

Comparative Study of Self-Curing Concrete Using Lightweight Aggregates and Hydrogel (SAP) as Internal Curing Agents

Parul Mangal¹, Jayesh Juremalani²

¹Research Scholar, Parul Institute of Engineering & Technology /Parul University

²Professor, Parul Institute of Engineering & Technology /Parul University

Abstract—Self-curing concrete, also referred to as internally cured concrete, is formulated to supply internal moisture from agents such as Polyethylene Glycol (PEG) and Superabsorbent Polymers (SAP), thereby maintaining long-term hydration. This research seeks to assess the performance of M45 grade self-curing concrete based on two self-curing agents:(i) a mixture of 50% lightweight aggregates (LWA) with 2.5% PEG-400, and (ii) 0.2% hydrogel (SAP), each added by cement weight. Concrete specimens were made using these self-curing agents and were tested for workability, compressive strength, and split tensile strength at 7, 14, and 28 days of curing. Microstructural analysis by Scanning Electron Microscopy (SEM) was also undertaken to monitor hydration development. The findings show that self-curing mixes had lower workability than conventionally cured concrete. Both LWA + PEG and SAP mixes showed around 15% higher compressive strength at 28 days. Split tensile strength decreased slightly for the LWA + PEG mix but was still close to conventional concrete in the SAP mix. SEM analysis proved enhanced hydration by the internal curing mechanism. In general, the results show self-curing concrete, especially with SAP, can enhance compressive strength but retain tensile properties on par with conventional concrete. These results indicate that self-curing agents present a real alternative for increasing concrete durability, particularly in environments where external curing is subpar.

Index Terms—Self-curing, Light weight aggregates, Hydrogel, Cement, SAP, Compressive strength, Workability, Split tensile strength.

I. INTRODUCTION

As we all know concrete is the most widely used construction material out of other materials, it's all because of its great strength, durability and versatility of being moulded into various shapes. However, it

has been noticed that the performance and longevity of concrete structures depend highly on the proper curing of the hardened concrete, which ensures the development of different mechanical properties by proper hydration of cement. Normally traditional curing methods such as water ponding, membrane curing, heat application etc. have been adopted in almost all places. But it is not feasible to use traditional curing of concrete in places like vertical structures or where there is scarcity of water. However, if insufficient curing can lead to incomplete hydration process which will result in reduction in strength and increasing permeability of concrete which in turn results in early-age cracking. Therefore, proper curing is very essential for complete hydration of concrete.

To address the challenges faced during traditional curing of concrete, the concept of self-curing or internal curing has been developed as an innovative solution. Self-curing concrete is the one which has the capability to retain moisture within and releases it whenever required for hydration process, which reduces the usage of traditional curing methods. This mechanism of retaining moisture internal can be achieved by adding certain internal curing agents such as Light Weight Aggregates, Super Absorbent Polymers, Polyethylene Glycol, Water Soluble Polymers, Natural or Synthetic Fibers etc. These agents can absorb a lot of water within and enhance the hydration process by releasing water whenever required. They can absorb the moisture either from concrete or from the atmosphere. This method of internal curing is one of the best practices for sustainable concrete which saves a lot of water.

Among the various approaches for self-curing concrete, usage of Light Weight Aggregates (LWA)

and Super Absorbent Polymers (SAP) have gained attention in the present research due to its effectiveness in improving hydration, reducing shrinkage and enhancing overall performance of concrete. Poly Ethylene Glycol (PEG-400) also played an important role as a self-curing agent in the present research as it is a water-soluble polymer which has an ability to retain moisture.

The present research aims to investigate the comparative performance of M45 grade self-curing concrete using two internal curing systems: a combination of 50% LWA and 2.5% PEG-400, and 0.2% SAP (hydrogel), each dosed by the weight of cement. The study evaluates key mechanical properties, including workability, compressive strength, and split tensile strength at 7, 14, and 28 days, and compares the results with those of conventionally cured concrete. This research provides insights into the effectiveness of different self-curing agents in enhancing the mechanical performance of high-strength concrete, with implications for sustainable and durable construction practices [3, 4, 6].

II. MATERIALS & METHODS

The materials used in the present investigations are as follows:

1. *Cement*

OPC 53 grade cement has been used with 3.15 specific gravity. Various physical and chemical tests have been conducted as per Indian Standard codes. The various physical properties have been shown in Table 1 below:

Table 1: Physical properties of Cement

| Sr. No. | Type of Test | Test Result |
|---------|--|-------------|
| 1 | Consistency (%) | 28.50 |
| 2 | Setting Time | |
| a | Initial Setting Time, min | 135 |
| b | Final Setting Time, min | 255 |
| 3 | Soundness, Le'chatelier, | 1.06 |
| 4 | Fineness by Blain Air Permeability, m ² /kg | 284.72 |

| 5 | Compressive Strength | |
|---|----------------------|-------|
| a | 72 ± 1 h, Strength | 30.90 |
| b | 168 ± 2 h, Strength | 42.10 |
| c | 672 ± 4 h, Strength | 56.18 |

2. *Aggregates*

The fine aggregate used was natural river sand as per IS:383. The specific gravity of sand is found to be 2.626 and fineness modulus obtained is 3.11. The coarse aggregate used in the present research was having 20 mm nominal size. The grain size analysis has been shown in fig.1 & fig.2 below.

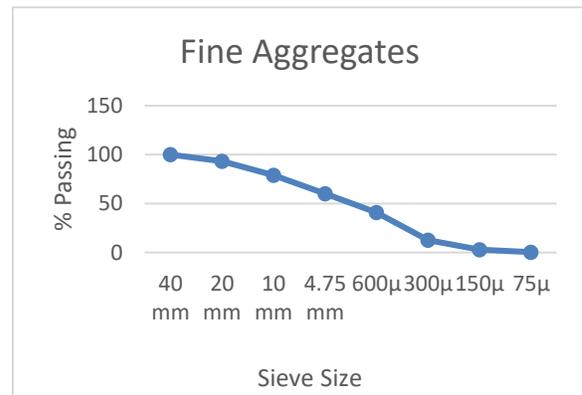


Fig.1 Fine Aggregate Sieve Analysis

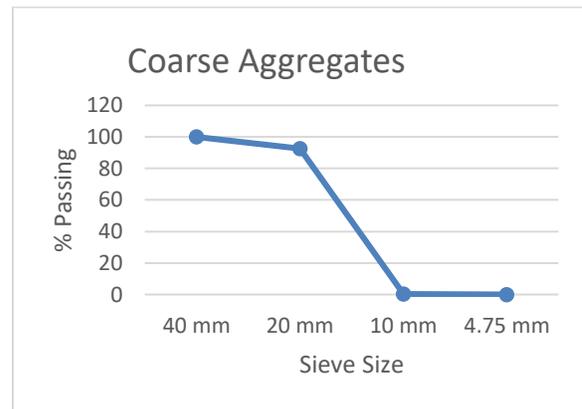


Fig.2 Coarse Aggregate Sieve Analysis

3. *Water*

Normal tap water has been used for the present research.

4. *Light Weight Aggregates*

LWA used in this present research has been purchased from Shri Goverdhan Quarry Works, Pavagadh, Vadodara of nominal size 20 mm with proportion of 50% as a replacement of coarse

aggregates having specific gravity 2.838. The grain size analysis has been shown in fig.3 below.

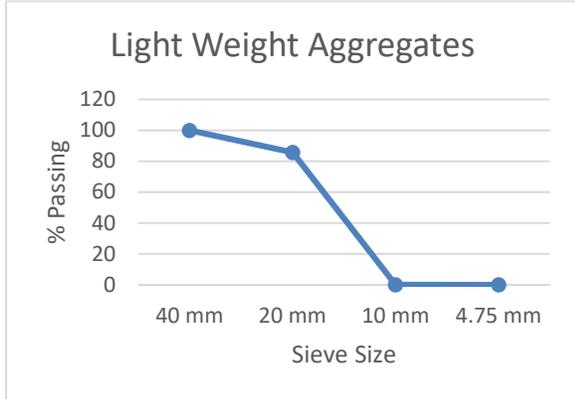


Fig. 3 Light Weight Aggregates Sieve Analysis

5. Poly Ethylene Glycol

In the present research Polyethylene Glycol-400 (PEG-400) as shown in fig. 4 with a proportion of 2.5% by the weight of cement has been used which is a water-soluble polymer widely used as an internal curing (self-curing) agent in concrete. Its primary function is to retain moisture within the concrete matrix, ensuring continuous hydration of cement, especially where external curing is challenging or water resources are limited.



Fig.4 PEG-400

6. Super Absorbent Polymers

Hydrogel has been used as SAP - 0.2% by the weight of cement. They are synthetic hydrogels used as internal curing agents in concrete to retain moisture,

improve hydration, and mitigate shrinkage. Their water-absorbing capacity (up to 500 times their weight) makes them effective for enhancing durability and mechanical performance in low water-to-cement (w/c) ratio concretes. Fig. 5 indicates the Hydrogel used in powdered form.



Fig. 5 Hydrogel

III. MIX PROPORTIONS

In this study three mix proportions have been casted which has been shown below in Table 2:

1. Control Mix: Conventional concrete with water curing
2. LWA Mix: 50% replacement of coarse aggregate with LWA
3. SAP Mix: 0.2% SAP by weight of cement

Table 2 Mix ID

| S.No. | Mix | Mix ID |
|-------|-------------|---|
| 1 | Control Mix | M1 |
| 2 | LWA Mix | M2 - 50% LWA+ 2.5% weight of cement (PEG) |
| 3 | SAP Mix | M3 - 0.2% Hydrogel by weight of cement |

IV. TESTS PERFORMED

Various tests performed have been performed as per specified IS Code and has been tabulated below in table 3:

Table 3 Tests Performed

| Sr. No. | Property | Tests | IS Code |
|---------|----------|------------------------------|-------------------|
| 1 | Fresh | Workability | IS: 1199-2018 (2) |
| 2 | Hardened | Compressive strength test | IS: 456-2000 |
| | | Split tensile strength test | IS :5816-1959 |
| | | Scanning electron microscope | - |

V. RESULTS & DISCUSSIONS

A. Workability

The workability is the fresh concrete property which has been done by using Slump cone test. It has been done for all mix proportions of concrete i.e. conventional concrete, concrete with replacement of aggregates with light weight aggregates and concrete with hydrogel as an addition by the weight of cement. It has been observed that workability decreases for both mixes M2 and M3 as compared to conventional concrete.

Table 4 Workability

| S.No. | Mix | Workability |
|-------|-----|-------------|
| 1 | M1 | 140 mm |
| 2 | M2 | 30 mm |
| 3 | M3 | 130 mm |

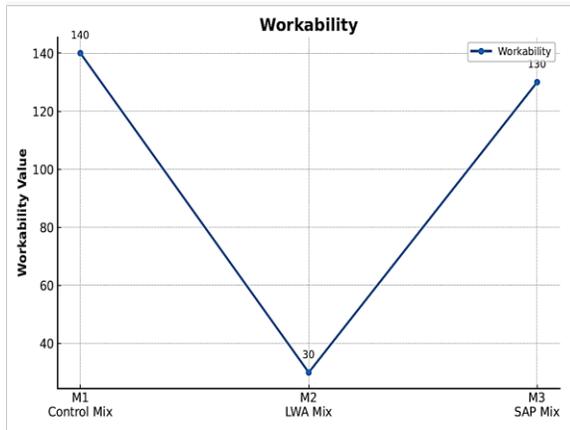


Fig. 6 Workability

B. Compressive Strength

It is one of the hardened concrete properties to check the strength of concrete for specific grade by using Compression Testing Machine (CTM). Cube specimen of size 150 x 150 x 150 mm has been casted and cured for 7, 14 and 28 days and tested for compressive strength. Three specimens have been casted out of which one has been cured conventionally and other two has been self-curing by using self-curing agents i.e. LWA with PEG-400 and Hydrogel. Results showed that self-cured concrete shows better strength as compared to conventional concrete. It has been observed that after 28 days of self-curing there is approximately 15% increase in compressive strength.

Table 5 Compressive Strength

| S.No. | Mix | Compressive Strength, N/mm ² | | |
|-------|-----|---|---------|---------|
| | | 7 days | 14 days | 28 days |
| 1 | M1 | 41.22 | 44.62 | 46.69 |
| 2 | M2 | 39.36 | 44.54 | 54 |
| 3 | M3 | 43.61 | 51 | 53.78 |

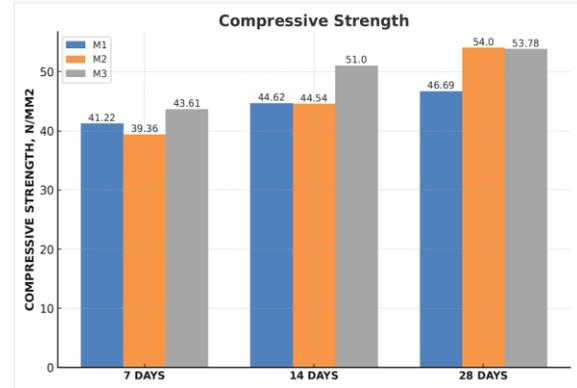


Fig. 7 Compressive Strength

C. Split Tensile Strength

This test measures the tensile strength of concrete which has the ability to withstand tensile stress of concrete to check the hardened property of concrete. In this test cylindrical specimen of size 150 mm x 300 mm has been used to check the tensile property of self-cured concrete after curing of 7, 14 and 28 days. In the present research, it has been observed that split tensile strength has been decreased for self-cured concrete with LWA + PEG but increases for SAP cured concrete as compared to conventionally cured concrete. Results showed that tensile strength for LWA + PEG self-curing agent has been decreased by 28% approximately, whereas for SAP as self-curing agent tensile strength has been increased by approximately 24%.

Table 6 Split Tensile Strength

| S.No. | Mix | Split Tensile Strength, N/mm ² | | |
|-------|-----|---|---------|---------|
| | | 7 days | 14 days | 28 days |
| 1 | M1 | 1.95 | 3.79 | 4.66 |
| 2 | M2 | 2.08 | 3.16 | 3.31 |
| 3 | M3 | 2.51 | 4.99 | 5.20 |

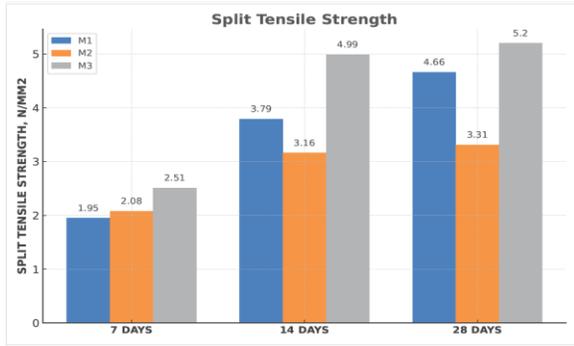


Fig. 8 Split Tensile Strength

D. Scanning Electron Microscope

For understanding the microstructure of concrete Scanning Electron Microscope study is very valuable in which high-resolution images have been captured that allows us to explore the detailed study of concrete particles at a nanometer scale. SEM not only allows all researchers to study all the microstructural properties of concrete materials but also allows to study the effect of various factors such as curing methods, environmental conditions and various supplementary elements present within the concrete. In our research study self-cured concrete have been developed by using Hydrogel, LWA and PEG as self-curing agents. Two different samples were there which has been internally cured for 28 days. After the curing period, microstructure analysis has been done by using SEM which has been shown in the figure 9 & 10:

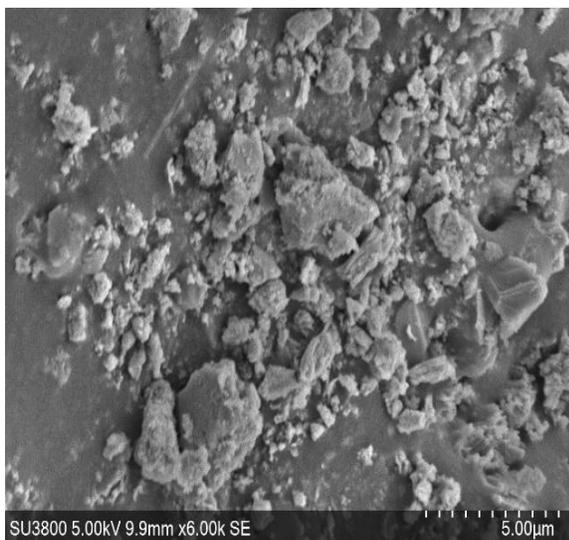


Fig. 9 SEM image 0.2% Hydrogel

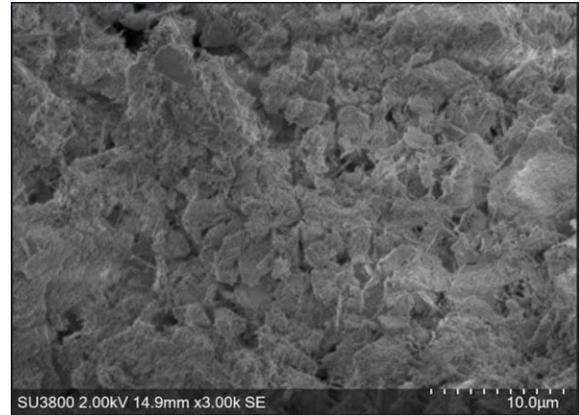


Fig. 10 SEM image LWA + PEG – 400

VII. CONCLUSION

This research effectively compares the different mechanical properties i.e. workability, compressive strength and split tensile strength of M45 grade for conventional concrete, light weight aggregate concrete with PEG-400 and hydrogel enhanced concrete. Also, comparative analysis of microstructure has been done by using Scanning Electron Microscope test. The results so obtained by conducting different tests have been summarized below:

- i. Workability for conventional concrete was found to be 140 mm which is approximately 78% higher than the workability obtained for light weight aggregate concrete in which LWA and PEG was used as self-curing agents, whereas for hydrogel enhanced concrete was approximately 7% lower than the workability obtained for conventional concrete.
- ii. Compressive strength test revealed that all the three mixes i.e. M1, M2 & M3 were meeting all the requirements required for compressive strength as for M45 grade concrete compressive strength should be 45 N/mm² at 28 days. The results thus obtained shows that there was increase in strength of 3.7%, 20% and 19.5% for M1, M2 & M3 respectively.
- iii. Split tensile strength results shows that for concrete mix containing hydrogel as self-curing agent has maximum tensile strength but for concrete mix having light weight aggregates with PEG-400 does not meet the requirements of minimum tensile

strength which is 29% lower than nominal strength after 28 days of curing.

iv. Finally, SEM analysis shows the valuable information in which different microstructural properties of concrete mixes have been identified, which demonstrates how different self-curing agents influences the internal structure of concrete mixes. The SEM photographs show the variation in particles count and arrangement in different samples. Overall, it has been concluded that by adding different self-curing agents in different concrete mixes of M45 grade, there was optimal increase in the different mechanical properties of concrete but certain aspects can be found in future for increasing the workability of concrete. Further research can be done for the selection and evaluation of the different curing agents which are necessary to achieve performance enhancement.

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