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Self Healing Concrete with Super Absorbent Polymer and Silica fumes

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ABSTRACT: Concrete is a widely used construction material, but it is susceptible to crack and damage over time due to various environmental factors. This paper aims to explore the innovative concept of self-healing concrete by incorporating Super Absorbent Polymers (SAP) and silica fumes. The paper analyses self healing capability of M20 concrete with 0.3% sodium polyacrylate as super absorbent polymer and silica fumes ranging from 5%, 10% and 15%. The specimen were pre-cracked at two days after curing in the range of 2mm width, the time set for healing was 28 days. At the age of 7, 14 and 28 tests are conducted to determine the compression, split tensile and flexural strength of concrete. The results shows that the concrete with 10% silica fumes and 0.3 % super absorbent polymer has best strength and crack healing ability. The potential benefits of this technology are numerous, including the extension of the service life of concrete structures, reduced maintenance costs by minimizing the need for repairs and replacements. Moreover, the project will contribute to sustainable construction practices by promoting the use of self-healing materials.

KEYWORDS: super absorbent polymer, silica fumes, self healing.

i. INTRODUCTION

Self healing concrete is characterized as the capability of concrete to fix its crack on its own autogenously. Crack inevitably exist in concrete. If micro cracks grow and reach the reinforcement, the concrete itself may be attacked and it will corrodes the reinforcing steel bars therefore its important to control cracks. Concrete, a ubiquitous construction material, continues to evolve to counter this issue with innovative additives like Superabsorbent Polymers (SAP), here we used sodium polyacrylate and silica fumes to enhance the self healing. Super Absorbent Polymer is renowned for its water-absorbing capabilities, has found its place within concrete by absorbing and retaining substantial water volumes. Superabsorbent Polymers with the absorption and desorption properties can change the water distribution in concrete. So that the process of cement hydration is promoted, the micro-structure of cement matrix is improved. This unique property transforms SAP-infused concrete into a self-healing marvel, effectively sealing micro cracks, improving water retention, and reducing shrinkage. In contrast, silica fumes is a byproduct of silicon and ferro-silicon production. Silica fume are fine particles, finer than cement particles thus the small voids form in the concrete is filled by silica fumes to improve the bonding between the particles due to the higher bonding area which led to increase density and structural integrity of concrete, thus the width of cracks formed on the concrete by natural means will be small, since cracks of larger size cannot be healed by SAP. Silica fumes also helps to retain so much cementitious particles that can be used for the hydration in the process of self healing when cracks are occurred. Together, they create a composite material that transcends traditional concrete's limitations. This fusion results in concrete structures that are denser, more impermeable, and capable of withstanding harsh conditions. This exploration showcases how these additives are reshaping the construction industry, pushing the boundaries of sustainable building practices and infrastructure development.

II. RELATED WORK

[1] KondaSrilakshmi, P. Eswanth, "Self-Healing of Concrete with Crystalline Admixture and Super-Absorbent Polymer", explain the effectiveness of superabsorbent polymer (SAP) in the process of healing cracks with in the concrete structure in different environmental conditions. The study involves pre-cracking concrete specimen within a controlled range of 0.10 to 0.40 mm at an early age (2 days). These specimen are then placed in different environment exposures for 28 days, allowing the healing process to take place naturally. [2] ManojKumaar. C & Dr. Mageswari. M,



“Recovery of Mechanical Properties of Self Healing Concrete Using Superabsorbent Polymer (SAP)”. This paper is on finding a solution to mitigate the impact of cracks and restore the mechanical properties of concrete. This research uses sodium silicate as SAP, different specimens were tested at various % of SAP. In this method the pre-crack are formed after the curing period (28 days) and allow the healing process take place in the next 28 days, that is 56 days after casting. In [3] V. Karthikeyan, S. Sasikumar, K. Sabari, S. Seyatharasan, “Self-Curing Concrete by using Super Absorbent Polymer”. The paper is about to find more enhanced abilities of SAP other than healing. The research mainly focus on strength and workability enhancements achieved by the concrete. It is found that 0.3% of SAP by weight of cement is optimum for gaining more strength and workability.

III. MATERIALS

Creating self healing concrete with sodium polyacrylate and silica fumes involves a systematic approach. Initially, to select high quality materials that can bind properly with each other.

A. Cement : Ordinary Portland cement of 53 grade is used for this experiment, tests like specific gravity, standard consistency and initial and final setting time is done on cement to assure the quality of cement, the result obtained are : Specific gravity = 3.18, Standard consistency = 32%, Initial setting time = 32 minutes, Final setting time = 600 minutes.

B. Fine aggregate : M-Sand is used as fine aggregate, the specific gravity of M-Sand is 2.73.

C. Coarse aggregate : Coarse aggregate of specific gravity 2.82 and size 20 mm is used for this experiment.

D. Superabsorbent polymer : SAP is an admixture that absorb moisture from the atmosphere and swells to increase the volume. This ability is used to enhance self healing of concrete. The SAP used in this experiment is sodium polyacrylate with pH of 7.2.

D. Silica fumes : Silica fumes is used to support the SAP to enhance the self healing. The chemical composition of silica fumes are, more than 90 percent silicon dioxide. Other constituents are carbon, sulphur and oxides of aluminium, iron, calcium, magnesium, sodium and potassium. The physical composition of silica fume are: Diameter is about 0.1 micron to 0.2 micron, Surface area about 30,000 m²/kg, Density varies from 150 to 700 kg/m³.

IV. MIX PROPORTIONING AND METHODOLOGY

A. Mix Design: Design mix proportion for M20 grade concrete for different ingredient composites were calculated based on code provisions of IS 10262 : 2009. The ratio for the concrete is 1:1.88:2.91. water cement ratio is 0.5. Two type of concrete mix are prepared. The first one (type1) was conventional concrete (0% silica fumes and 0% SAP), the second one (type 2) was a combination of cement with 0.3% SAP and various % of silica fumes (5%, 10%, 15%)

B. Experimental Methodology: Casting of concrete concrete each 10 no. of cubes of size 150 x 150 x 150 mm, 3 no. of cylinders of size 150 x 300 mm and 3 no. of prisms of size 100 x 100 x 500 mm are carried out and cured. After 2 days of curing pre cracks are induced in 1 specimen of normal and other concrete(5%, 10%, 15%) by applying load gradually and the curing is continued. The compression, split tensile and flexural strength on specimen are determined on 7, 14 and 28 days. The results of normal concrete and SAP concrete are compared to obtain the best mix. The self healing of the specimen with crack is analysed after 28 days.

V. RESULT AND DISCUSSION

A. Workability test

Workability is the property of freshly prepared concrete which determines the homogeneity with which it can be mixed, placed, consolidated and finished. In general terms, workability represents the amount of work which is to be done to compact the concrete in a given mould. The slump cone test is used to measure the workability. According to IS 7320: 1974 the slump cone test is conducted. The decrease in height of concrete to that of mould is noted with measuring scale.

Table 1: Slump cone test value

% silica fumes in concrete	Slump value
0%	45mm
5%	95 mm
10%	75 mm
15%	50 mm



B. Compressive Strength Test

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension (being pulled apart). By reference of IS 516: 1959 compression strength test is conducted in cubes.

Table 2: Compressive Strength of Concrete

No of days	0%	5%	10%	15%
7	18.9 N/mm ²	19.1 N/mm ²	21 N/mm ²	17.8 N/mm ²
14	25.21 N/mm ²	25.6 N/mm ²	28.78 N/mm ²	24.6 N/mm ²
28	27.1 N/mm ²	28 N/mm ²	30.2 N/mm ²	26.4 N/mm ²

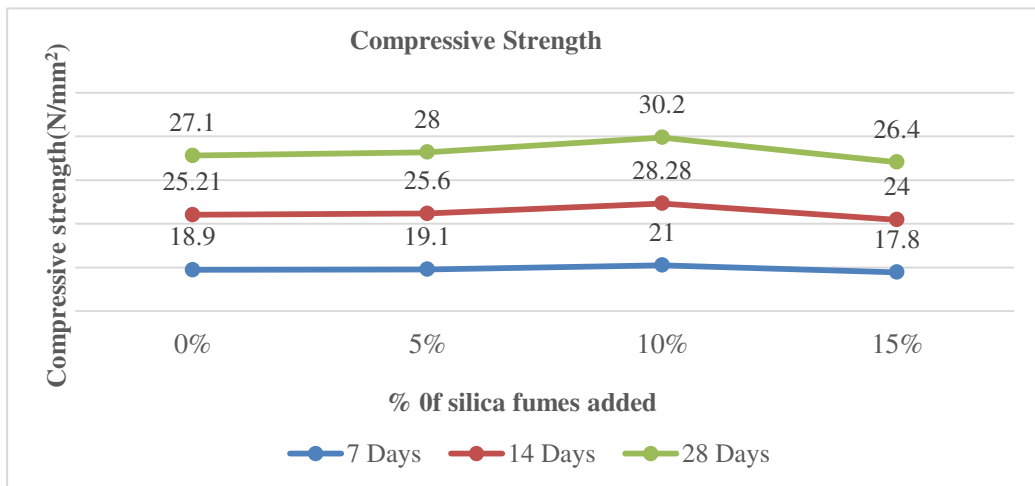


Fig 1: 7, 14, 28th day test on Compressive strength

The compressive strength of M20 concrete with silica fumes and sodium polyacrylate is increased upto 10% and with further increase in silica fumes compression strength decreases as shown in fig 1. Maximum compression strength of 30.2 N/mm² is achieved for 10% silica fumes and 0.3% sodium polyacrylate.

A. Split Tensile Strength Test

The resistance of a material to longitudinal stress, measured by the minimum amount of longitudinal stress required to rupture the material. By reference of IS 516: 1959 split tensile strength test is conducted in cylinder.

Table 3: Split Tensile Strength of Concrete

No of days	0%	5%	10%	15%
28	3.67 N/mm ²	3.83 N/mm ²	4.21 N/mm ²	3.55 N/mm ²

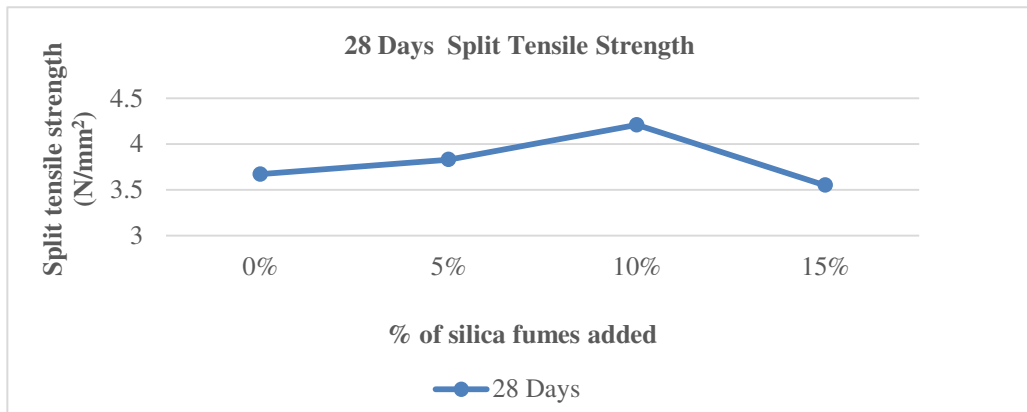


Fig 2: 28th Day Test on Split Tensile

Split tensile strength of M20 concrete with silica fumes and sodium polyacrylate is increased upto 10% and with further increase in silica fumes compression strength decreases as shown in fig 2. Maximum compressive strength of 4.21 N/mm² is achieved for 10% silica fumes and 0.3% sodium polyacrylate.

B. Flexural strength Test

Flexural tests are generally used to determine the flexural modulus or flexural strength of a material. A flexural test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is used in calculating the flexural strength of that particular sample. In this test, two point loading is preferred. By reference of IS 9399 : 1979 and IS 516 : 1959 flexural strength test is conducted in prism.

Table 4: Flexural Strength of Concrete

No of days	0%	5%	10%	15%
28	3.8 N/mm ²	3.92 N/mm ²	4.32 N/mm ²	3.3N/mm ²

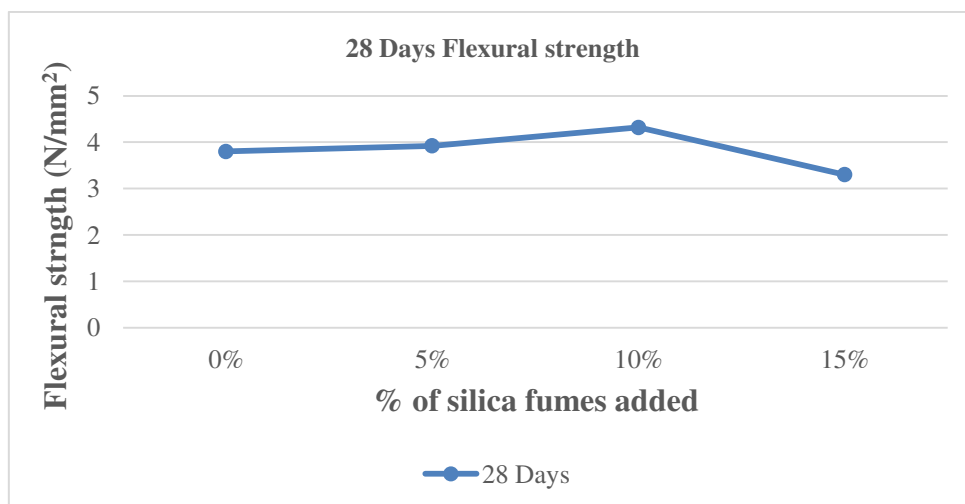


Fig 3: 28th Day Test on Flexural Strength

Flexural strength of M20 concrete with silica fumes and sodium polyacrylate is increased upto 10% and with further increase in silica fumes compression strength decreases as shown in fig 3. Maximum compression strength of 4.32 N/mm² is achieved for 10% silica fumes and 0.3% sodium polyacrylate.

E. Self Healing

Upon concrete cracking, a pivotal event triggers the self-healing mechanism. As the cracks propagate, the SAP particles situated within the concrete matrix come into contact with water seeping through the cracks. This contact prompts the SAP to release the stored water, which flows into the voids created by the cracks. As the released water infiltrates the crack sites, it encounters unreacted cement particles present within the concrete matrix. These cement particles, which did not participate in the initial hydration reaction during concrete placement, are now given the opportunity to react and form additional hydration products. The interaction between the released water and the unreacted cement particles initiates a secondary hydration process, leading to the formation of calcium silicate hydrates (C-S-H) and other binding agents. These newly formed hydration products fill the cracks, effectively sealing them and restoring the structural integrity of the concrete.

After the specified healing period of 28 days, the specimens are removed from the curing environment, and their condition is observed and analyzed (Fig 4) manually induced concrete crack at two days after curing and (Fig 5) concrete after self healing mechanism.



Fig 4: Before healing



Fig 5: Healed cracks

VI. CONCLUSION

The mechanical properties are found to be improved in concrete with SAP and silica fumes compared to normal concrete before and after self healing. The concrete sample with 10% silica fumes and 0.3% SAP shows 11.4% increment in compressive strength, 14.7% increment in tensile strength and 13.68% increment in flexural strength than normal concrete. The workability of the concrete is also increased due to the SAP added to the concrete. 10% concrete shows a 57.8% increment in workability as compared to normal concrete. The strength and workability is reduced when we add silica fumes more than 10%. Concrete with 10% silica fumes also shows greater results in self healing since the crack formed in the 10% specimen is almost fully healed but showing a scar of the crack in the surface after 28 days.

VII. FUTURE SCOPE

As the technology matures, standardization and regulatory frameworks are needed to govern the use of self-healing concrete in construction projects. Future initiatives may focus on establishing industry standards, guidelines, and certification protocols to ensure the reliability, performance, and safety of self-healing concrete products. Moreover, increased commercialization efforts and partnerships between researchers, manufacturers, and construction firms may accelerate the adoption of self-healing concrete technologies in the global construction market.



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