Effect of self curing agent on mechanical properties of concrete with GGBS replacement

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Abstract

Concrete is the most preferable and widely used construction material in the infrastructure development. For concreting and curing huge amount of potable water is required and it is difficult to get this at all places and all times. One of the best alternative solution for this problem is using the self curing concrete. In this experimental study the mechanical properties of hardened concrete by partial replacement of cement by 0, 40 an 60% of GGBS for M20 and M35 grades of concrete using 0.5 and 1 percent of Poly ethylene glycol as self curing agent. Cubes and cylinders are cast and tested at age of 7 and 28 days, for compressive strength and split tensile strength. The results of conventional concrete are compared with the results of concrete with GGBS and Polyethylene glycol 400 for both grades of concrete. The test results have revealed that addition of 0.5% of self curing agent show higher strengths for 60% replacement of cement with GGBS while 1.0% of self curing agent showed good results for 40% replacement for M20 grade of concrete.

Key words: self curing concrete, self curing agent, polyethylene glycol 400, ground granulated blast furnace slag.

1. Introduction

The main ingredients of concrete are cementations material, fine aggregate, coarse aggregate and water. Curing is a crucial in the development of strength of concrete, hence proper curing is necessary to arrive at the desired strength. It is not always possible to cure concrete properly because of non availability of required suitable water for construction.[1]. The researchers are looking to get alternative solution for curing of concrete. Curing concrete entails retaining a sufficient amount of water or moisture content in order to produce desirable properties. The aim of using self curing agent is to maintain the presence of required water for hydration of concrete from the freshly placed concrete's surface, which is needed for developing the strength to the concrete.

Concrete's strength is based on the properties of its constituents, mix proportions, and hydration level. Sufficient quantity and quality of water is needed for complete hydration of cement in concrete[2], [3]. The amount of water in concrete is adequate for hydration, but when mineral admixtures in cement fully react in wet concrete mix, the demand for curing water increases, and empty pores form due to chemical shrinkage during cement hydration. This causes a decrease in internal humidity inside the concrete, as well as the formation of shrinkage cracks at early age [4]–[6]. Curing entails not just the application of water, but also the establishment of a climate condition for continuous process of hydration.

There are two types of curing of concrete namely, external curing and internal curing. Wetting of the freshly placed concrete's surface with water is method of external curing, which can be done by pouring water on surface of the concrete, spraying of water on the surface, or covering with a wet gunny bags. Whereas in the internal curing, the concrete cures itself by retaining water or moisture present in it. The use of a self-curing agent is critical in considering the fact that water supplies are becoming increasingly valuable as the shortage of suitable water is growing day by day[7]. In self-curing or internal curing of concrete the hydration process continued due to the presence of moisture present in concrete.

Internal curing, often known as self-curing, is the alternative method for curing of concrete that cures itself by maintaining moisture. There are different methods that can be used for internal concrete curing. Physical or
chemical factors that may lead to the continuous presence of moisture. That may be due to chemically bound water like crystalline water in ettringite, physically held water like water in super absorbent polymer, physically absorbed water like capillary water in fine pores and unbound water in the form of encapsulated water\[8\]. Continuous evaporation of moisture occurs from the exterior surface of concrete due to the chemical potential differential between the vapor and liquid phases. The polymers added to the concrete mix primarily form hydrogen bonds with water molecules, decreasing the chemical potential of the molecules, decreasing the vapor pressure, and thereby slowing evaporation from the surface\[9\]–\[11\].

GGBS, or ground granulated blast furnace slag, is a byproduct in the production of iron or steel. The key components of ground granulated blast furnace slag are calcium silicates and alumina silicates. Ground slag in the presence of water and activators, which are commonly sulphates and / alkalies that are supplied by cement in ordinary Portland cement, and hydrates and sets in a manner similar to Portland cement\[12\], \[13\]. Since the GGBS reaction is both hydraulic and pozzolanic, it often outperforms fly ash blended concrete in terms of long-term strength, sulphate resistance, and durability. Because of the particle shape and increased hydration, GGBS concrete has greater particle packing. The permitted replacement ratio of GGBS in concrete is 25-70 percent, depending on the application. Since the specific gravity of GGBS is closer to that of cement than fly ash based concrete, the density and volume of GGBS based concrete do not differ significantly from normal concrete. As a result, higher substitution of OPC with GGBS is possible\[14\]–\[16\].

2. Literature review

Bala Subramanian et al. \[17\] experimented regarding the development of high strength self curing concrete using super absorbent polymer as self curing agent. Polyethylene glycol 400 is used as self curing agent at different proportions (0.2, 0.3 and 0.4)% by weight of cement and cement. To attain high strength silica fume is used as cement replacement with varying percentages as 5%, 10% and 15% by weight of cement. It is concluded that the use of self curing agent has improved the workability of the concrete mix. The strength of concrete has increased with the increase in the percentage of self curing agent. 0.4% of polyethylene glycol 400 gave more strength than 0.2% and 0.3%.

Gopala krishna sastry et al. \[11\] carried out various experiments for M20 grade of concrete on mechanical properties by using polyethylene glycol 4000(PEG 4000), polyethylene glycol 6000(PEG 6000), polyvinyl alcohol(PVA) and super absorbent polymers(SAP) as self curing agents. Different proportions of self curing agent is added and the results were compared. PEG 4000 and PEG 6000 were added in proportions of 0.5%, 1.0%, 1.5% and 2.0% by weight of cement. PVA and SAP were added in proportions of 0.25%, 0.5%, 0.75% and 1.0% by weight of cement. Maximum compressive strength was obtained when 1.5% of PEG 4000 was used whereas maximum split tensile strength and flexural strength was obtained when 1.0% of PEG 6000 was used.

A.S. El-Dieb \[18\] investigated the water retention for concrete mixes where polyethylene glycol is used as self curing agent. Self dessication is less for self curing concrete when compared with conventional concrete. Self curing concrete has good hydration and the water transportation through self curing concrete is less than water cured concrete. The water sorptivity and permeability has decreased with the increase in the age of concrete.

Alaa A Bashandy \[19\] has investigated the effect of polyethylene glycol is studied when the concrete is subjected to elevated temperatures. In this the combined effect of temperature and heating time are considered and the strength of the concrete is determined. The casted specimens are heated at 200°C, 400°C and 600°C for 2hours and 4hours and they are air and water cooled. The residual splitting strength always reduced when compared with compressive strength. Water cooling is good for self curing concrete till 400°C up to 2hr but when temperature is increased to 600°C or heating time is increased then air curing gave good results.

3. Materials and mix proportions
3.1. Materials

Cement: In this study, OPC of 53 grade is used with specific gravity of 3.15.

GGBS: GGBS is a mineral admixture that is added in concrete as partial replacement of cement in this study with specific gravity of 2.81.

Water: In the present investigation fresh and clean potable water with pH is used.

Super plasticizer: Super plasticizer of hi-bond with specific gravity of 1.121 is used.

Fine aggregate: Locally available river sand passing 4.75mm sieve and retained 150 micron sieve of zone II as for specifications of IS 383 with specific gravity 2.65 is used.

Coarse aggregate: Locally available blue granite angular metal passing through 20 mm sieve and retained on 12.5 mm sieve and passing through 12.5 mm sieve and retained on 4.75 mm sieve with specific gravity 2.71 is used.

Self curing agent: Polyethylene glycol 400 is 0.5% and 1.0% by weight of cement is used as self curing agent.

| Table1: Properties of polyethylene glycol 400 |
|-----------------------------------------------|
| Form-wet | Transparent gel |
| Specific gravity | 1.125 |
| Molecular weight | 380-420 g/mol |
| Density | 1.13 /cm³ |

3.2. Mix Proportions

The mix proportions are finalized after several trials as per guide lines of IS 10262:2019 for the two different grades of concrete M20 and M35 (normal and standard concrete). Poly ethylene glycol 400 of 0.5% and 1.0% by weight of cement is used as self curing agent for both grades of concrete. The mix proportions are shown in Table 2.

| Table 2: Details of mix proportions |
|-------------------------------------|
| Mix | W/C Ratio | Water Kg/m³ | Cement Kg/m³ | GGBS Kg/m³ | Coarse Aggregate (20mm) Kg/m³ | Coarse Aggregate (10mm) Kg/m³ | Sand Kg/m³ | Admixture Kg/m³ | Self curing agent Kg/m³ |
| CM1-M20 | 0.51 | 186 | 364.705 | - | 695.58 | 463.72 | 718.71 | - | - |
| M1 | 0.51 | 186 | 364.705 | - | 695.58 | 463.72 | 718.71 | - | 1.82 |
| M2 | 0.51 | 186 | 218.82 | 145.88 | 695.58 | 463.72 | 718.71 | - | 1.82 |
| M3 | 0.51 | 186 | 145.88 | 218.82 | 695.58 | 463.72 | 718.71 | - | 1.82 |
| M4 | 0.51 | 186 | 364.705 | - | 695.58 | 463.72 | 718.71 | - | 3.64 |
| M5 | 0.51 | 186 | 218.82 | 145.88 | 695.58 | 463.72 | 718.71 | - | 3.64 |
| M6 | 0.51 | 186 | 145.88 | 218.82 | 695.58 | 463.72 | 718.71 | - | 3.64 |
| CM2-M35 | 0.41 | 164.61 | 401.48 | - | 721.8 | 481.42 | 697.16 | 2 | - |
| M7 | 0.41 | 164.61 | 401.48 | - | 721.8 | 481.42 | 697.16 | 2 | 2 |
| M8 | 0.41 | 164.61 | 216 | 185.48 | 721.8 | 481.42 | 697.16 | 2 | 2 |
4. Experimental work

Cubes of 150 mm × 150 mm × 150 mm and cylinders of 150 mm diameter and 300 mm height are cast for determining the compressive strength and split tensile strength. A total of 12 different mixes were cast for both M20 and M35 grades of concrete in which two mixes are of control mixes for M20 and M35 grades. The casted specimens are kept aside for curing for 7 days and 28 days as shown in fig1. For the mixes where polyethylene glycol 400 is used as self curing agent, the specimens are kept aside and air cured at room temperature. Whereas for control mixes, the specimens are cured in water for 7 days and 28 days. After the desired age is completed the specimens are tested for compressive strength as per stipulations of IS 516 and split tensile strength as per IS 5816 at constant and uniform rate of loading without any shocks in the compression testing machine. The testing of specimens for compressive strength and split tension are shown in Fig.1 and 2 respectively. The obtained results are compared for conventional wet curing concrete mix, mix where self curing agent is used without any replacement of cement with GGBS and for mixes where cement is replaced with different percentages of GGBS.

5. Discussion of tests results

5.1. Compressive Strength

The compressive strength test was performed on cube specimens. A total of 12 different mix proportions are considered along with two control mixes for both M20 and M35 grades are considered. For every mix 6 cubes were casted in which 3 are tested at an age of 7 days and the other 3 are tested at an age of 28 days as shown in fig 2 and the results are tabulated in table 3. The test results showed an increase in strength for M20 grade of concrete for 1.0% of polyethylene glycol 400 used and 60% replacement of cement with GGBS.

| Mix | Polyethylene glycol | Compressive Strength | Split Tensile Strength |
|-----|---------------------|----------------------|------------------------|
| M9  | 0.41                | 164.61               | 185.48                 |
| M10 | 0.41                | 401.48               | 216                    |
| M11 | 0.41                | 164.61               | 216                    |
| M12 | 0.41                | 185.48               | 216                    |

Table 3: Results of compressive strength and split tensile strength for different mixes.

Fig 1: Testing of cube specimen for compressive strength
Table 3: Compressive strength test results

| Mix    | Compressive strength in Mpa |
|--------|-----------------------------|
|        | 7 days | 28 days |
| CM1-M20| 17.33  | 25.7    |
| M1     | 18.22  | 28.44   |
| M2     | 17.33  | 26.66   |
| M3     | 19.55  | 28.88   |
| M4     | 18.66  | 28      |
| M5     | 20     | 29.33   |
| M6     | 12.44  | 17.77   |
| CM2-M35| 26.22  | 39.14   |
| M7     | 28     | 41.77   |
| M8     | 19.55  | 37.33   |
| M9     | 17.77  | 32.44   |
| M10    | 23.11  | 38.22   |
| M11    | 18.22  | 33.33   |
| M12    | 15.11  | 31.11   |

Fig. 2: Compressive Strength for M20 grade of concrete

Fig. 3: Compressive Strength for M35 grade of concrete
5.2. Split tensile strength

Split tensile strength test is performed for cylinders of size 300mm height and 150mm diameter. The tests were performed at 7 days and 28 days as shown in Fig 3 and results are tabulated in Table 4. There is an increase of 36.77% for 0.5% self curing agent used for 60% replacement with GGBS and an increase of 45.8% for 1.0% of self curing agent used for 40% replacement of cement with GGBS.

Table 4: Split tensile strength test results

| Mix           | Split tensile strength in Mpa |
|---------------|------------------------------|
|               | 7 days | 28 days |
| CM1-M20       | 1.55   | 1.83   |
| M1            | 1.62   | 1.97   |
| M2            | 1.69   | 1.83   |
| M3            | 2.12   | 2.54   |
| M4            | 1.76   | 2.12   |
| M5            | 2.26   | 2.61   |
| M6            | 0.98   | 1.55   |
| CM2-M35       | 2.26   | 3.95   |
| M7            | 2.12   | 4.31   |
| M8            | 1.83   | 3.53   |
| M9            | 1.83   | 3.23   |
| M10           | 2.05   | 3.81   |
| M11           | 1.13   | 3.53   |
| M12           | 1.06   | 2.54   |

Fig. 4 split tensile strength testing for cylinder
Conclusions

From the test results of compressive strength and split tensile strength the following conclusions are drawn.

1. For both M20 and M35 grades of concrete, 40% replacement of cement with GGBS gave good strengths.
2. With use of 0.5% of self curing agent poly ethylene glycol 400 show higher strengths for 60% replacement of cement with GGBS while 1.0% of self curing agent showed good results for 40% replacement for M20 grade of concrete.
3. When compared with water curing of concrete, self curing concrete showed increase in strength at the same age of concrete for M20 grade of concrete.
4. For M20 grade concrete with 0.5% of polyethylene glycol 400 an increase of 10.66% of compressive strength and for 1.0% of self curing agent used an increase of 8.94% of compressive strength is observed when compared with wet cured concrete. Whereas for M35 grade there is an increase of 6.71% of compressive strength is observed when 0.5% of polyethylene glycol 400 is used.
5. There is an increase of 15.4% of compressive strength at age of 7 days and an increase of 14.12% of compressive strength at age of 28 days is observed for 40% replacement of cement with GGBS when 1.0% of polyethylene glycol 400 is used.
6. For split tensile strength there is an increase of 38.79% when 0.5% self curing agent is used for 60% replacement of cement with GGBS and an increase of 42.6% for 1.0% of self curing agent used for 40% replacement of cement with GGBS is observed for M20 grade of concrete.

Finally it is concluded that both compressive strength and split tensile strength are significantly increased for M20 grade of concrete at an age of 28 days with 40% replacement of cement with GGBS.

7. REFERENCES

[1] I. Version and S. Evangeline, “Self Curing Concrete and Its Inherent properties,” vol. 4, no. 8, pp. 66–71, 2014.

[2] M. M. Kumar and D. Maruthachalam, “Experimental Investigation on Self-curing Concrete Properties of Super Absorbent Polymer,” Int. J. Adv. Sci. Tech. Res., vol. 2, no. 3, pp. 300–306, 2013.

[3] M. I. Mousa, M. G. Mahdy, A. H. Abdel-reheem, and A. Z. Yehia, “Mechanical properties of self-curing concrete (SCUC),” pp. 311–320, 2015.

[4] Z. Jiang, X. Guo, W. Li, and Q. Chen, “Self-Shrinkage Behaviors of Waste Paper Fiber Reinforced Cement Paste considering Its Self-Curing Effect at Early-Ages,” Int. J. Polym. Sci., vol. 2016, 2016, doi: 10.1155/2016/8690967.

[5] L. Barcelo, M. Moranville, and B. Clavaud, “Autogenous shrinkage of concrete: A balance between autogenous swelling and self-desiccation,” Cem. Concr. Res., vol. 35, no. 1, pp. 177–183, 2005, doi: 10.1016/j.cemconres.2004.05.050.

[6] B. Persson, “Self-desiccation and its importance in concrete technology,” Mater. Struct. Constr., vol. 30, no. 5, pp. 293–305, 1997, doi: 10.1007/bf02486354.

[7] P. M. Dahyabhai and J. R. Pitroda, “Introducing the Self-Curing Concrete in Construction Industry,” vol. 3, no. 3, pp. 1286–1289, 2014.

[8] O. Mejlhede and J. Æ. Pietro, “Techniques and materials for internal water curing of concrete,” pp. 817–825, 2006, doi: 10.1617/s11527-006-9136-6.

[9] D. Joseph, “Effect of Self Curing Agents on Mechanical Properties of Concrete,” vol. 5, no. 09, pp. 46–49, 2016.

[10] M. V. J. Kumar, M. V. J. Kumar, M. Srikanth, and K. J. Rao, “STRENGTH CHARACTERISTICS OF SELF-CURING CONCRETE,” pp. 51–57, 2012.

[11] A. Adamtsevich and L. Shilova, “Self-curing concrete with different self-curing agents Self-curing concrete with different self-curing agents,” 2018, doi: 10.1088/1757-899X/330/1/012120.

[12] P. Brightson, M. Premanand, and M. S. Ravikumar, “Flexural behavior of beams incorporating GGBS as partial replacement of fine aggregate in concrete,” Adv. Mater. Res., vol. 984–985, pp. 698–706, 2014, doi: 10.4028/www.scientific.net/AMR.984-985.698.

[13] P. Ganesh and A. Ramachandra Murthy, “Fatigue performance of damaged RC beams rehabilitated with GGBS based ultra high performance concrete,” Int. J. Fatigue, vol. 138, no. April, p. 105707, 2020, doi: 10.1016/j.ijfatigue.2020.105707.

[14] M. G. S. A. Ligoria, “Flexural behaviour of cold - formed steel beams filled with GGBS concrete and wrapped with GFRP,” Asian J. Civ. Eng., no. 2012, 2018, doi: 10.1007/s42107-018-00105-x.

[15] S. E. E. Profile, “Flexural Behavior of Geopolymer Concrete Beams with GGBS Flexural Behavior of Geopolymer Concrete Beams with GGBS Flexural Behavior of Geopolymer Concrete Beams with GGBS,”
[16] S. P. Sangeetha and P. S. Joanna, “Open Access Flexural Behaviour of Reinforced Concrete Beams with Partial Replacement of GGBS,” no. 01, pp. 119–127, 2014.

[17] B. K. Subramanian, A. Siva, S. Swaminath, and A. M. G. Ajin, “Development of High Strength Self Curing Concrete Using Super Absorbing Polymer Development of High Strength Self Curing Concrete Using Super Absorbing Polymer,” Int. J. Civil, Environ. Constr. Archit. Eng., vol. 9, no. 12, pp. 1536–1541, 2016.

[18] A. S. El-Dieb, “Self-curing concrete: Water retention, hydration and moisture transport,” Constr. Build. Mater., vol. 21, no. 6, pp. 1282–1287, 2007, doi: 10.1016/j.conbuildmat.2006.02.007.

[19] A. A. Bashandy, “Performance of self-curing concrete at elevated temperatures,” Indian J. Eng. Mater. Sci., vol. 22, no. 1, pp. 93–104, 2015.