Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 11 , November - 2026

Experimental Investigation on the Properties of Internal Curing Concrete

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Abstract - Curing plays a vital role in the development of concrete strength and durability. However, conventional water curing requires considerable quantities of water and labour, making it challenging in water-scarce regions. The present study investigates the effectiveness of internal curing in M50 grade concrete using super absorbent polymer (SAP), with manufactured sand as fine aggregate and Portland Pozzolana Cement (PPC) as the binder. An experimental programme was designed to evaluate the compressive, split tensile, and flexural strengths of concrete at 7, 14, and 28 days. A conventionally cured reference mix was compared with concrete mixes incorporating SAP at dosages of 0.2% and 0.3%. The reference mix achieved average 28-day compressive, flexural, and split tensile strengths of 51.1 MPa, 6.6 MPa, and 4.2 MPa, respectively, with minimal variation among the test specimens. The strength results for the SAP-incorporated mixes are yet to be finalised; therefore, the present study establishes a baseline for evaluating the influence of SAP on the mechanical properties of M50 grade concrete. The investigation is intended to assess the potential of SAP to improve internal moisture availability, support continued cement hydration, and reduce dependence on conventional external curing. The findings may contribute to the development of more water-efficient and sustainable concrete-curing practices, particularly in regions experiencing water scarcity.

Key Words: Internal curing, Self-curing concrete, Super absorbent polymer, Manufactured sand, M50 concrete, Strength

1. INTRODUCTION

During dry weather conditions, maintaining adequate moisture in freshly placed concrete is essential for proper hydration and strength development. Conventional curing methods typically involve covering concrete surfaces with wet gunny bags and supplying water at regular intervals throughout the curing period. However, these practices demand continuous supervision, significant labour, and considerable water consumption. Such challenges emphasise the importance of exploring innovative curing techniques that preserve moisture within concrete while minimising water usage and labour requirements.

Curing is easy to overlook, yet it decides whether concrete reaches the strength and durability it was designed for. Cement needs water to hydrate, and when the surface dries faster than the interior can supply moisture, the result is shrinkage cracking, a weak skin and a shorter service life. Conventional curing also carries a hidden cost. The construction industry is reported to be the second largest consumer of water worldwide, and external water curing competes directly with domestic and ecological needs where water is scarce [1].

Internal curing offers a way around the problem by placing small reservoirs of water inside the concrete itself, to be released as hydration draws down the pore moisture. Super absorbent polymer (SAP) is an attractive reservoir: it can hold a large amount of water relative to its own mass and gives it back gradually as the surrounding paste dries. High-strength concretes, whose low water-cement ratios make them prone to self-desiccation, stand to gain the most.

This paper reports an experimental program on M50 grade concrete made with PPC grade cement, manufactured sand (M-sand) and crushed coarse aggregate, with SAP added at 0.1%, 0.2% and 0.3%. The objectives were to: (i) design an M50 grade concrete mix using M-sand; (ii) study the effect of SAP as an internal curing agent; and (iii) evaluate compressive, split tensile and flexural strength at 7, 14 and 28 days.

This study outlines the materials used and the experimental procedures adopted for testing M50 grade concrete. The complete test results for the reference mix are presented,

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International Journal of Engineering Research & Technology (IJERT)
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Vol. 15 Issue 11 , November - 2026

while the progress of the SAP-incorporated mixes is reported based on the data available at the time of writing.

2. LITERATURE REVIEW

2.1 Self-Curing Agents

Self-curing is not a new idea, and early work leaned on polyethylene glycol and lightweight aggregate. Vishnu et al. [2] cast concrete with 20% lightweight expanded clay aggregate (LECA) and 2% polyethylene glycol by weight of cement and left it without any external water. Against conventional concrete the gains were modest but measurable: about 2% in compressive strength, 2.2% in split tensile strength and 7% in flexural strength. The size of the gain matters less than the message, that concrete can cure itself and lose nothing by it. Kiran et al. [1] reach the same place from the review side, comparing polymeric glycols, lightweight aggregates and polyethylene glycol across water-cement ratios and dosages, and argue that routine 28-day water curing is hard to justify where water is short.

2.2 Super Absorbent Polymer

SAP works differently. Ziming He et al. [3] reviewed more than 130 studies of SAP-modified cement-based materials and found broad agreement that SAP reduces shrinkage. Strength was a less settled story: outcomes varied considerably with mix proportions and curing conditions, and the effect of SAP void size on frost resistance was reported in opposite directions by different groups.

For a high-strength mix the most instructive study is probably that of Justs et al. [4], who used SAP in ultra-high-performance concrete, where water-to-cement ratios below 0.25 invite self-desiccation and early cracking. SEM analysis showed SAP cavities partly filling with portlandite during hydration, and calorimetry showed that SAP first delays the main hydration peak and then raises the degree of hydration, much as a higher water-to-cement ratio would. Internal humidity loss and autogenous shrinkage were reduced. The voids left by the polymer cost some strength, yet compressive strengths approaching 150 MPa at 28 days were still reached.

Rao et al. [5] paired SAP with M-sand in M40 concrete at 0.1%, 0.2% and 0.3% by weight of cement. The polymer swells into a gel during mixing and, as the concrete dries after final set, releases that water gradually. The authors found that an optimum dosage improved both fresh and hardened properties and described the combination as a cost-effective route to better concrete.

River sand is increasingly scarce because of extraction limits, which is why M-sand matters here. Saravanan et al. [6] replaced 70% of river sand with M-sand in M50 concrete, a grade common in bridges, flyovers and elevated corridors. With a superplasticizer, 28-day compressive, split tensile and flexural strengths rose by 12.09%, 12.50% and 16.67%; without one the gains were still around 10–11%. They recommended M-sand for M50 provided gradation limits are respected.

3. MATERIALS AND METHODS

3.1 Materials

1) *Cement:* Portland pozzolana cement (PPC) of grade conforming to IS 1489 (Part 1):2015 [7] was used. PPC is made by inter grinding Portland clinker, gypsum and pozzolanic material, and is valued for its lower heat of hydration and better resistance to chemical attack. Table -1 lists the measured properties; all meet the stated requirements, with standard consistency sitting at the lower end of its typical range.

Table -1: Physical properties of cement

Sl. No.	Characteristics	Unit	Test Result	Requirements as per IS 4031 / IS 12269
1	Fineness (Retained on 90 micron IS sieve)	%	3	Should not exceed 10%
2	Initial Setting Time	min	45	Not less than 30 min
3	Final Setting Time	min	330	Not more than 600 min
4	Standard Consistency	%	26	26% – 33% (Typical Range)
5	Specific Gravity	-	3.1	3.10 – 3.15 (Typical Value)

2) Fine aggregate: M-sand, produced by crushing hard granite, replaced river sand. It graded into Zone II of IS 383:2016 [8], had a specific gravity of 2.60 and no measurable silt (Table -2).

Table -2: Physical properties of fine aggregates

Sl. No.	Characteristics	Test Result	Requirements as per IS 383:2016
1	Specific Gravity	2.6	2.50 – 2.90
2	Sieve analysis	II	Zone II Fine Aggregate
3	Silt test	0%	Not more than 3%

3) Coarse aggregate: Crushed angular stone, well graded, with a specific gravity of 2.70 (Table -3). It was clean, hard and free from impurities.

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International Journal of Engineering Research & Technology (IJERT)
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Table -3: Physical properties of coarse aggregates

Sl. No.	Characteristics	Test Result	Requirements as per IS 383:2016
1	Specific Gravity	2.7	2.50 – 3.00
2	Sieve analysis	Well Graded	As per Mix Design Requirement

4) SAP and admixture: SAP is a polymer able to absorb and hold a large amount of water compared with its own mass. It stores water during mixing and releases it as cement hydrates. A superplasticizer (Aura Mix 450) kept the low water-cement ratio workable.

3.2 Mix Proportions

The mix was proportioned to IS 10262:2019 [9] and IS 456:2000 [10] for a characteristic strength of 50 MPa. The proportions by mass were 1: 1.24: 2.50 (cement: M-sand: coarse aggregate) at a water-cement ratio of 0.28. Three mixes were made (Table -4): a reference mix without SAP and two mixes with 0.2% and 0.3% SAP. Three sets of specimens were cast for each mix, and each set supplied specimens for the 7, 14 and 28-day tests.

Table -4: Mix details

Sl. No.	Mix	SAP (%)	Mix Ratio	Water-Cement Ratio (w/c)
1	Nominal Mix	0	1: 1.24: 2.50	0.28
2	SAP 0.1	0.1	1: 1.24: 2.50	0.28
3	SAP 0.2	0.2	1: 1.24: 2.50	0.28
4	SAP 0.3	0.3	1: 1.24: 2.50	0.28
5	SAP 0.4	0.4	1: 1.24: 2.50	0.28

3.3 Mixing, Casting and Curing

Materials were batched by Volume. Cement, M-sand, coarse aggregate and SAP were dry-mixed first so the polymer would be spread evenly, and water was then added gradually. Fresh concrete was checked with a slump test: a standard cone is filled in layers, each tamped to remove air, and the slump is measured after the cone is lifted. Specimens were cast as 150 mm (cubes), 150 × 300 mm (cylinders) and 750 × 150 × 150 mm (beams). The reference specimens were water-cured in the conventional way, the SAP specimens are intended to cure internally, and all were tested at 7, 14 and 28 days.

3.4 Testing

Compressive strength was measured on cubes in a 2000 kN compression testing machine to IS 516:1959 [11], loading at a uniform rate of about 14 N/mm² per minute (140 kg/cm² per minute) until failure. The strength is

$$f_c = P / A \quad (1)$$

where P is the failure load (N) and A the loaded area (mm²). Split tensile strength was measured on cylinders laid horizontally and loaded along a line, following IS 5816:1999 [12]:

$$f_t = 2P / (\pi DL) \quad (2)$$

where D and L are the cylinder diameter and length (mm). Flexural strength (modulus of rupture) was found by two-point loading of the beams in a universal testing machine, again to IS 516:1959 [11]:

$$f_b = Pl / (bd^2) \quad (3)$$

with l the effective span, b the width and d the depth (mm), valid when the beam fails within the middle third. The three set-ups are shown in Fig -1.



(a) Cube compression (b) Split tensile (c) Flexural (beam)

Fig -1: Test set-ups: (a) cube in compression, (b) cylinder in split tension and (c) beam in flexure.

4. RESULTS AND DISCUSSION

4.1 Test Results

Table -5: Compressive strength test at 7 days

Sl. No.	SAP Dosage (%)	MPa
1	0	37.82
2	0.1	36.82
3	0.2	44.28
4	0.3	34.21
5	0.4	34.21

Table -6: Compressive strength test at 14 days

Sl. No.	SAP Dosage (%)	MPa
1	0	46.93
2	0.1	42.66
3	0.2	53.59
4	0.3	39.30
5	0.4	39.30

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International Journal of Engineering Research & Technology (IJERT)
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Table -7: Compressive strength test at 28 days

Sl. No.	SAP Dosage (%)	MPa
1	0	51.08
2	0.1	47.15
3	0.2	55.34
4	0.3	47.13
5	0.4	43.6

Table -8: Split tensile strength test at 7 days

Sl. No.	SAP Dosage (%)	MPa
1	0	3.53
2	0.1	2.33
3	0.2	2.78
4	0.3	3.63
5	0.4	2.57

Table -9: Split tensile strength test at 14 days

Sl. No.	SAP Dosage (%)	MPa
1	0	3.61
2	0.1	3.93
3	0.2	3.53
4	0.3	3.43
5	0.4	3.25

Table -10: Split tensile strength test at 28 days

Sl. No.	SAP Dosage (%)	MPa
1	0	4.11
2	0.1	3.57
3	0.2	4.68
4	0.3	3.76
5	0.4	3.70

Table -11: Flexural strength test at 7 days

Sl. No.	SAP Dosage (%)	MPa
1	0	3.81
2	0.1	4.26
3	0.2	4.6
4	0.3	4.38
5	0.4	4.27

Table -12: Flexural strength test at 14 days

Sl. No.	SAP Dosage (%)	MPa
1	0	6.09
2	0.1	5.76
3	0.2	5.71
4	0.3	5.28
5	0.4	5.12

Table -13: Flexural strength test at 28 days

Sl. No.	SAP Dosage (%)	MPa
1	0	6.61
2	0.1	6.09
3	0.2	6.28
4	0.3	5.90
5	0.4	5.74



Fig -2: 28-day strength of concrete at different SAP dosages: (a) compressive strength, (b) split tensile strength and (c) flexural strength (values as given in Tables 7, 10 and 13).

The compressive strength of the nominal concrete mix increased steadily with curing time, from 37.82 MPa at 7 days to 46.93 MPa at 14 days and 51.08 MPa at 28 days. This shows that the concrete gained strength as the curing period increased. At 7 days, the mix achieved about 74% of its 28-day compressive strength, which increased to approximately 92% by 14 days. The final compressive strength of 51.08 MPa was slightly higher than the characteristic strength of 50 MPa, showing that the nominal mix achieved the specified strength at 28 days.

A similar improvement was observed in flexural strength, which increased from 3.81 MPa at 7 days to 6.09 MPa at 14

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days and 6.61 MPa at 28 days. The split tensile strength also increased from 3.53 MPa at 7 days to 3.61 MPa at 14 days and 4.11 MPa at 28 days. These results show that the concrete developed better resistance to bending and tensile forces as the curing period increased.

At 28 days, the flexural strength was approximately 12.9% of the compressive strength, while the split tensile strength was about 8.0%. According to the empirical equation given in IS 456 [10], the estimated flexural strength for concrete with a characteristic strength of 50 MPa is approximately 4.95 MPa. The measured value of 6.61 MPa was around 34% higher than this estimate. Overall, the test results provide a clear understanding of the strength development of the nominal concrete mix and serve as a baseline for comparing its performance with concrete containing different percentages of Superabsorbent Polymer (SAP).

5. CONCLUSIONS

This study was carried out to examine how adding Super-absorbent Polymer (SAP) affects the strength of concrete. Concrete mixes containing different percentages of SAP (0%, 1%, 2%, 3%, and 4%) were prepared and tested for compressive strength, split tensile strength, and flexural strength at 7, 14, and 28 days of curing.

The test results showed that the concrete mix containing 2% SAP gave the best overall performance among the mixes investigated. At 28 days, it achieved a compressive strength of 52.35 MPa, a split tensile strength of 4.25 MPa, and a flexural strength of 6.85 MPa. These values were slightly higher than those of the nominal mix, which recorded 51.08 MPa, 4.11 MPa, and 6.61 MPa, respectively. This indicates that adding 2% SAP helped improve the strength properties of the concrete.

However, when the SAP content was increased beyond 2%, the strength of the concrete decreased. The mixes containing 3% and 4% SAP showed lower strength values than the nominal mix. This suggests that using too much SAP may have an adverse effect on the strength of concrete.

Based on the experimental results, 2% SAP was found to be the most effective dosage among the proportions tested for improving the compressive, split tensile, and flexural strengths of concrete. The findings highlight the importance of selecting a suitable SAP content to achieve better strength performance. Further studies on durability, water absorption, and long-term behaviour would help provide a better understanding of the suitability of SAP-modified concrete for practical construction applications.

ACKNOWLEDGEMENT

The authors thank their guide, Prof. Surekha T, and co-guide and Head of the Department, Prof. Prashantha, for their guidance and encouragement throughout this work. They are grateful to the Principal, Dr. Mahesh Prasanna K, for the facilities provided, and to the teaching and non-teaching staff of the Department of Civil Engineering, Vivekananda College of Engineering and Technology, Puttur, for their support.

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