Role of Super Absorbent Polymer as an Internal Curing Catalyst: An Experimental Assement based on Strength and Durability Properties of Concrete

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Abstract— Strength and durability properties of concrete play a very crucial role in the present era of insfrastructural development. In the modern construction field, the study of concrete and its strength properties has become a major subject of study. Super Absorbent Polymer (SAP) is a polymer that plays a crucial role in construction industry as it can be used as an internal curing agent to eliminate cracks in concrete.SAP is examined for many characteristics of strength. Thus, it eliminates the requirement for external curing. This paper investigates how SAP affects the strength and qualities of concrete. Variable proportions of 0.1%, 0.2%, 0.3%, 0.4%, and 0.5% are used in this experiment to cast test specimens. Additionally, durability testing such as water permeability and fast chloride penetration tests are performed. In this study we attempted to illustrate the different types of performance depicted by concretes in which SAP has been used in different percentages. The obtained results are satisfactory and can be used for future development of integrating SAP in concrete for augmenting the strength and quality of concrete.

Index Terms— Durability, compressive strength, internal curing, Super Absorbent Polymer, permeability, external curing, cracks,

1 Introduction

THIS process, which develops the qualities of hardened cement paste with appropriate water and heat over the course of time, is referred to as "curing." Curing is a term that is used to explain the series encouragement of internal chemical processes in hydrated cement and concrete. The curing process encourages hydration, stops water loss in the concrete, and maintains the material at a saturated or nearly saturated state for as long as possible or as long as is necessary [1]. 1991 saw the development of the idea of using lightweight aggregate to give more moisture for the curing of high-strength concrete, as well as the concept of using internal curing concrete. Both of these innovations were presented. Internal curing was first defined by the American Concrete Institute (ACI) in 2001 as the "cement hydration process produced by excess water in concrete that is different from mixing water" [2]. At the moment, there are a total of two typical forms of treatment administered from the inside components of concrete include inorganic materials with pores and chemical components polymers. The typical materials are porous ceramic and SAP representatives of synthetic and inorganic porous polymers curing from the inside out curing. At the present time, there are two predominant types of materials used for the interior curing of concrete, including inorganic porous materials as well as synthetic chemical polymers. The typical materials are porous ceramic and SAP representatives of synthetic and inorganic porous polymersboth the external and the internal curing materials, respectively [2]. Super absorbent a recently developed category of additives for concrete are called polymers, abbreviated as SAP. They are cross-linked polymers that have the ability to absorb water at a rate similar to several times that of its own mass. They are reliable as a result of the cross connecting. Take up the water in water mostly through osmosis in the fresh state of cement paste, mortar, and concrete, and then release the water. This process occurs in water during the process of hydration in cement. This behavior has the potential to facilitate internal the process of aging concrete [3]. The SAP absorbs the water and transforms into a gel, after that, it is gradually released over the course of time. From a quality perspective, the growth of SAP into concrete needs to go in the other direction while the create holes in the solid, which, in turn, causes the volume to decrease quality, the internal water relieving offered by SAP improves, which in turn leads to improved the degree of hydration and contributes to the development of the quality [4].

The current research investigates the extent of dehydration while also working to improve the quality [4]. The purpose of this research is to investigate the effects of employing sodium polyacrylate (SAP) as an internal curing agent on the mechanical and long-term durability of concrete. A number of different tests were carried out, and the outcomes of those experiments were analyzed. Because the permeability of the concrete has decreased, the link between the lightweight aggregate and the hydrated cement has become more continuous, which has resulted in an increase in the concrete's strength.

2 Experimental Procedure

2.1 Materials and Methodology

Ordinary Portland cement (OPC) that complies with Indian Standard 4031–1998 was utilized in the task that was being experimented on. In accordance with the strength of the cement, the O.P. C was divided into three grades: 33 grade, 43 grade, and 53 grade. This particular research endeavor made use of 53-grade cement in the preparation of the concrete mix.

The specific gravity of ordinary Portland cement is 3.15, and the specifics are presented in Table1 below. The fine aggregate consisted of locally available natural sand with a maximum particle size of 4.75 millimeters. Fine aggregate typically has a measurement of 4.75 millimeters or less, while coarse aggregate often measures 4.75 millimeters or more. Table 2 and Table 3, respectively, illustrate the characteristics that coarse and fine aggregates have to provide. The super-absorbing polymer is a type of chemical substance that, in comparison to its own mass, is capable of absorbing an extraordinarily high volume of water. Through the formation of hydrogen bonds with individual water molecules, water-absorbing polymers, which, once combined, are referred to as hydro gels, are able to absorb aqueous solutions. Polymerization of acrylic acid combined with sodium hydroxide in the presence of an indicator results in the formation of a poly-acrylic acid sodium salt, which is the typical starting material for the production of superabsorbent polymers (sometimes referred to as sodium polyacrylate). This particular kind of polymer is the one that is utilized as SAP the vast majority of the time. In our experiment, the super-absorbing polymer that is most readily available is sodium polyacrylate, and we utilize it.

Table 1: Properties of Cement

Serial	Properties	Values
1	Fineness	3%
2	Specific Gravity	3.15
3	Initial Setting Time	50 minutes

Table 2: Properties of Coarse Aggregate

Serial	Tests	Results
1	Specific Gravity	2.68
2	Water Absorbtion	1.3%

Table 3: Properties of fine aggregate

Serial	Tests	Results
1	Specific Gravity	2.65
2	Water Absorbtion	1.1%

Table 4: Properties of Polyacrylate

Serial	Tests	Results
1	Specific Gravity	1.3
2	Compoun Type	Organic Polymer
3	State	Salt
4	Solubility	Insoluble in water, swells in water

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2.2 Mixture Proportioning

For the purpose of the experiment, the BIS is used to compute the mix proportioning (IS :10262-2009). Quantifying the different components of the M20 mix results in a proportional breakdown of the mix that is 1 to 2.8 to 3.9 respectively. In addition, a number of different percentages of SAP are added to the concrete and evaluated in order to determine the optimal range of SAP for the concrete. N-normal concrete mix, SAP 1-concrete with 0.1%SAP, SAP 2-concrete with 0.2%SAP, SAP 3-concrete with 0.3%SAP, SAP 4-concrete with 0.4%SAP, and SAP 5-concrete with 0.5%SAP are the various percentages of SAP. N-normal concrete mix contains no SAP at all. The laboratory is where all of the concrete's preparation takes place. It is necessary to have components such as coarse aggregate, M-sand, regular Portland cement of grade 53 (according to the mix design), super absorbent polymer (sodium polyacrylate), and magnetized water. After doing the math, we found that the proportion of the mix should be 1:2.8:3.9. In order to incorporate the super-absorbing polymer into the mixture, a portion of the cement in the mixture must first be removed. In order to zero in on the optimal proportion of SAP, various percentages of the compound are incorporated into each combination. Each mix contains 0.1 percent, 0.2 percent, 0.3 percent, 0.4 percent, and 0.5 percent SAP; in addition, a normal concrete is prepared for the purpose of comparing the strengths of various concrete blocks; the results of this comparison, which help us determine the optimal range of SAP that should be used, are shown in Table 5.

Table 5: Quantity of materials used

M	N	SAP 1	SAP 2	SAP 3	SAP 4	SAP 5
CA	39.1 kg	68.40 kg	68 kg	68 kg	68 kg	68 kg
FA	30.3 kg	57.2 kg	46.5 kg	46.5 kg	46.5 kg	46.5 kg
SAP	0 g	23 g	34.1 g	48.55 g	64.69 g	82.46 g
Water	6 L	8.3 L	8.3 L	16.24 L	16.24 L	16.24 L
OPC	13.56 kg	24.87 kg	19.23 kg	19.23 kg	19.23 kg	19.23 kg

M- Materials, CA- Coarse Aggregate, FA- Fine Aggregate

2.3 Test Methods

2.3.1 Compressive Strength

In accordance with IS: 516-1959, cubes of concrete measuring 15 centimeters on a side were used for the testing. The test was carried out on a machine capable of 120T compression testing. The force was applied at a rate of around 140 kilograms per square centimeter per minute until the specimen broke. During the phase of testing, each specimen needs to be stored in a machine that can do compressive testing. The maximum load that could be applied to the concrete specimen before it broke will be recorded. The compressive strength can be determined using the values as indicated in the following example.

Compressive Strength = Load / Area

2.3.2 Flexural Strength

In accordance with IS: 516-1959, the beams made of concrete measured 10 centimeters by 10 centimeters by 50 centimeters. The load was applied using two rollers that were identical to one another and were installed at locations that were one third of the way along the supporting span. The load was continued to be applied in a steady manner until the failure occurred. Take a measurement along the line of fracture to see how far away the nearest support is.

$$\text{Flexural Strength} = (P*L)/(B*d^2)$$

Here, P=Applied Load
B= Breadth of the beam
d= Depth of the beam
L= length of the beam

2.3.3 Split tensile strength

The split tensile strength of concrete cylinders of 15 centimeters in diameter and 30 centimeters in height was evaluated in accordance with IS: 5816-1999. The test specimen was placed in a horizontal orientation in between the loading surfaces of the compression testing equipment. The load was then delivered in a manner free from shock up until the point when the test specimen failed. The computation was done using the formula that is presented below.

$$\text{Split tensile strength} = 2P/(\Pi*d*L)$$

Where, P= Maximum load in Newton
L= Length of the specimen
D=Diamter of the specimen

2.3.4 Water Absorption Test

The absorptivity index of a concrete sample can be determined with the help of this test. After coring and slicing the specimens, they are either 70 millimeters in diameter and 30 millimeters in thickness or 100 millimeters in diameter and 50 millimeters in thickness. After curing, the sample is allowed to dry at a temperature of 50 degrees Celsius for a period of seven days before being tested. The material that was dried in the oven is given time to cool in a laboratory setting. After the specimen has been weighed, it is supported by supports inside a tray that contains a test solution (either water or a saturated calcium hydroxide solution), and the test solution is poured over the specimen until the bottom 2 mm of the specimen is submerged. After removing surplus water from the bottom surface of the specimen using a damp towel, the mass of the specimen is measured at predetermined time intervals. After this step, the mass of the concrete is measured once more after it has been vacuum-saturated.

Table 6: Classification Characteristics

Serial	Water Absorptivity Test (mm/√H)	Quality of Concrete
1	<6	Very good
2	6-10	Good
3	10-15	Poor
4	>15	Very poor

2.3.5 Water Permeability Test

The purpose of this test is to ascertain the depth to which water has penetrated a sample of concrete as a result of permeation. Cubes measuring 150 millimeters on a side are used for the evaluation. A test surface that was chosen to be perpendicular to the cast face was then given a roughened texture with the use of a steel wire brush. In order to prevent water leakages, the specimens were mounted on the permeability cells and the screws that held them in place were tightened thoroughly. After turning on the water intake valve, the first thing that was turned on was the air compressor. Adjusting the air pressure through the use of a valve system results in the application of a water pressure of 0.5 N/mm2 per bar on the top of the cube. This pressure is maintained at the same level during the course of three days. After a period of three days, the pressure in the permeability cell was lowered, and the specimens were extracted from the device. Almost immediately after having them removed, the specimens are divided in half. A marker pen is used to indicate the level of water penetration that has taken place prior to the evaporation process. It is necessary to note both the greatest and the typical depth of the water penetration.

Table 7: Classification Characteristics

Serial	Type of Concrete	Depth of water penetration
1	Dense concrete with slag and superplasticizer	5
2	Concrete to be used in aggressive environment	<30
3	Concrete to be used in water retaining structures	<50

2.3.6 Rapid Chloride Permeability Test

The purpose of this test is to assess the electrical conductivity of concrete so that a quick indication can be provided regarding the material's resistance to the invasion of chloride ions. The test consists of applying a voltage of sixty volts to a cylindrical concrete specimen that has been vacuum saturated. A solution containing 3% NaCl is applied to one side of the specimen, while a solution containing 0.3M NaOH is applied to the other side. The current that is produced is measured at regular intervals of half an hour over a duration of six hours in total. Using the trapezoidal method, one may determine the total charge that has been passed (expressed in coulombs) based on the current measurements. This charge that was passed is what is used to place the concrete into one of several different classes.

Table 8: Classification Characteristics

Serial	Type of Concrete	Depth of water penetration
1	Dense concrete with slag and superplasticizer	5
2	Concrete to be used in aggressive environment	<30
3	Concrete to be used in water retaining structures	<50

3 Results and Discussions

3.1 Mechanical Properties

3.1.1 Compressive Strength

It is clear from looking at table 9 that when 0.3% of SAP (SAP 3) is added, there is an increase in the compressive strength both on the seventh day and on the 28th day after the addition of the SAP. As a result, if compressive strength is the primary consideration, the SAP value of 3 may be selected as the optimal value for SAP. The variation of compressive strength on day 7 and day 28 is depicted graphically in Figure 1, which is a graph that was created to show the variance.

Table 9: Compressive Strength Results

Serial	Concrete Mix	Day 7 Compressive Strength (N/mm²)	Day 28 Compressive Strength (N/mm²)
1	N	24	35.2
2	SAP 1	29.23	38.56
3	SAP 2	26.8	39
4	SAP 3	33.55	38
5	SAP 4	34.1	35.89
6	SAP 5	26.5	31.2

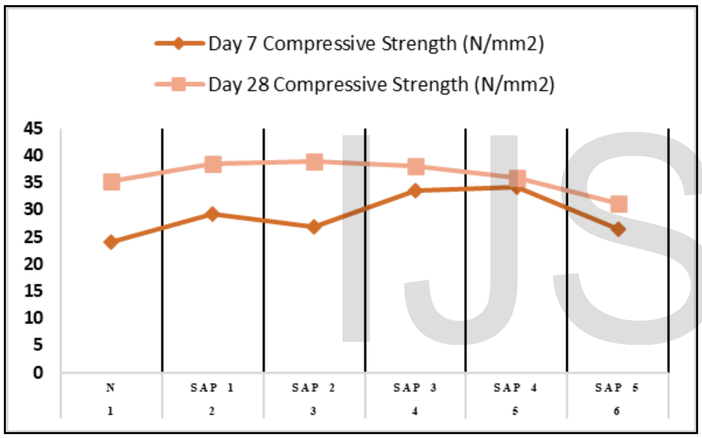

Figure 1: Graphical Illustration of Compressive Strenghth Test

3.1.2 Flexurale Strength Test

It is clear from looking at table 10 that when 0.3% of SAP is applied, the flexural strength of the material increases both on the seventh day and on the 28th day after it has been treated. Therefore, a SAP value of three can be chosen as the optimal value of SAP when the flexural strength of normal and other concrete mixes is compared with one another. The fluctuation in flexural strength that was measured on the 7th day and the 28th day after different percentages of SAP were applied is depicted in the graph that can be found in Figure 2.

Table 10: Flexural Strength Results

Serial	Concrete Mix	Day 7 Flexural Strength (N/mm²)	Day 28 Flexural Strength (N/mm²)
1	N	4.1	5.92
2	SAP 1	4.89	6.31
3	SAP 2	5.61	6.20
4	SAP 3	5.98	7.18
5	SAP 4	5.36	6.90
6	SAP 5	5.49	6.73

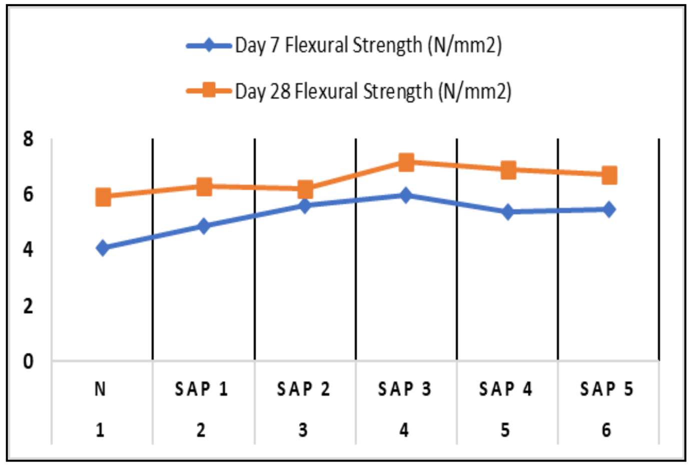

Figure 2: Graphical Illustration of Flexural Strenghth Test

3.1.3 Split Tensile Strength Test

It is clear from looking at table 11 that when 0.3% of SAP is introduced, the split tensile strength increases both on the seventh day and on the 28th day after it has been applied. This was seen. When split tensile strength is compared to normal and other concrete mixes, the optimal value of SAP may therefore be decided to be 3, and this can be chosen as the optimal value of SAP. The fluctuation in flexural strength that was seen on the 7th day and the 28th day, when different percentages of SAP were added, is depicted in the graph that can be found in Figure 3.

Table 11: Split Tensile Strength Test Results

Serial	Concrete Mix	Day 7 Flexural Strength (N/mm²)	Day 28 Flexural Strength (N/mm²)
1	N	4.29	6.24
2	SAP 1	4.99	6.77
3	SAP 2	5.5	7.10
4	SAP 3	5.59	6.98
5	SAP 4	4.78	6.45
6	SAP 5	4.30	6.73

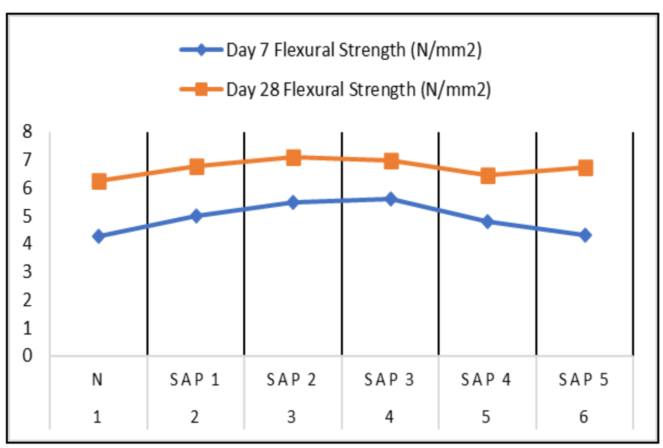

Figure 3: Graphical Split Tensile Strenghth Test

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3.2 Durability Properties

The ability of cement concrete to withstand deterioration from natural elements, chemical attack, or any other type of wear and tear is what we refer to as its durability. Concrete that is considered durable keeps its initial quality as well as its usability even after being exposed to the elements. The permeability of concrete determines whether or not hostile gases or liquids may be transported into the concrete. When it comes to the durability of concrete in hostile settings, one of the most important factors to consider is how well contaminants can penetrate the material. In this experiment, the durability properties of optimum mixes of SAP replacement (SAP 3) and ordinary mixes of concrete (N) are compared and contrasted.

3.2.1 Water Absorptivity Test

The results of the test are presented in table 12, and they indicate that there has not been a discernible decline in the standard of the concrete. This is evidenced by the fact that the values of both the conventional and optimum % of concrete specimens fall within the range of 6-10 mm/h. As a result, both of the concrete samples that were taken are of a high quality.

Table 12: Water Absorptivity Test Results

Serial	Concrete Mix	Water Absorptivity (mm/√H)	Quality of concrete
1	N	11	Good
2	SAP 3	9	Good

3.2.2 Water Permeability Test

Table 13 indicates that the depth of water penetration for a normal (N) concrete specimen is 25 millimeters, whereas the depth of water penetration for a SAP 3 concrete specimen is 28 millimeters. Since the depth of water penetration is less than 30 millimeters for both concrete mixes, it is expected that the concrete specimens will be employed in hostile environments.

Table 13: Water Permeability Test Results

Serial	Concrete Mix	Depth of penetration (mm)
1	N	24
2	SAP 3	25

3.2.3 Rapid Chloride Permeability Test

Table 14 indicates that the resistance of SAP 3 to chloride penetration is comparable to that of standard concrete. Normal (N) and 0.3% SAP replaced concrete (SAP 3) show low chloride penetrability, are cured internally without wasting too much by the curing process, and the properties of concrete are improved by the use of magnetized water and SAP. Normal (N) and 0.3% SAP replaced concrete (SAP 3) show low chloride penetrability.

Table 14: Rapid Chloride Permeability Test Results

Time (s)	N(mA)	SAP 3 (mA)
0	49	57
30	51	57
60	52	59
90	53	60
120	53	61
150	53	62
180	54	66
210	55	66
240	56	67
270	58	68
300	58	68
330	58	69
360	61	69
Passing of charge	1138.2	1321.4
Permeability of chloride ion	Low	Low

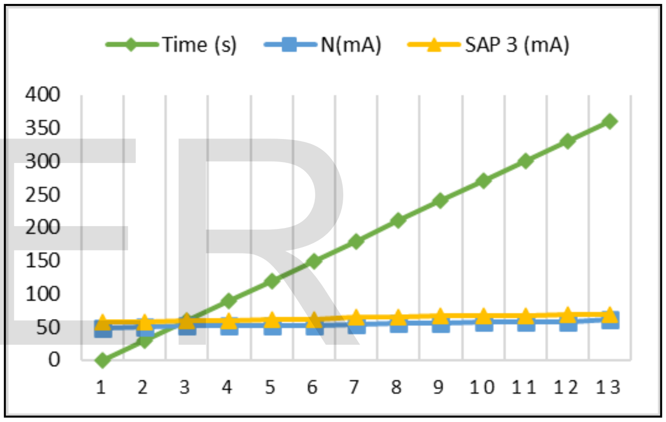

Figure 4: Graphical Illustration of Charge vs Time

4 Conclusion

In addition to its other name, water lock, sodium polyacrylate is another name for this extremely effective and widely used super-absorbing polymer. Because of its remarkable capacity to take in and cling to individual molecules of water, it is most commonly applied in the form of a thickening agent. The characteristics of concrete can be improved by employing magnetized water and SAP, which allows for the concrete to be cured internally while minimizing the amount of material that is lost during the curing process.

- It has been determined that a range of 0.3% for super absorbent polymer (SAP) is optimal.
- When compared to ordinary concrete, it was discovered that modified concrete, when it was at its optimal value, had a compressive strength that was enhanced by 25.5%. When the strength of modified concrete with 0.3% SAP is compared to that of ordinary concrete, the modified concrete with 0.3% SAP displays the best outcome in terms of strength.

- When compared to conventional concrete, it was discovered that the flexural strength of modified concrete at its optimal value was improved by a factor of 40%.
- When compared to conventional concrete, it has been discovered that modified concrete, when it is at its optimal value, possesses a split tensile strength that is 21% higher than that of normal concrete.
- Because the value of both conventional and optimum percentages of concrete specimens are of good quality, there is no discernible difference in the quality of the concrete.
- Because the depth of water penetration in the water permeability test was less than 30 millimeters for both concrete mixes, it is likely that the concrete specimens will be employed in a hostile environment.
- When compared to regular concrete, SAP 3 has a resistance to chloride penetration that is comparable to that material. Concrete that has been replaced with N and SAP 3 has a low chloride permeability.

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