Studies on strength parameters of blended self cured concrete with natural and manufactured sand on the impact of fly ash and ground granulated blast furnace slag

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Abstract. Construction companies now use manufactured sand instead of natural river sand in concrete for a day, where the exploration limitation applies to river sand along with the implementation rule. Water, meanwhile, is also the most prevalent aspect of the concrete manufacturing curing process, and it is now scarce for a few days due to a greater rise in human population growth. In contrast to the traditional curing process, self-curing concrete minimizes the use of potable water. In addition to chemical admixture with the mixture, this paper deals with the various studies of fresh and hardened concrete specimens and findings with the self-curing agent mixed with PEG 400 with Fly Ash and GGBFS in different proportions. The results for the various combinations of blended proportions are correlated with the substitution of manufactured sand (M-Sand) with river sand with both ordinary self-curing concrete and mixed self-curing concrete with M30 grade. Attempts have been made to study the properties of blended self-curing concrete with Manufactured Sand.

1. Introduction

Because of the high compressive strength of the most used building material in the world of hard concrete. To gain greater durability, conditional curing needs to be achieved one day after fresh concrete. Hydration of cement occurs after levelling the concrete in a specified position. Internal concrete curing decreases the demand for water than traditional curing. In addition to compaction, the curing process plays a major role in achieving improved strength, durability, water tightness, abrasion resistance, volume stability and thawing resistance. Curing is a very important component that remains important for the hydration process, especially in the early ages of concrete strength. Though, acceptable curing is not continuously probable by conventional curing methods and it is suggested to make the entrenched water available for curing to overcome this problem.

To minimize water evaporation from the concrete surface and thereby increase the water retaining ability of the concrete relative to traditional concrete, self-curing agents should be added. This problem also is not solved by conventional curing methods, but internal curing involving materials such as hydrophilic compounds, lightweight aggregates (LWA) and super-absorbent polymers (SAPs) contributes to specific concretes with superior performance (Zhutovsky et al., 2002). Practically good curing is not possible in many cases due to practical difficulties. There the benefit of self-curing admixture is more significant.

The process of self-curing agents relates to the atmospheric state of surface moisture. The hydrogen bond between polymerized fresh concrete water molecules decreases the evaporation of surface water as time contributes to concrete reinforcement. In case chemical admixture does not react
readily with cement paste, causes the concrete to shrink with open pores and cracks at early ages in chemical shrinkage. After the potable water, which is not recurrently available, substantial autogenous deformation and early-age cracking may result due to hydration and other processes. Empty pores are formed within in the cement paste due to its chemical shrinkage hitting during cement hydration, prominent to a reduction in its internal relative humidity and shrinkage influencing the cracking of the early age. For this purpose, the significance of self-curing agents is largely effective in reducing the water content in concrete as well as internal curing is also possible.

Internal curing (IC) is a way of providing the water to hydrate all the cement, achieving what the mixing water by itself does not do. Internal curing provides water to maintain higher relative humidity and prevent the occurrence of self-desiccation. It also eliminates autogenous shrinkage and retains mortar/concrete early age strengths, i.e. from 12 to 72 hours above the level, where cracking can be generated by internal & externally induced strains. The main extent of the paper is experimentally to examine the effect of polyethylene glycol (PEG 400) on strength characteristics of Self-curing concrete.

The purpose of the experimental study was to understand the strength characteristics of internal cured concrete and to acquire the optimal percentage of compounds which are self-curing. Also, the durability properties of hardened concrete should be studied. Despite improved knowledge of concrete curing methods, research reports suggest that even the most essential curing requirements in practical engineering are not met or are completely ignored. Attempts have thus been made to facilitate internal curing in concrete through the addition of self-curing admixtures, which may produce concretes that are equal or superior to traditional forms of curing.

The aim of this research is to vary the mechanical characteristics of concrete such as compressive strength, split tensile strength and rupture modulus by varying the % PEG proportion by cement weight for both ordinary self-curing and blended self-curing concrete with partial replacement of M Sand in Fine Aggregate for grade concrete M30.

2. Materials
All the constituents of concrete making materials are properly tested under laboratory condition. The materials are listed as follows.

Polyethylene Glycol is an ethylene oxide group, general formula H(OCH2CH2)nOH. Where n represents the average number molecular weight in ethylene oxide group ranges from 400 to 4000. PEG is non-toxic, odourless, lubricating, neutral pH value & non-irritating and used in many medical applications. Jagannadha Kumar et al. studied the impact of admixture (PEG 400) on compressive, split tensile strength and modulus of rupture by differing the proportion of Polyethylene Glycol 400 by weight of cement varies from 0% to 2% for M20 and M40 mixes. It was found that 1% of PEG 400 by weight of cement was optimum for M20, while 0.5 % for M40 grade concrete for achieving maximum strength without compromising workability. Joseph et al., experimented on self-cured concrete with PEG400 for M20 grade of concrete also suggested 1% of PEG400 by weight of cement gives optimum strength for M20 grade of concrete and gets increased the workability. Shikha Tyagi et al., made M25 and M40 grade of concrete and found the optimum dosage of PEG-400 to be 1% for M25 and 0.5% for M40 grades of concrete.

As per previous investigations, it is founded that, Polyethylene Glycol (PEG) is widely used self-curing compound, which is taken to be chemical admixture in this experimental work having molecular weight as 400, pH value as 6.5 and specific gravity of PEG 400 as 1.12 respectively.

To conform with the IS 1489-1991 standard, ordinary Portland (OPC 53) cement and a specific gravity of 3.05 were used. With sieve analysis, locally available aggregates of sizes from 4.75mm and 20.0mm were used. Relevant gravity, water absorption and fineness modulus are measured according to IS: 383-1970, 2.74, 0.25 % and 3.05 respectively.

The manufactured sand (M-Sand) used in this experimental work conforms to the 4.75 mm sieve passage. The other properties were also been checked and it is having the specific gravity as 2.6, Water Absorption as 1.3% and fineness modulus as 3.10, respectively. Normally employed quality drinking water conforming to IS:456-2000. In this study, it was acquired from the National Thermal Power Plant, Dadri, where fly ash Class F was used. The characteristics of this fly ash are light grey
and the specific gravity ranges from 1.90-2.55 if the uniformity is 3.1-10.7. Apart from diminished permeability, GGBFS blended concrete is considerably more resistant to the ingress of chloride ions through concrete.

In Jindal South West Steel Ltd, Karnataka, GGBFS was acquired predominantly with SiO2 at 35.20 percent, Al2O3 at 19 percent and CaO at 34.90 percent. GGBFS is also an aluminosilicate with major components such as SiO2, Al2O3, CaO, and MgO, and it has been discovered that the incorporation of GGBFS develop workability and prolonged compressive strength. The integration of Flyash and granulated blast furnace slag was found to deliver lower early age strength to coral aggregate-concrete although superior late age strength due to late production of the pozzolanic reaction. As a super plasticizer, a polycarboxylate-type, new-generation high-range water reducing admixture confirming ASTM C494 was used to enhance the flow or workability of blends with a decreased water-cement ratio.

### Table 1. Chemical Composition of Class F Fly Ash

| Chemical properties | SiO2  | Al2O3 | Fe2O3 | CaO   | MgO   | Na2O  | K2O   | SO3   | Loss of Ignition | Cl |
|---------------------|-------|-------|-------|-------|-------|-------|-------|-------|------------------|----|
| Compounds %         | 45.98 | 23.55 | 4.91  | 18.67 | 1.54  | 0.24  | 1.80  | 1.47  | 2.31             | 0.0053 |

3. Mix Proportioning of M30 Mix

The mix proportioning was based on the Indian Code for Mix design approach (IS 10262: 2019 for mixing concrete M30 of binary and ternary mixed concretes rendered with optimum mixtures of Fly ash (FA) and Ground Granulated Blast furnace Slag (GGBFS). The proportioning of a blend was made with reference of the Indian Code for Design Mix (IS 10262: 2019 for blending M30 concrete of binary and ternary combined concretes with optimal mixtures of Fly ash (FA) and Ground Granulated Blast Furnace Slag (GGBS). From the above literatures and investigations, Slump Cone test was conducted for Workability and variation in dosage of 0.5%, 1% and 1.5% , was taken for both the natural sand and Manufactured sand as shown in Table 2.

### Table 1. Proportions of Self Cured Concrete with M30 grade mix

| Material                  | Quantity (kg/m³) |
|---------------------------|------------------|
| Cement                    | 350              |
| Fine aggregate (River Sand)| 744.25           |
| Fine aggregate (M Sand)   | 744.25           |
| Coarse aggregate (Angular)| 1314.18          |
| Poly Ethylene Glycol (PEG 400) | 2.28         |
| Super Plasticizer         | 3.5              |
| Water                     | 175              |
| Water Binder ratio        | 0.4              |

As per IS 456-2000, clause 8.2.4.2, the maximum cement content is limited to 450 kilograms per cubic meter of concrete. Revised quantities in kg per cubic metre for grade (M30) mixed concrete mix are reached in subsequent trial mixes without compromising the necessary strength property. The estimated quantity of OPC is 350 kg and pozzolanic materials such as Flyash (FA) and Ground Granulated Blast Furnace Slag (GGBFS) have been segregated from the literature studies on different dosages formulated in Table 3.

Skump cone test was the common way of finding workability in both construction site and laboratory. In the desired design mix, as per code provision IS:1199-1959, the percentage of PEG 400 kept constant as 1 % for the slump value also increases consequentially in different replacements of Flyash and Ground Granulated Blast Slag with the blended mixing parameters of River sand and Manufactured Sand (M-Sand) as shown in Table 2.
Table 2. Slump values for various PEG 400 percentages for Natural & M-Sand

| Percentage of PEG | Slump in Natural Sand | Slump in Manufactured Rock fines |
|-------------------|------------------------|---------------------------------|
| 0.0%              | 74                     | 55                              |
| 0.5%              | 92                     | 78                              |
| 1.0%              | 112                    | 106                             |
| 1.5%              | 140                    | 130                             |

Table 3. Mix Proportion of M30 grade Blended mix for various percentages for Flyash & GGBFS

| Mix (%)   | Cement | Flyash | GGBFS | C.A | River Sand | M sand | S.P | Water |
|-----------|--------|--------|-------|-----|------------|--------|-----|-------|
| M1 (100)  | 350    | --     | --    | 744.255 | --         |
| M2 (65+25+15) | 87.5   | 35.0   | 744.255 | -- |
| M3 (65+15+25) | 35.0   | 87.5   | 744.255 | -- |
| M3 (65+25+15) | 87.5   | 35.0   | --    | 744.255 |
| M4 (65+15+25) | 35.0   | 87.5   | --    | 744.255 |
| M5 (65+20+15) | 70.0   | 52.5   | 744.255 | -- |
| M6 (65+15+20) | 52.5   | 70.0   | 744.255 | -- |
| M7 (65+20+15) | 70.0   | 52.5   | --    | 744.255 |
| M8 (65+15+20) | 52.5   | 70.0   | --    | 744.255 |
| M9 (65+10+25) | 87.5   | 35.0   | 744.255 | -- |
| M10 (65+25+10) | 87.5   | 35.0   | 744.255 | -- |
| M11 (65+10+25) | 87.5   | 35.0   | --    | 744.255 |
| M12 (60+20+20) | 35.0   | 87.5   | --    | 744.255 |
| M13 (60+20+20) | 70.0   | 70.0   | 744.255 | -- |
| M14 (70+10+20) | 70.0   | 70.0   | --    | 744.255 |
| M15 (70+20+10) | 35.0   | 70.0   | 744.255 | -- |
| M16 (70+10+20) | 70.0   | 35     | 744.255 | -- |
| M17 (70+20+10) | 35.0   | 70.0   | --    | 744.255 |
| M18 (70+20+10) | 70.0   | 35     | --    | 744.255 |

*All the materials proportioned in this table is having the unit of kg/m³*

**Slump values with different SCM’s on cement mixes between M1 to M13 only with incorporation of PEG 400 as 1.0%.

4. Mechanical Properties of Blended SCC mix with M-Sand replacements

The mixing both of materials were controlled for a period of two minutes throughout this blended mix of self-curing concrete associated with SCMs. 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 with Natural sand and M Sand replacement levels.

Numerous specimens were cast with accurate blending of Flyash and Ground Granulated Blast Furnace Slag 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.

Self Curing Concrete mixtures with their strength parameters blended with Supplementary Cementitious components in various proportions of different percentages of Class F Flyash and Ground Granulated Blast Furnace Slag of various mixed percentages of M1 (Conventional mix) and M2 to M18 has been tabularized in Table no.4. The cube and cylinder specimens are casts in
accordance to table 3 for 7 days and 28 days curing of conventional full curing and self-curing concrete specimens kept at shadow of temperature 300c ± 30c. The different curing was carried out till the respective concrete specimens were tested after 7 & 28 days for compressive and split tensile strength.

Table 3. Strength parameters of M30 grade Blended SCC for various ratios for Flyash & GGBFS

| Mix (%)   | Cement | Flyash | GGBFS | River Sand | M sand | Compressive Strength (MPa)  | Split Tensile Strength (MPa) |
|-----------|--------|--------|-------|------------|--------|-----------------------------|------------------------------|
|           |        |        |       |            |        | 7 Days | 28 Days | 7 Days | 28 Days |
| M1 (100)  | 350    | --     | --    | 744.255    | --     | 10.87  | 35.1    | 1.98   | 4.89   |
| M2 (60+25+15) | 87.5  | 35.0   | 744.255 | --         | 9.87   | 33.2   | 1.68    | 3.56   |
| M3 (60+15+25) | 35.0  | 87.5   | 744.255 | --         | 9.9    | 34.1   | 1.49    | 4.28   |
| M4 (60+25+15) | 87.5  | 35.0   | --     | 744.255    | 9.4    | 34.6   | 1.59    | 3.6    |
| M5 (60+15+25) | 35.0  | 87.5   | --     | 744.255    | 9.5    | 33.8   | 1.68    | 3.49   |
| M6 (65+20+15) | 70.0  | 52.5   | 744.255 | --         | 9.49   | 33.1   | 1.77    | 3.48   |
| M7 (65+15+20) | 227.5 | 52.5   | 70.0   | 744.255    | 9.66   | 33.5   | 1.89    | 4.26   |
| M8 (65+20+15) | 70.0  | 52.5   | --     | 744.255    | 9.4    | 32.8   | 2.1     | 4.15   |
| M9 (65+15+20) | 52.5  | 70.0   | --     | 744.255    | 8.98   | 33.41  | 2.01    | 3.75   |
| M10 (65+10+25) | 87.5  | 35.0   | 744.255 | --         | 8.69   | 32.1   | 1.98    | 4.21   |
| M11 (65+25+10) | 87.5  | 35.0   | 744.255 | --         | 8.48   | 32.14  | 2       | 4.1    |
| M12 (65+10+25) | 87.5  | 35.0   | --     | 744.255    | 8.36   | 31.21  | 2.12    | 3.99   |
| M13 (60+20+20) | 210.0 | 35.0   | 87.5   | --         | 744.255 | 8.29   | 32.12   | 1.89    | 3.87   |
| M14 (60+20+20) | 70.0  | 70.0   | 744.255 | --         | 9.3    | 33.21  | 1.87    | 3.86   |
| M15 (70+10+20) | 70.0  | 70.0   | --     | 744.255    | 9.12   | 31.4   | 1.78    | 3.73   |
| M16 (70+20+10) | 70.0  | 70.0   | --     | 744.255    | 9.14   | 32.6   | 1.65    | 4.25   |
| M17 (70+10+20) | 70.0  | 35.0   | 744.255 | --         | 8.96   | 33.2   | 1.88    | 3.65   |
| M18 (70+20+10) | 70.0  | 35.0   | --     | 744.255    | 8.88   | 34.1   | 2.16    | 4.01   |
| M19 (70+20+10) | 70.0  | 35.0   | --     | 744.255    | 9.15   | 33.6   | 2.01    | 3.77   |

Fig 1. Compressive Strength of M30 grade Blended SCC for various ratios for Flyash & GGBFS
5. Results and Discussions

The mechanical properties like workability, compressive strength, split tensile strength and acid resistance which been improved with binary and ternary blended with the Fly ash and GGBFS in the concrete mix of grade M30 with several mixes of River Sand and Manufactured Sand. After this percentage of replacement the mechanical properties decreased and very similar for Manufactured sand to the river sand. Therefore, an optimum value of 1% of Polyethylene glycol is considered and added to the mix.

For all replacements of Flyash and GGBFS when M-Sand was incorporated there was an increase in mechanical properties in the strength parameter in M4 (60% OPC +25% FA+15% GGBFS), M9 (65% OPC +15% FA+20% GGBFS) M13 (60% OPC +20% FA+20% GGBFS) and M18 (70% OPC +20% FA+10% GGBFS) provides very slight variation in the compressive strength. More over with the blended mix of 20% of Ground Granulated Blast Furnace Slag provides greater strength in all the mixes of Self Cured Concrete, which did not affects the other parameters of concrete strength. The mix of 15% to 20% of Class F Flyash with M-Sand achieved a maximum of 15% increase in compressive strength when compared to control concrete mix at the age of 28 days.

The split tensile strength of mix 10% Flyash and GGBFS with M-Sand was found to decrease to a maximum of 10% when compared to the control mix. While for the mixes M3 (60% OPC +25% FA+15% GGBFS), M7 (65% OPC +15% FA+20% GGBFS) M10 (60% OPC +20% FA+20% GGBFS) and M16 (70% OPC +20% FA+10% GGBFS) incorporating M-Sand varying with 15% to 25% of Flyash and 10% to 20% of the slight increase and decrease in split tensile strength at the age of 28 days was in the range of 8 to 15%.

In this experimental investigation, it is found that use of manufactured sand doesn’t really influence the compressive strength of concrete rather than river sand. Replacing cement with high volume fly ash enhances the compressive strength marginally by up to 10 percent, after which the rise in quantity of fly ash gradually decreases its compressive strength.

In the slump test, a workable slump of 112 mm for natural sand and 106 mm for Polyethylene Glycol 400 manufactured sand was obtained for a water-cement ratio of 0.45, which is taken in mixed design in accordance with IS 10262:2009. It is noted from the test result that the reduction in strength of concrete cubes is more due to the rise in the days of specimen immersed in chemicals, so that in the case of an acid resistance test, the reduction in compressive strength was maximum.

In the initial 7 days, there was a substantial loss of weight. After the percentage of weight loss has been steadily increased up to 28 days with a minimum percentage of weight loss at 3.5 kg/m3, it can therefore be concluded that M Sand can be used as an efficient 4 kg/m3 natural sand replacement in terms of strength, workability and durability properties.
6. Conclusions

As the percentage replacement of natural sand through manufactured sand is increased, it is observed that there is a decrease in workability properties. Characteristics for minimizing workability are the angular aggregate form and surface structure of processed sand, which imparts greater internal friction through reducing its flow properties of the concrete.

It is noted throughout this experiment conducted that use of the M sand instead of natural river sand doesn't really affect its concrete's strength development. Replacing cement for high volume fly ash up to 15 percent marginally raises the compressive strength, and the rise in fly ash quantity steadily reduces the compressive strength and also the split tensile strength. Whereas the blending of GGBFS provides the initial early strength and increased workability of M30 grade self cured mix with PEG 400 as 1% ranging percentage varies from 10 % to 20 % of blended mix.

The prospect of manufactured sand and cement substituting natural fine aggregate with industrial by-products such as fly ash, silica fume, metakaolin, etc. The GGBFS provides technological, environmental, and economic advantages that would be of great importance in the current development circumstance in the construction industry.

It concluded that high fines, compared to concrete made from natural sand, whereas the concrete had higher flexural strength, improved strength and ductility, and higher unit weight and lower permeability due to micro fines filling the pores. Compared to river sand, there is no significant difference in dry shrinkage in concrete made with manufactured sand.

7. References

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