Experimental Study On Effect Of Super Absorption Polymers In Surface Cracked Concrete Structures

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Abstract: Superabsorbent polymers (SAP) are new chemical admixtures for concrete that are extremely capable and multiuse. They offer a number of new options for controlling the mixture's free water. They also contribute to the regulator of the rheological properties of fresh concrete and to the decrease of plastic shrinkage by internal healing. This SAP can be used as different from air-entrainment agents. It is also helpful in reducing the crack width when they appear during the service stage. It thus increases the life span of the structure and also reduces the cost by not allowing any additional repair and rehabilitation of structures. In this paper, specimens are prepared at the addition of 0.5%, 1.0%, &1.5% Super absorption Polymer called Sodium polyacrylate and testing are done at various stages, and conclusions are made based on the results.

Keywords: Superabsorbent Polymer,Self-healing,Sodium Polyacrylate,Microscope

INTRODUCTION

Concrete is exposed during operation to external factors with extreme heat, cold, pressure. Concrete decreases and increases with moisture and temperature variations. Cracks may occur when changes are not applied in the design and growth to accommodate these aspects. Shrinking, design flaws, or poor quality of construction materials. Concrete experiences a number of heavy vehicle charging, earthquakes, and strong winds. For these reasons, it is likely that reinforced concrete will eventually develop cracks in addition to several more. In those structures, a series of serious events start to occur when cracks arise within concrete structures. They also affect the structure's flexibility and endurance.The technology of self-healing concrete is promising to advance concrete resistance to these flaws and degradations. Concrete self-healing can be described as concrete with self-healing agents that "automatically heal" concrete structures when cracks occur during their life cycle. Self-healing agents can be transferred. All these methods are being checked and evaluated to assess their dependability and effectiveness. This work discusses a number of self-healing chemicals that are used by polymer techniques in the encapsulation process.

MIXING OF SODIUM POLYACRYLATE IN CONCRETE

Concrete cracks due to the moderately low tensile strength are a common phenomenon. If micro-cracks grow and reach the reinforcement, it is possible not only to attack the concrete itself but also to decompose the reinforcement. It is, therefore, significant that the crack width is measured and that the cracks are repaired as soon as possible. structures are usually high. This research focuses on the development of concrete self-healing. self-healing of concrete cracks would give concrete structures a longer service life and make the constituent more sustainable as well as more durable. The SAP absorbs water and translates it into the gel, then gradually releases it over time, while the volume of gel increases proportionally. When it originates from watering vegetation over time, this asset is very useful. The volume extension tends to obstruct the waterways in the concrete mass and thus improve its water tightness. Using SAP as a sealant in plain concrete is established to be very efficient if sufficient quantity is used. The research also focuses on the long-term impact of using the SAP in plain concrete on the short-term effect.

SODIUM POLYACRYLATE

Sodium polyacrylate, also known as water lock, is a polyacrylic acid sodium salt with the chemical formula [$-CH_2-CH(CO_2Na)-]_n$ and wide use in consumer products. The superabsorbent material is proficient in absorbing its weight in liquid as much as 200 to 300 times. Sodium polyacrylate is an anionic polyelectrolyte with carboxylic groups in the main chain that are negatively charged, while sodium neutralized polyacrylic acids are the most common form used in industry, other salts, including potassium, lithium, and ammonium, are also available.

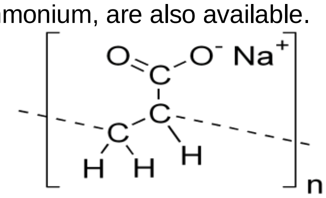

Fig 1 *Chemical Structure of Sodium Polyacrylate*

PROPERTIES OF SODIUM POLYACRYLATE POLYMER

IUPAC name	Poly (sodium prop-2-enoate)
Chemical formula	$(C_3H_3NaO_2)_n$
Molar mass	Variable
Density	1.22 g/cm^3

USES OF SODIUM POLYACRYLATE

The use of sodium polyacrylate in concrete as a super absorbent polymer has promising potential to increase numerous concrete properties, including concrete strength. This can be explained by having an internal source of healing that gradually releases moisture over days and weeks. Even at the maximum level of sodium polyacrylate used in cement, this enhancement in strength is relatively small. In the absence of concrete curing, this may become beneficial. Frost resistance is the other important property that can be strengthened by using this admixture by absorbing the liquid increase hydraulic pressure. The application of SAP to the concrete mix carries flexibility and uniformity to the fresh concrete. It helps to position the concrete and to finish it. When using the SAP, the bleeding water is significantly reduced related to the plain concrete.

MATERIALS

Cement
Portland Pozzolana Cement (PPC) is by far the most important type of cement. Portland pozzolana cement has advanced durability of a concrete structure due to less permeability of water. Due to high fineness, PPC has better cohesion with aggregates and makes denser concreteness.

Fine Aggregate
As a small average, the aggregate length is less than 4.75 mm. It fulfills with IS 383-1970 and falls within Zone II. Fine aggregate may have a larger impact on the building's strength than cement. Natural sand or crushed stone sand should consist of fine sand. It should be difficult, durable, clean and free of organic matter, etc

Coarse Aggregate
Coarse Aggregate consists of crushed, uncrushed, or broken stones. The length of the aggregate greater than 4.75 mm. The aggregate particle shape contributes to the efficiency of a high-performance concrete being produced. The crushed rock provides a much better bond than gravel between the paste and the aggregate.

Sodium Polyacrylate
Due to its unique capacity to absorb and hold water molecules, sodium polyacrylate is mainly used as a thickening agent. The absorbent material is sodium polyacrylate. The polymer structure consists of one oxygen molecule, one sodium oxide molecule, one carbon base, and three molecules of hydrogen. Super Absorbent Polymer (SAP) can be utilized as an alternative internal curing agent. In this study, sodium polyacrylate (SP) as SAP has been used to produce internally cured concrete. Desorption isotherm of SP has been established to study its effectiveness as an internal curing agent. Test results showed that internally cured concrete with performed better in terms of both strength and durability as compared to control samples when exposed to adverse curing conditions where the supply of additional water for external curing was absent.

MATERIAL PROPERTIES
The materials are tested with various aspects of properties, and the values are attached below from the tests.

Table 1 *Properties of Cement*

PROPERTIES	OBSERVED VALUE	INDIAN STANDARD LIMITATIONS
INITIAL SETTING TIME	28 min	30 min
FINAL SETTING TIME	9 hrs.	10 hrs.
STANDARD CONSISTENCY	28%	26-33%
SPECIFIC GRAVITY	2.90	2.90

Table 2 *Properties of Sand*

PROPERTIES	OBSERVED VALUE	INDIAN STANDARD LIMITATIONS
SPECIFIC GRAVITY	2.65	2.65

Table 3 *Properties of Normal Aggregate*

PROPERTIES	OBSERVED VALUE	INDIAN STANDARD LIMITATIONS
SPECIFIC GRAVITY TEST	2.65	2.5-3.0
WATER ABSORPTION TEST	1%	-

MIX DESIGN
Mix Design was done as per the codebook, IS 10262-2009, and the number of materials was calculated. Table 4 gives the quantities required for the M25 grade of Concrete Mixes. The specimens were cast by adding 0.5% 1.0% 1.5% sodium polyacrylate in concrete in addition to the normal concrete mix of M25 grade.

Table 4 *Mix Proportions for M25 Concrete*

1	Cement Content	425.77 kg/m^3
2	Water content	191.6 kg/m^3
3	Coarse aggregate	966.32 kg/m^3
4	Fine aggregate	790.62 kg/m^3
5	W/B ratio	0.45
6	Mix Ratio	1:1.85:2.26

Table 5 *Mix Design for Super Absorption Polymer Concrete*

CONCRETE GRADE	WATER CONTENT Kg/m^3	CEMENT Kg/m^3	SAND Kg/m^3	SAP Kg/m^3	COARSE AGGREGATE Kg/m^3
M25	191.6	425.77	790.62	-	966.32
SAPC 0.5%	192.55	425.77	790.62	2.12	966.32
SAPC 1 %	193.52	425.77	790.62	4.25	966.32
SAPC 1.5%	194.46	425.77	790.62	6.38	966.32

MIXING, DEMOULDING, AND CURING:
For achieving good concrete, the most important factors are proper mixing and adequate curing, which were followed during the casting process. Hand mixing was used for the mixing process, and the mixing time was kept for 3-4 minutes. Demolding was done after 24hrs of casting. Curing was done for 7 days, 14 days and 28 days.

BRINELL MICROSCOPE

This device makes exact indentation measurements for all hardness testers of the Brinell type. Our RBM-55 Brinell Microscope is a lightweight and durable tool that makes it ideal for both the shop and the laboratory. The reticle is 0.01 mm fine. Units over a 6 mm distance and the observing area are 7 mm. Measure the diameter of the indentation against the reticular scale. This microscope is designed to simply measure the Brinell hardness value of different ferrous and non-ferrous metals including crude or annealed steel (non-austenitic steel only), quenched and tempered steel (non-austenitic steel only), cast iron, brass casting, rolled brass, rolled copper, an alloy of tin and bronze and cast. By calculating the diameters of the indentations left on the test piece and the standard block of the hardness test, it can determine the Brinell hardness.

Fig 2 *Brinell Microscope*

RESULTS AND DISCUSSION

COMPRESSION STRENGTH TEST:

A compression test is done for specimens of size 150 mm X 150 mm X 150 mm.

Table 6 *Table Compressive Strength Values for Different Days*

S. No	CUBE ID	7 days value(N/mm^2)		14 days value(N/mm^2)		28 days value(N/mm^2)	
1	M 25(Control)	15.24	15.27	21.5	21.35	25.2	25.50
		15.30		21.2		25.8	
Self-healing concrete using super absorption polymers							
2	SHC-0.5%	17.37	17.43	22.02	22.135	26.10	26.16
		17.49		22.25		26.23	
3	SHC-1.0%	17.51	17.53	22.27	22.235	26.84	26.85
		17.55		22.20		26.86	
4	SHC-1.5%	17.67	17.635	22.38	22.415	27.90	27.92
		17.60		22.45		27.95	

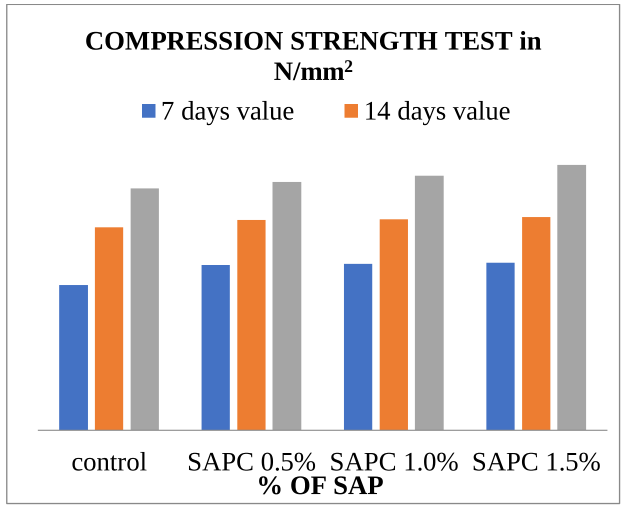

Fig 3 *Compression Strength Value*

SPLIT TENSILE STRENGTH TEST

Split tensile tests are done for specimens of size 150 mm dia X 300 mm height. Specimens are prepared for each percentage for different testing days.

Table 7 *Split Tensile Strength Values*

S. No	CUBE ID	7 days value(N/mm^2)		14 days value(N/mm^2)		28 days value(N/mm^2)	
1	M 25(Control)	1.97	1.91	2.19	2.17	2.47	2.48
		1.86		2.15		2.49	
Self-healing concrete using super absorption polymers							
2	SAPC-0.5%	3.45	3.43	3.62	3.63	3.97	3.97
		3.41		3.64		3.98	
3	SAPC-1.0%	3.46	3.48	3.64	3.67	4.03	4.01
		3.50		3.70		4.00	
4	SAPC-1.5%	3.75	3.715	3.91	3.915	4.44	4.50
		3.68		3.92		4.56	

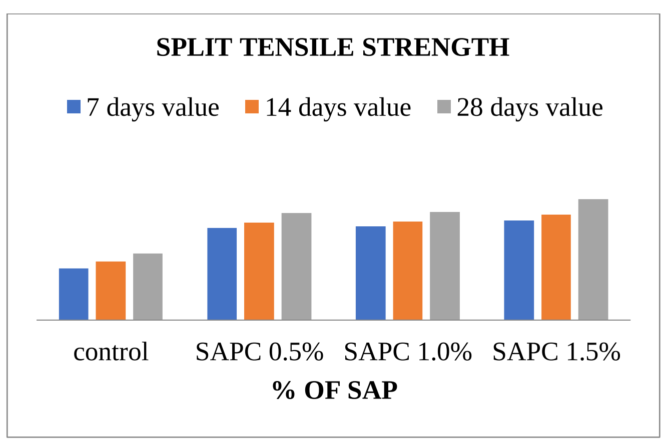

Fig 4 *Split Tensile Strength Values*

CRACK MEASUREMENTS VALUE

Cracks are induced in the concrete specimens using the Universal Testing Machine. Then the widths of the cracks are measured using a Brinell microscope, and two cracks are measured for each type of sample. Again, the crack induced Structures are cured for one week. The specimens are taken out, and the crack widths are measured again using the Brinell Microscope. Tabulations are made using crack width values.

***Table 8** Crack Measurement Values For 14 Days Specimen*

S.NO	CUBE ID	CRACK WIDTH (mm)		CRACK WIDTH AFTER HEALING (mm)	
1	SAPC 0.5%	0.3	0.3	0.1	0.2
2	SAPC 1.0%	0.3	0.1	0.25	0
3	SAPC 1.5%	0.2	0.3	0.1	0.19

***Table 9** Crack Measurement Values For 28 Days Specimen*

S.NO	CUBE ID	CRACK WIDTH (mm)		CRACK WIDTH AFTER HEALING (mm)	
1	SAPC 0.5%	0.4	0.3	0.15	0
2	SAPC 1.0%	0.2	0.2	0.2	0.2
3	SAPC 1.5%	0.3	0.5	0.15	0.3

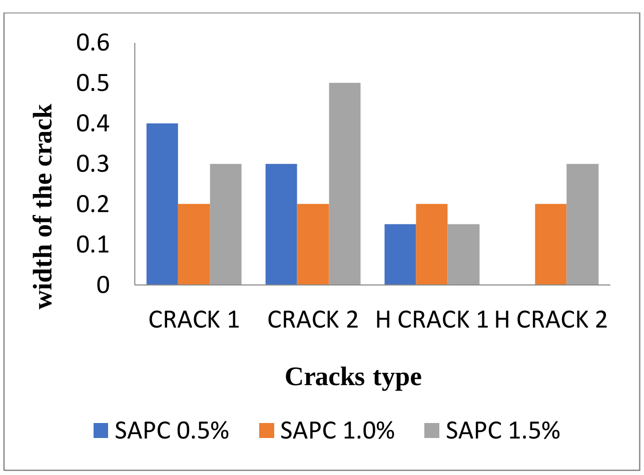

***Fig 5** Crack Width Calculation Chart For 14 Days*

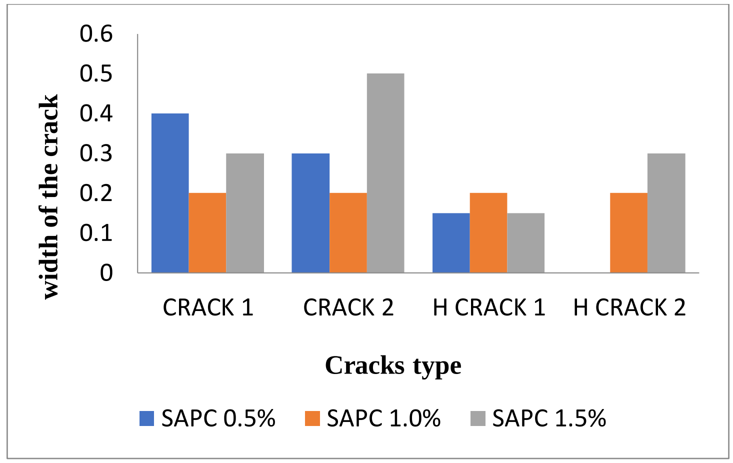

***Fig 6** Crack Width Calculation Chart For 28 Days*

CONCLUSION

The cracks are healed at all the percentages of Super Absorption Polymers, i.e.., (0.5%,1.0%,1.5%), but the most effective sealant of cracks is at 0.5%. in which the cracks get reduced to 0mm, which is of great significance because the cracks get reduced at very low percentage which is also cost-effective. Further, the Compressive Strength of the cube also increases in addition to the sealing of cracks. The Compressive Strength of the Super absorption polymer concrete is 27.90 $N/mm^{2,}$ while the Compressive strength of the normal mix is about 25.10 N/mm^2. This increases with an increase in time, therefore, making the structure durable and also increase the lifespan of a structure.

SUGGESTION

Super absorption Polymers can be used as a sealant for cracks than other methods because of its effective performance. It also eliminates the cost of replacement of the structures due to the autogenous healing mechanism. Super absorption Polymers also results in an increase in the Compressive strength of Concrete Structures. This smart material could be used in the construction of a structure, which requires high strength performance and which would also help us to maintain the balance between economy and assured high strength, which is very important to an in today's construction Industry.

REFERENCES

[1] Jonkers, H.M., 2011. Bacteria-based self-healing concrete. Heron, 56 (1/2).
[2] Meera, C.M. and Subha, V., 2016. Strength and Durability Assessment of Bacteria Based Self-Healing Concrete. IOSR Journal of Mechanical and Civil Engineering,(IOSR-JMCE), pp.1-7.
[3] Sun, L., Yu, W.Y. and Ge, Q., 2011. Experimental research on the self-healing performance of micro-cracks in concrete bridge. In Advanced Materials Research (Vol. 250, pp. 28-32). Trans Tech Publications.
[4] Prabahar, A.M., Dhanya, R., Ramasamy, N.G. and Dhanasekar, S., 2017. an Experimental Study of Self Healing of Cracks in Concrete Using Sodium Silicate Capsule. Rasayan Journal of Chemistry, 10(102), pp.577-583.

[5] Soundharya, S. and Nirmalkumar, D.K., 2014. Study on the effect of calcite-precipitating bacteria on self-healing mechanism of concrete. IJERMT, 1(4), pp.202-208.

[6] Wang, X., Xing, F., Zhang, M., Han, N. and Qian, Z., 2013. Experimental study on cementitious composites embedded with organic microcapsules. Materials, 6(9), pp.4064-4081.

[7] Sudha, N., Gowsalaya, T., Hemavarshini, A. and Lakshmi, S.G., 2019. Experimental Investigations on Strength Properties of Self-healing Bacterial Concrete Using M-Sand. International Journal, 6(4), pp.1-4.

[8] Buchhlz, F.L. and Graham, T., 1998. Modern superabsorbent polymer technology. Tew York: Wiley-VCH.

[9] Peppas, N.A., Bures, P., Leobandung, W.S. and Ichikawa, H., 2000. Hydrogels in pharmaceutical formulations. European journal of pharmaceutics and biopharmaceutics, 50(1), pp.27-46.

[10] Lin, C.C. and Metters, A.T., 2006. Hydrogels in controlled release formulations: network design and mathematical modeling. Advanced drug delivery reviews, 58(12-13), pp.1379-1408.

[11] Xue, W. and Hamley, I.W., 2002. Thermoreversible swelling behaviour of hydrogels based on N-isopropylacrylamide with a hydrophobic comonomer. Polymer, 43(10), pp.3069-3077.

[12] Brüdern, A.E. and Mechtcherine, V., 2010, August. Multifunctional use of SAP in strain-hardening cement-based composites. In International RILEM conference on use of superabsorbent polymers and other new additives in concrete (pp. 11-22). RILEM Publications SARL.

[13] Hilloulin, B., Van Tittelboom, K., Gruyaert, E., De Belie, N. and Loukili, A., 2015. Design of polymeric capsules for self-healing concrete. Cement and Concrete Composites, 55, pp.298-307.

[14] Lee, H.X.D., Wong, H.S. and Buenfeld, N.R., 2016. Self-sealing of cracks in concrete using superabsorbent polymers. Cement and concrete Research, 79, pp.194-208.

[15] Van Zijl, G.P.A.G. and Wittmann, F.H. eds., 2010. Durability of strain-hardening fibre-reinforced cement-based composites (SHCC) (Vol. 4). Springer Science & Business Media.