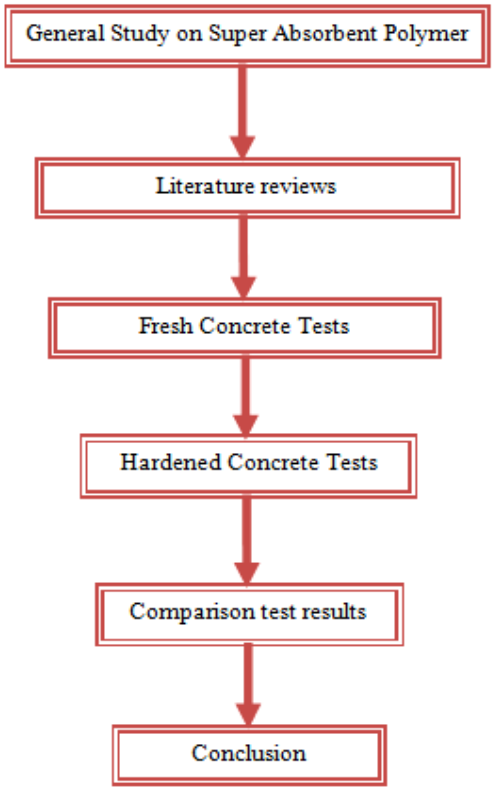
3. OBJECTIVES OF THE PROJECT

The objectives of this project work involves

- To study the properties of Super Absorbent Polymer
- To conduct the strength assessment test on Super Absorbent Polymer concrete.
- To compare the test results of Super Absorbent Polymer added concrete with conventional M20 grade of concrete to estimate the optimum level of Super Absorbent Polymer to be used.

4. METHODOLOGY

The methodology which was followed in this project has shown in below flow chart.



5. MATERIALS USED

a. Cement

Cement is a binding material when it mixed with water. It is grey in color with finely powdered material. The Portland Pozzolana Cement is a kind of Blended Cement which is produced by either intergrading of OPC clinker along with gypsum and pozzolanic materials in certain proportions or grinding the OPC clinker, gypsum and Pozzolanic materials separately and thoroughly blending them in certain proportions.

Table-1: Chemical constituents of PPC

Lime (Cao)	60 to 67%
Silica (Sio_2)	17 to 25%
Alumina (Al_2O_3)	3 to 8%
Iron Oxide (Fe_2O_3)	0.5 to 6%
Magnesia (MgO)	0.1 to 4%
Sulphur Trioxide (SO_3)	1 to 3%
Soda and /or Potash ($Na_2O + K_2O$)	0.5 to 1.3%

b. Silica Fume

Silica fume is a by-product from the production of elemental silicon or alloys containing silicon in electric arc furnaces. At a temperature of approximately 2000°C the reduction of high-purity quartz to silicon produces silicon dioxide vapor, which oxidizes and condenses at low temperatures to produce silica fume. Silica fume particles are extremely small, the mean primary particle size ranges from 0.1 to 0.2 µm, 95% of the particles are finer than 1 µm. It contains 85%–95% silica (SiO2). The particles are spherical in shape. The high surface area of silica fume particles is an important factor affecting the reactivity of the particles and plays very important role in improving the physical and chemical properties of concrete.

Table-2: Physical properties of Silica Fume

Property		Value
Particle size (typical)		1 micro meter
Surface Area		13,000-30,000m^2/kg
Specific gravity		2.22
Bulk density	As produced	130-430 kg/m^3
	Densified	480-720 kg/m^3
	Slurry	1320-1440 kg/m^3

c. Fine Aggregate

Fine Aggregate are the material passing through an IS sieve that is less than 4.75mm. Gauge usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as a fine aggregate. The sand is used for the experimental works that was procured and conformed to grading zone II. Sieve analysis of the fine aggregate was carried out in the laboratory as per IS 383-1970. The fine aggregate was first sieved through 4.75mm sieve to remove any particle greater than 4.75mm sieve and then was washed to remove the dust. According to IS 383-1970 the fine aggregate is being classified in to four different zone, that is zone I, zone II, zone III, zone IV.

d. Coarse Aggregate

The materials which are retained on 4.75mm sieve are called coarse aggregate. The broken stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 20mm was used in the present work. According to IS 383-1970 coarse aggregate maximum 20mm coarse aggregate is suitable for concrete work. But where there is no restriction 40mm or large size may be permitted.

e. Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Potable water is generally considered satisfactory. In the present investigation, tap water was used for both mixing and curing purposes.

f. Super Absorbent Polymer

Sodium polyacrylate, also known as water lock, is a sodium salt of polyacrylic acid with the chemical formula [-CH2-CH (COONa)-] n. The SAPs are cross – linked polymer which is made from the polymerization of acrylic acid blended with sodium hydroxide in the presence of poly-acrylic acid. Superabsorbent polymer can absorb and retain extremely large amounts of a liquid relative to their own mass. The total absorbency and swelling capacity are controlled by the type and degree of cross-linkers. Low-density cross-linked SAP has a higher absorbent capacity and swells to a larger degree and vice.

Fig.1 Swelling of Super Absorbent Polymer

The physical and chemical properties of Super Absorbent Polymer have been discussed in below table.

Table-3: Some physical and chemical properties of SAP

SAP	Composition	Bead size mm	Adsorbed Cation mm olc g-1
WOTE	15% acrylic + 85% acrylamide (65%) + attapulgite (35%)	0.4–1.5	K, 2.81
GNKH	60% acrylic + 40% acrylamide	0.5–1.0	Na, 7.37
BJ-2101M	15% acrylic + 85% acrylamide	3–4	Na, 2.13
BJ-2101S	15% acrylic + 85% acrylamide	0.2–0.5	Na, 1.85

6. LABORATORY INVESTIGATIONS

a. Test on cement

Various tests were conducted on cement like Fineness, Consistency, setting time and their results as follows.

Table-4: Laboratory test results of Cement

Properties	Test value	Standard value
Normal Consistency	25%	30%
Initial setting time	45 minutes	30 minutes
Fineness	5%	<10%

b. Test on Fine Aggregate

Various tests were conducted on fine aggregate like Sieve analysis, specific gravity and fineness modulus and their results as follows.

Table -5: Laboratory test results of Fine Aggregate

Characteristics	Test Value	Standard Value
Type	Natural sand	Natural sand
Specific Gravity	2.70	2.8
Fineness modulus	2.705	2.6 - 2.9

c. Test on Coarse Aggregate

Various tests were conducted on fine aggregate like Sieve analysis, specific gravity and fineness modulus, impact test and crushing strength test and their results as follows.

Table -6: Laboratory test results of Coarse Aggregate

Characteristics	Test value	Standard Value
Type	Crushed Stone	Crushed Stone
Specific Gravity	2.74	2.5-2.8
Maximum Size	20 mm	20 mm
Fineness modulus	3.33	2.9-3.5
Impact value	44%	<45%
Crushing value	42.2%	<45%

d. Test on Silica Fume

Various tests were conducted on Silica fume like Consistency, setting time and their results as follows.

Table -7: Laboratory test results of Silica Fume

Characteristics	Test value
Consistency	20%
Initial setting Time	1 hour 45 minutes

e. Test on Super Absorbent Polymer

Various tests were conducted on Super Absorbent Polymer like Consistency, setting time and their results as follows.

Table-8: Laboratory test results of Super Absorbent Polymer

Characteristics	Test value
Particle size	300 microns
Water absorption	140ml Water by 1gm of SAP.

f. Slump test on Concrete

Slump test on concrete has been conducted on conventional M20 grade concrete and super absorbent polymer added concrete and the test result has shown in below table.

Table-9: Slump con test result

S. NO	Degree of Workability	% of SAP	Slump value
1	Slump Value (50 – 100) Medium	0.1	132
2		0.3	74
3		0.5	45

7. SPECIMEN CASTING

a. Cube Specimen

24 cubes are prepared with different percentage of SAP as additives of concrete. The size of cube is 150 x 150 x 150 mm.

Table-10: List of Cubes

Cubes	No. of Cubes	
	7 days	28 days
Conventional concrete	3	3
0.1% of SAP with Silica Fume	3	3
0.3% of SAP with Silica Fume	3	3
0.5% of SAP with Silica Fume	3	3

b. Cylinder Specimen

The split tensile test is an indirect way of evaluating the tensile test of concrete. In this test, a standard cylindrical specimen is laid horizontally, and the force is applied on the cylinder radially on the surface which causes the formation of a vertical crack in the specimen along its diameter. Concrete cylinders cast for acceptance testing are typically 4x8in or 6x12in (100x200mm or 150x300mm) in diameter by length. In this project cylindrical specimen is 150 mm in diameter and 300 mm in height has been casted.

Table-10: List of Cylinders

Cylinders	No. of Cylinders	
	7 days	28 days
Conventional concrete	3	3
0.1% of SAP with Silica Fume	3	3
0.3% of SAP with Silica Fume	3	3
0.5% of SAP with Silica Fume	3	3

c. Prism Specimen

Indian standard determined the size of the concrete specimen as 150mm width, 150mm depth, and span of 700mm. It also states that a size of 100mm width, 100mm depth, and span of 500mm can be used if the maximum aggregate size used is not greater than 20 mm.

Table-11: List of Prisms

Prisms	No. of Prisms	
	7 days	28 days
Conventional concrete	3	3
0.1% of SAP with Silica Fume	3	3
0.3% of SAP with Silica Fume	3	3
0.5% of SAP with Silica Fume	3	3

8. EXPERIMENTAL INVESTIGATION

a. Compressive Strength Test

As per IS: 516-1959 Compressive testing machine (2000KN), 15cm×15cm×15cm steel cube molds. Concrete gains maximum strength at 28days. Since in construction sector great amount of capital is at stake, so instead of checking strength at 28 days we can check strength in terms of concrete strength psi at 7 and 14 days to predict the target strength of construction work.

Table-12: Compressive Strength test result of Cubes

S. No	Cube Description	Trial	Compressive strength (7 days) N/mm²	Average Strength N/mm²	Compressive Strength (28 days) N/mm²	Average Strength N/mm²
1	Conventional Concrete	T1	13.20	13.23	20.20	20.76
		T2	13.40		20.67	
		T3	13.10		21.40	
2	0.1% of SAP	T1	10.24	9.75	17.86	17.19
		T2	9.45		16.50	
		T3	9.64		17.20	
3	0.3% of SAP	T1	12.80	12.70	20.20	19.73
		T2	13.10		19.80	
		T3	12.20		19.20	
4	0.5% of SAP	T1	11.30	10.76	18.45	18.15
		T2	10.42		17.40	
		T3	10.56		18.60	

b. **Split Tensile Strength Test on Cylinder**

As per IS 5816: 1999 the splitting tensile strength test is performed on hardened concrete to determine its tensile strength. Marginal variations in water to cement ratio, ingredient proportioning, and increase in a slump, etc impacts the desired concrete strength. This in turn affects the strength and stability of structures. There are several tests to determine the strength of concrete. The unit of tensile strength is N/mm. The splitting test is easy to perform and we can get uniform results. It is a simple, reliable and convenient method to determine the strength of concrete.

Table-13: Split tensile Strength test result of Cylinders

S. No	Cylinder Description	Trial	Split tensile strength (7 days) N/mm²	Average Strength N/mm²	Split tensile strength (28 days) N/mm²	Average Strength N/mm²
1	Conventional Concrete	T1	2.45	7.13	3.26	3.19
		T2	2.37		3.12	
		T3	2.31		3.18	
2	0.1% of SAP	T1	1.97	2.01	2.89	2.79
		T2	2.13		2.67	
		T3	1.91		2.82	
3	0.3% of SAP	T1	2.56	2.65	3.36	3.52
		T2	2.77		3.53	
		T3	2.61		3.68	
4	0.5% of SAP	T1	2.25	2.18	3.18	3.16
		T2	2.07		3.08	
		T3	2.21		3.22	

c. Flexural Strength Test on Prism

According to ASTM the size of the specimen is 150mm width, 150mm depth and the length should not be at least three times the depth of the specimen. Indian standard determined the size of the concrete specimen as 150mm width, 150mm depth, and span of 700mm. It also states that a size of 100mm width, 100mm depth, and span of 500mm can be used if the maximum aggregate size used is not greater than 20 mm. British standards specifies square specimen cross section with 100mm or 150mm dimension and the span ranges from four to five times specimen depth. However, it preferred 150mm width, 150mm depth, and span of 750mm for the specimen.

Table-14: Flexural Strength test result Prisms

S. No	Prism Description	Trial	Flexural strength (7 days) N/mm²	Average Strength N/mm²	Flexural strength (28 days) N/mm²	Average Strength N/mm²
1	Conventional Concrete	T1	1.72	1.77	2.58	2.63
		T2	1.92		2.88	
		T3	1.68		2.44	
2	0.1% of SAP	T1	1.12	1.25	2.01	2.08
		T2	1.29		2.16	
		T3	1.34		2.06	
3	0.3% of SAP	T1	1.82	1.81	2.77	2.84
		T2	1.68		2.93	
		T3	1.92		2.82	
4	0.5% of SAP	T1	1.34	1.47	2.37	2.36
		T2	1.52		2.22	
		T3	1.56		2.48	

9. CONCLUSION

Super Absorbent Polymer used as a concrete additive to achieve greater later age properties. Here SAP used as Self curing agent which reduces the formation of shrinkage cracks due to freeze – thaw effect of concrete. Study conducted with M20 concrete. Based on experimental investigation following conclusions were drawn.

- Optimum usage of 0.3% SAP, gave notable compressive strength than other proportions of SAP. At the age of 7 days the compressive strength achieved as 63% and at the 28 days the compressive strength achieved as 98%.
- Similarly usage of 0.3% SAP, gave higher split tensile strength than other proportions of SAP. At the age of 7 days and 28 days the split tensile strength increased effectively compared to other proportions of SAP added to concrete.
- For the same usage of 0.3% SAP, gave effective flexural strength than other proportions of SAP. At the age of 7 days and at the 28 days the flexural strength achieved as standard value compared to other proportions.
- In this project, we concluded that 0.3% of SAP added to concrete will give effective and reliable result compared to other proportions.

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