Evaluation of optimum dosage in blended self curing concrete on the impact of supplementary cementitious materials (scm's) and durability studies on different proportions

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Abstract. Now a days, the shortage of potable water increases, for domestic and commercial purposes due to environmental conditions. Due to this scarcity, curing of concrete is affected and in this point of view water assets are more valuable every day and becomes more economical. Traditional Curing used for retaining moisture within the concrete elements during the early days and beyond to develop the desired properties in terms of strength & durability. To develop the modern era curing, a few of self-curing agents like Super Absorbent Polymers, Polyethylene Glycol (PEG 400) has been used for internal curing of concrete used for reducing the hydration process. In this experimental study, Supplementary Cementitious Materials like Class F Flyash, Silica Fume and Ground Granulated Blast Furnace Slag (GGBFS), have been casted for 65%+25%+15% (M2), 65%+20%+15% (M6), 65%+25%+10% (M10) and 65%+20%+15% (M11) of optimal mix proportions. The sorptivity assessments have being carried out on all blended mixes of Self Cured Concrete with size of 15 cm x 15cm x15cm. The pH value of the acidic medium was at 0.45 by submerging in acid, the specimen samples are brought out and were cleaned in repeatedly with water and kept in atmospheric condition for two days for constant weight and then the specimens are balanced using weighing scale and loss in weight and hence the percentage in loss of weight was premeditated within and after 28 days with different mix proportion of M30 grade of concrete supplementary cementitious materials like Flyash, Ground Granulated Blast Furnace Slag and Silica Fume with PEG 400 as 1% by its weight.

1. Introduction

Plain Cement concrete (PCC) is very weak in tension comprises several micro cracks which propagates within the concrete matrix underneath the constantly applied load. Subsequently, PCC members cannot endure tensile stresses created due to the applied force without the addition of reinforcing elements which are capable to resist these stresses. The addition of Supplementary Cementitious Materials (SCM’s) like Flyash, Ground Granulated furnace Slag and Silica Fume to the structural concrete enhances its stiffness, ductility, and load bearing capacity, while at the identical time reduced crack enhancement and propagation. According to the composite material theory, positive synergy of distinct admixtures may be supplementing with each other to make a new composite material with high structural implementation and excellent economic benefits.

Ternary blended concrete demonstrates the adjunct of numerous pozzolanic materials to the concrete with cement behaving as the most important binding material. Fly ash from power plants and
metakaolin have being the both essential in modern day concrete practice. Widening the extent of SCM’s such as Fly ash, Silica fume, GGBFS, Rice Husk Ash and Metakaolin in the consumption of concrete making, leads to the concept of blended cements and concretes. Thus, due to the influence for the point of early hydration was decline in generation of excess Ca(OH)$_2$, control on heat of hydration and mitigation of uninterrupted bleed channels. By reorienting the mix design parameters for superior structural performance of concrete with thrust on controlling OPC content but increasing the whole cementitious material and controlling water content, consuming chemical admixture, for amended workability, for offsetting deliberate hydration with SCM’s.

The response of Fly ash versus Calcium hydroxide has been released during the cement hydration method which have being affected by that oxidation procedure, mineralogical and structure level as well as grain size distribution. Several amendments remained provided the information regarding the chemical activation of the Fly ash versus Ca(OH)$_2$ reaction are also called pozzolanic reaction, in order to consent the escalation of the fly ash content in the blended Portland cements exclusive of a major negative impact on the early strength in the effort to create clinker free binders. Concrete incorporating self-curing agents will imply a new set of drift in the construction in the new millennium, due to the intensified use of performance built concrete. Newer procedures may be used for the inclusion of internal or self-curing of water in concrete. Most of the researchers proposed to the use of soaked aggregates to deliver internal curing for concrete and polyethylene glycol PEG 400 in concrete mixes as self-curing agent.

2. Research Significance

The primary objective of this section is to assess the outcomes of distinct kinds and percentage of self-curing agents on the mechanical properties of concrete such as Compressive and Flexural strength of reinforced concrete beam with M30 grade mix. According the Compressive strength of concrete of M30 Grade with water-binder ratio as 0.40 and mix proportion of 1:2.12:3.75 with addition of self curing agents PEG as 1%.

The self-curing agent Polyethylene Glycol 400 which utilized in this paper have been added as constant, where the proportioning of blending proportions have been made with the results have been concluded with the compressive strength and split tensile results. The optimal self-cured concrete is have been derived as 65%+25%+15% (M2), 65%+20%+15% (M6), 65%+25%+10% (M10) and 65%+20%+15% (M11) and with the same combination of blending proportioning is made for performance of blended concrete, which was testing under loading. Also, these results offer more knowledge about the determination of self-curing agent ratios and the greatest category to optimize the mechanical properties of self cured concrete built upon their performance of structural behaviour under loading conditions.

In this investigation, an attempt has been made to investigate the performance of strength parameters of casted control samples with incorporation of Polyethylene Glycol, PEG 400 as 1.0% in Blended Self Curing Concrete and controlled self-curing concrete with M30 Grade concrete mix. Ordinary Portland Cement, Fine and Coarse Aggregate, Potable Water, Class F Fly Ash, Ground Granulated Blast Furnace Slag, Silica Fume, Poly-Carboxylate Super Plasticizer and PEG Plasticizer were the materials used in the recent findings.

3. Materials and Proportioning of M30 Blended Mix

Ordinary Portland cement, Class F Flyash, GGBFS and silica fume, commonly available in India for modern-day concrete, silicious river sand with a fine aggregate fineness modulus of 2.73 and a nominal maximum size of 20 mm, were used to take this study. The coarse aggregate consumed cooperates with the Indian Standard IS 383-1970 code and is evaluated for its physical characteristics, its specific gravity 2.6 as an angular coarse aggregate, in conjunction with the Indian Standard IS 2386-1963.Bulk density with free state as 1455 kg/m$^3$ and compressed state as 1529 kg/m$^3$. Potable water have been used in the investigations for both mixing of SCM specimens.

Class F Flyash were acquired with a specific gravity of 2.172 from Mettur Thermal Power Plant. Though with the chemical configuration consisting of 63.98 % silica content, 1.721 % calcium oxide, 1.0 % magnesium oxide, 10 % pH value and 2.12 % ignition loss. GGBFS is more importantly
resistant to the ingress of ions found in chloride and within concrete away with each other in the concrete mixtures, associated with decreased permeability.

Ground Granulated Blast Furnace Slag have been obtained in Jindal South West (JSW) Steel Ltd, Karnataka mainly having Silica content of 35.25%, Alumina as 19.2 % and Calcium Oxide content as 34.90 % was found. Consequently, the silica fume used has a 92.5 % SiO\textsubscript{2} content and was in fine and powdered form. In the present study, low - molecular weight polyethylene glycols (PEGs) (400) have been used, whereas these chemical compounds were systematically mixed with water in PEG as a curing agent subsequent to the addition or mixing of water into the concrete.

As super plasticizer (polycarboxylate-type), a new - generation high - variety water mitigating chemical admixture corroborating to American Society for Testing and Materials (ASTM) C494 has been used to improve the workability of self-curing blended mix with reduced water-cement ratio.

Several number of dosages of Class F Flyash, Ground Granulated Blast Furnace Slag and Silica fume proportion has been provided to the optimal content arrived from the previous investigation made as per literature study providing the blended proportioning of self cured concrete as 65%+25%+15% (M2), 65%+20%+15% (M6), 65%+25%+10% (M10) and 65%+20%+15% (M11) has derived in Table 2 [17], of numerous mix proportions have been determined, in which the performing the optimum level of dosage of blended mix elements were arrived for the given mix M30 grade of concrete with polycarboxylate-type super plasticizer and PEG 400 as 1% to the weight of the cement content. Though the specimen’s samples of M30 grade blended concrete beams made with optimum amount of Flyash, GGBFS and Silica fume replacement were casted. Tests for workability was obtained by Slump cone test and defined in Table 2 [17].

### Table 1. Proportioning of Standard Self Cured mix for M30 Concrete

| Materials | Cement | Fine Aggregate | Coarse Aggregate | PEG 400 | Super Plasticizer | Water | Water-Cement Ratio |
|-----------|--------|----------------|------------------|--------|------------------|-------|-------------------|
| Quantity  | 350    | 744.25         | 1314.18          | 2.28   | 3.5              | 175   | 0.4               |

### Table 2. Mix proportions of Blended Self Curing Concrete for M30 Grade [17]

| Mix (%)   | Cement | Flyash | GGBFS | Silica fume | Fine Aggregate | Coarse Aggregate | S.P | Water | Slump (mm) |
|-----------|--------|--------|-------|-------------|----------------|------------------|-----|-------|------------|
| M1 (100)  | 350    | --     | --    | --          | --             | --               | 227.50 | --     | 744.3     |
|           |        | 87.50  | 35.0  | --          | --             | --               | --          | 1314.2 | 3.5       | 140.0     |
|           |        | 70.0   | 52.50 | --          | --             | --               | --          | --     | 52.50     | 251       |
|           |        | 70.0   | 52.50 | --          | 70.0           | 52.50            | --          | 1314.2 | 3.5       | 140.0     |
|           |        | 70.0   | 52.50 | 70.0        | --             | 52.50            | --          | 1314.2 | 3.5       | 140.0     |
|           |        | 87.50  | --    | 87.50       | 87.50          | 35.0             | 227.50 | --     | 744.3     |
|           |        | 87.50  | 35.0  | --          | --             | 35.0             | --          | --     | 52.50     | 251       |
|           |        | 87.50  | --    | 87.50       | --             | 35.0             | --          | --     | 52.50     | 252       |
|           |        | 70.0   | 52.50 | --          | 70.0           | 52.50            | --          | 1314.2 | 3.5       | 140.0     |
|           |        | 70.0   | 52.0  | --          | --             | 52.50            | --          | 1314.2 | 3.5       | 140.0     |
|           |        | 70.0   | 52.0  | --          | --             | 52.50            | --          | 1314.2 | 3.5       | 140.0     |

*** The Slump Cone values for mixes of SCM's with cement from M1 to M13 with addition of PEG 4000 as 1.0 % .

### 4. Mechanical Behaviour of Blended Self Curing Concrete with SCM’s

The mixing both of materials were controlled for a period of two minutes throughout this blended mix of self-curing concrete associated with SCMs. In order to achieve the desired workability without even any segregation resistant over fresh condition, the amount of polycarboxylate-type superplasticizer was altered for each appropriate mix. Numerous specimens were cast using compressive cubic moulds and split-tensile cylindrical moulds accompanying the mixing of concrete.
After the castings were filled with a consolidated mix of self-curing concrete that were well compacted, the surface of the concrete was levelled and the specimens were kept in the moulds for 24 hours or one day in experimental conditions, while the mould surface were protected by plastic wrap and afterwards, and during experimental study, the demoulded specimens were incubated at room temperature. For cubic specimens, compressive strengths and split tensile strengths were carried out, whereas strengths were properly evaluated at 7, 14 and 28 days, as well as for split tensile tests for blended concrete grade M30 mixtures.

Self Curing Concrete mixtures with their strength parameters blended with Supplementary Cementitious components in various proportions of different percentages of Class F Flyash, Ground Granulated Blast Furnace Slag including Silica Fume of various mixed percentages of M1 (Conventional mix) and M2 to M13 has been tabularized in Table no.3.

**Table 3.** Strength parameters of Self Curing Concrete blended with SCM’s in various proportions

| Mix (%) | Compressive Strength (N/mm²) | Split Tensile Strength (N/mm²) |
|---------|------------------------------|-------------------------------|
|         | 7 days | 14 days | 28 days | 7 days | 14 days | 28 days |
| M1 (100) | 12.48  | 20.15   | 31.21   | 1.34   | 2.1    | 3.4     |
| M2 (65+25+15) | 16.04  | 26.67   | 41.12   | 1.48   | 3.11   | 4.21    |
| M3 (65+25+15) | 16.79  | 25.6    | 38.16   | 1.54   | 3      | 4.18    |
| M4 (65+25+15) | 15.52  | 25.89   | 37.85   | 1.47   | 2.99   | 4.13    |
| M5 (65+20+15) | 13.06  | 24.52   | 35.21   | 1.42   | 2.6    | 4.03    |
| M6 (65+20+15) | 13.97  | 22.52   | 36.76   | 1.39   | 2.48   | 4.1     |
| M7 (65+20+15) | 14.03  | 20.78   | 35.07   | 1.35   | 2.56   | 4.19    |
| M8 (65+25+10) | 13.36  | 21.42   | 34.25   | 1.47   | 2.49   | 3.94    |
| M9 (65+25+10) | 14.08  | 20.76   | 33.53   | 1.49   | 2.44   | 3.91    |
| M10 (65+25+10) | 14.64  | 23.78   | 34.86   | 1.45   | 2.5    | 3.86    |
| M11 (65+20+15) | 15.97  | 25.29   | 38.95   | 1.33   | 2.24   | 3.54    |
| M12 (65+20+15) | 15.17  | 23.9    | 35.29   | 1.29   | 2.19   | 3.68    |
| M13 (65+20+15) | 14.25  | 21.19   | 33.93   | 1.3    | 2.28   | 3.79    |

**Fig 1.** Impact of SCM’s % on Compressive strength of Blended Self-curing concrete

**Fig 2.** Impact of SCM’s % on Split Tensile strength of Blended Self Curing concrete
4.1. pH Value

The pH values of all studied concretes of various proportions 65%+25%+15% (M2), 65%+20%+15% (M6), 65%+25%+10% (M10) and 65%+20%+15% (M11) for the specified mix of M30 grade blended concrete with Flyash, GGBFS and Silica fume with Cement have been derived in Table 2 [17]. As the blended self curing concrete mix which exhibits the amount of heat of hydration have been increased steadily with time due to the production of Calcium Hydroxide (Ca(OH)₂) as the result of continuance of hydration of cement content and definite higher values compared to their corresponding concretes with Ground granulated blast furnace slag and Silica fume after 28 days. Fig.3. demonstrates the difference in the pH values of the concrete mixes studied due to the exposure to blended mixes of Class F FA, Ground Granulated Blast Furnace Slag and Silica fume content.

Comparing the results, these blended SCC mix incorporates the difference in pH values, Where the pH value have been lowered in the with percentage with 25 % of Class F Flyash and 15% of Ground granulated blast furnace slag, meanwhile there is a gradual increase in the mix proportion of 25 % of GGBFS and 10 % of Silica Fume and it has been lowered 3 % over the mix of 25 % Flyash and 15 % Silica fume. All the concrete mixes which exhibits the continuous increase and sudden decrease in the pH value with distinct rates corresponding to the concrete type.

fig 3. Influence of SCM’s % on pH value of Blended Self Curing concrete

4.2. Sorptivity Test

Sorptivity experiments were run on all Self Curing Concrete specimens with dimensions of 15x15 x15cm. Water impermeability of their adjacent faces was also included in the preparation of samples, decreasing the concentration of water evaporation. The experiment started with the observation of the weight of the samples and then they were positioned in contact with the water depth capable of drenching them from around 5 mm in the recipient. The samples were withdrawn from the recipient after a predetermined period of to proceed to weight identification. These samples of surface water with a damp cloth were removed prior to weighing. The samples were replaced in the container immediately after weighing until the following measurement period was reached. The procedure was repeated consecutively at different intervals, including 15 minutes, 30 minutes, 1 hour, 2 hours, 4 hours, 6 hours, 24 hours, 48 hours, 72 hours, 7 days, 14 and 28 days.

Table 4. Sorptivity values at early and consequent stages (mm/s 0.5)

| Mix %       | Early absorption | Resultant absorption |
|-------------|------------------|----------------------|
| M1 (100)    | 0.0288           | 0.0081               |
| M2 (65+25+15)| 0.0395           | 0.0069               |
| M3 (65+25+15)| 0.0412           | 0.0088               |
| M4 (65+25+15)| 0.0325           | 0.0099               |
| M5 (65+20+15)| 0.0255           | 0.0072               |
| M6 (65+20+15)| 0.0274           | 0.0075               |
4.3. Resistance to Acid
In accordance with ASTM C2677 (2001), the relative acid resistance has been calculated (2001). (2001). Using 5% pH sulfuric acid (H2SO4) of 0.50. pH, the aggressive acid environmental condition was replicated. The 28 days of cured mortar cubes were immersed for 28 days in an aggressive acid environment. In order to mitigate evaporation, the glass containers with submerged mortar specimens were kept covered during the test phase, as shown in Figure 5. The blended SCC mortar specimens were washed with distilled water at 2, 7, 14, 28, 56 and 90 days of exposure; the acid resistance was then measured by calculating the weight loss of the specimens as follows: where \( W_0 \) is the weight (grams) of the specimens before immersion and the weight \( W_t \) (grams) of the specimens cleaned after day \( t \) immersion. Average weight losses were reported in Fig 4 for each mortar specimen.

| Mortar Specimen | Weight Loss Wt (g) | Weight Loss Wt (g) |
|-----------------|--------------------|--------------------|
| M7 (65+20+15)   | 0.0287             | 0.0068             |
| M8 (65+25+10)   | 0.0271             | 0.0088             |
| M9 (65+25+10)   | 0.0277             | 0.0096             |
| M10 (65+25+10)  | 0.0286             | 0.0092             |
| M11 (65+20+15)  | 0.0415             | 0.0103             |
| M12 (65+20+15)  | 0.0396             | 0.0098             |
| M13 (65+20+15)  | 0.0310             | 0.0083             |

Fig 4. Loss of Weight (%) due to the influence of SCM’s % of Blended Self-curing concrete

4.4. Mass loss
It can be seen from the test results that, the mass loss of all self-curing and conventional concretes increased gradually with time under air curing due to water evaporation from concrete as shown in Fig. 7. The presence of silica fume and self-curbing agents in concretes caused an additional reduction in mass loss relative to conventional concrete during the experiment to confirm that a better water retention occurred. It could be seen on the test results that, due to water evaporation from concrete, the mass loss of both self-curing and traditional concretes increased substantially with time under air curing, which is shown in Fig. 7. Also during experiment, the development of silica fume and self-curbing agents in concrete caused a modification actions in mass loss compared to conventional concrete to demonstrate a stronger preservation of water.
Fig 5. Loss of Mass (%) due to the impact of SCM’s % of Blended Self-curing concrete

5. Discussions
The concrete was formed according to Mix Design M30 grade (IS 10262:2009) and blended concrete was examined for strength properties, which include compression test and split tensile test with different ratios, such as 65% +25% +15%, 65% +20% +15%, 65% +25% +10% and 65% +20% +15% from M1 as Traditional SCC mix. The concentrations of Polyethylene Glycol 400 were adjusted from 1 percent by concrete weight as a self-relieving agent with different concentrations of SNF rapidly changing from 1 percent by solid weight through one self-renovating solid blend and distinguishing the test result and the triple mixed self-curing concrete with various percentages replacements of FA, SF, GGBFS and their combinations of concrete from these final quantities continued to optimize the quantities for various blended SCC mixes of grades considered. The percentage adjustments, correlating to their desired strengths, are shown in table 3. The final optimal quantities of various grades of Cementitious materials are listed in Table-4, along with their total powder content and water/powder ratios. In Table-5, compressive strengths are tabulated for different binary, ternary and quaternary blended optimal SCC blends, the self-curing performance of PEG 400 applied to concrete is the maximum if 45 kg/m3 PEG 400 incorporated water through ensures with 1 kg/m3.

Table 4. Parameters of optimally blended M30 grade concrete mixes for 28 days

| Mix | Designation (% by weight) | Compressive Strength in MPa | Split Tensile Strength in MPa | Resultant absorption mm/s 0.5 | pH Value | Resistance to Acid % | Mass Loss % |
|-----|----------------------------|-----------------------------|-------------------------------|--------------------------------|----------|----------------------|-------------|
| M2  | 65%+25%+15%                | 41.12                       | 4.21                          | 0.0069                         | 11.89    | 23.41                | 63          |
| M6  | (65%+20%+15%)              | 36.76                       | 4.19                          | 0.0075                         | 12.08    | 26.77                | 67          |
| M10 | 65%+25%+10%                | 34.86                       | 3.94                          | 0.0093                         | 13.20    | 25.60                | 66          |
| M11 | 65%+20%+15%                | 38.95                       | 3.79                          | 0.0103                         | 11.69    | 26.00                | 64          |

6. Conclusion
The following conclusions are documented as below, based on the investigational studies and test findings;
The addition of polyethylene-glycol into concrete reduces water evaporation, contributing to the increase in the concrete’s water retention capacity, subsequently resulting in increased mechanical properties. Although 45 kg/m3 of water is used in practices for 1 kg/m3 of self-curing concrete, the prevalence of internal self-curing by PEG 400 procedures used for concrete is higher. The PEG 400 seems to be more effective than traditional concrete curing methodologies. The concrete component and the water to cement ratio remain significantly determined by the implementation of the self-curing...
agent. Micro silica use has been important and mandatory for the development of high-strength concrete mixes (M30) due to the enhanced reactive and micro-filler characteristics. Either GGBS and Silica fume will be incorporated to optimize the opportunities of micro-filler functionality in M30 grade fly ash integrated concrete mixes. Due to its greater sensitivity, the addition of silica fume (SF) to blended concrete mixes facilitates accelerated hydration. M30 concrete mixes blended with 65 % OPC +25 % FA +10 % GGBFS optimally blended mix grade tends to produce both necessary workability and predicted compressive strengths. From that same observation, GGBFS transmits high strength in blended SCC mixtures, although both Fly Ash and GGBFS are expected in blended concrete mixes developed directly proportional with lower water powder. As the Flyash and GGBS content with M2, M3 and M4 getting a higher compressive strength for blends having M5, M6 and M7, M8, M9 and M10 increased to an optimum point in M11, M12 and M13, the compressive strength properties of conventional concrete. And therefore it was determined that, again for efficient use of GGBFS content, the optimum level yields the highest strength in the proportions of M2, M3 and M4 at 65 percent + 25 percent + 15 percent. To increase its strength by about 30 % of the total binder content, that results the optimum level of GGBS content.

As the Flyash and GGBFS content has increased significantly in Concrete mixture proportions of M2, M3 and M4 with a higher compressive strength for mixes with a marginal decrease of M5, M6, M7, M8, M9 and M10, the split tensile strength characteristics of concrete increase to an optimal level in M11, M12 and M13. It can therefore be hypothesized that, for the optimized use of GGBFS material, there is an acceptable amount that delivers the maximum intensity in M2, M3 and M4. Comparison of these findings, the differential in pH values is included with the blended SCC mixture, where the pH value has been decreased in the percentage of 25 % of Flyash and 15 % of GGBFS, although the mix ratio of 25 % of GGBFS and 10 % of Silica Fume has increased dramatically and 3 % has been decreased over the combination of 25 % Flyash and 15 % Silica Fume. The resultant absorption in the sorptivity test is significantly greater in M11 with 65 percent OPC+20 percent FA +15 percent SF with 0.0103 mm/s 0.5 compared to the mixing proportions of M2,M6 and M10 compared to the mixing proportions of M2,M6 and M10. This indicates that even more absorption is transferred by the combination of Flyash and Silica Fume comparable to GGBFS. Within that combination M2 with 65 percent OPC+25 percent FA+15 percent GGBFS compared to M6, M10 and M11 mix proportions, acid resistance is much lower, suggesting that the aggressive acid ambient environment was associated with 5 percent sulfuric acid (H2SO4) which is much more resistant to GGBFS blends. It is observed that there is a gradual increase in mass loss between 7 days to 28 days ranging from M2 to M13 blends, implying that the mass loss significantly increased by 60% of its weight continuously with air curing period caused by the absorption of water from concrete consisting of all blended supplementary cement materials.

7. Discussions
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