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# AN EXPERIMENTAL INVESTIGATION ON COMPRESSIVE STRENGTH OF HVGGBFS CONCRETE CURED WITH DIFFERENT CURING TECHNIQUES

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## ABSTRACT
Improvement in construction and chemical industry have covered an approach for development of new curing techniques. Significant amount of research has been conducted to evaluate curing effectiveness and its effect on various concrete properties. This paper synthesizes outcome from experimental investigation carried out as per IS: 10262-2009 standards to evaluate the compressive strength of high volume ground granulated blast furnace slab (HVGGBFS) concrete made by replacing cement by 0%, 50% and 60% GGBFS at various curing techniques. The curing techniques adopted for the present experimental work are water curing, steam curing, steam curing with high pressure, compound curing, lime water curing and curing by super absorbent polymers (SAP). Finally comparing the results of compressive strength of different curing techniques. An effort has been made here to understand the compressive strength property of HVGGBFS concrete for different curing methods adopted and are compared with conventional water curing method. Results indicates that, HVGGBFS concrete cured by using lime water curing technique gives more compressive strength compared to conventional water curing technique.

**KEYWORDS**: HVGGBFS, Curing techniques, Compressive strength.

## I. INTRODUCTION
Curing is the name given to the procedures used for promoting the hydration of the cement and consists of a control of temperature and of moisture movement from and into the concrete. Curing allows continuous hydration of cement and consequently continuous gain in the strength, once curing stops strength gain of the concrete also stops. Proper moisture conditions are critical because the hydration of the cement virtually ceases when the relative humidity within the capillaries drops below 80% [1]. With insufficient water, the hydration will not proceed and the resulting concrete may not possess the desirable strength and impermeability. The continuous pore structure formed on the near surface may allow the ingress of deleterious agents and would cause various durability problems. Moreover, due to early drying of the concrete micro-cracks or shrinkage cracks would develop on surface of the concrete [2]. When concrete is exposed to the environment evaporation of water takes place and less of moisture will reduce the initial water cement ratio which will result in the incomplete hydration of the cement and hence lowering the quality of the concrete. Various factors such as wind velocity, relative humidity, atmospheric temperature, water cement ratio of the mix and type of the cement used in the mix will affect the curing of concrete. Evaporation in the initial stage leads to plastic shrinkage cracking and at the final stage of setting it leads to drying shrinkage cracking.

Curing temperature is one of the major factors that affect the strength development rate. At elevated temperature ordinary concrete losses its strength due to the formation of the cracks between two thermally incompatible ingredients, cement paste and aggregates. When concrete is cured at high temperature normally develops higher early strength than concrete produced and cured at lower temperature, but strength is generally lowered at 28 days and later stage [3].

Curing of the concrete is also governed by the moist curing period, longer the moist curing period higher the strength of the concrete assuming that the hydration of the cement particles will go on. American Concrete

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Institute (ACI) Committee 301 recommends a minimum curing period corresponding to concrete attaining 70% of the specified compressive strength [4].

Curing has a strong influence on the properties of hardened concrete; proper curing will increase the durability, strength, volume stability, abrasion resistance, impermeability and resistance to freezing and thawing.

## II. MATERIALS AND METHODS

### Materials

OPC 43 grade ACC cement and GGBFS obtained from Zindal steel plant, Ballary was used as binder material throughout the laboratory investigation program. The cement and GGBFS procured were tested for physical properties in accordance with IS: 8112-1989 [17] and are presented in table 1 and chemical properties of GGBFS are presented in table 2. Fine aggregate used were locally sourced natural river sand (Krishna river sand, Maharashtra, India), the physical properties are shown in table 3 is determined in accordance with IS: 383-1970 [18]. Coarse aggregate used were locally sourced quarry.

***Table 1. Physical properties of Ordinary Portland Cement and GGBFS***

| Property | Cement | GGBFS |
|---|---|---|
| Specific gravity | 3.15 | 2.95 |
| Normal consistency (%) | 28 | --- |
| Initial and final setting time (min) | 64 and 189 | --- |
| Fineness- Specific surface ($cm^2/gm$) | 2850 | 3500 |

***Table 2. Chemical composition of cement and GGBFS***

| Constitute | Cement | GGBFS |
|---|---|---|
| CaO | 64.64 | 37.34 |
| $Al_2O_3$ | 05.60 | 14.42 |
| $Fe_2O_3$ | 03.36 | 01.13 |
| $SiO_2$ | 21.28 | 37.73 |
| MgO | 02.06 | 08.71 |
| MnO | --- | 00.02 |
| Sulphide Sulphur | --- | 00.39 |
| Loss of ignition | 00.64 | 01.41 |
| Insoluble residue | --- | 01.59 |
| Glass content | --- | 92.00 |
| Sulphur Trioxide ($SO_3$) | 02.14 | --- |
| Nitrous Oxide ($N_2O$) | 00.00 | --- |
| Lime saturated factor | 00.92 | --- |

***Table 3. Physical properties of aggregate***

| Property | Fine aggregate | Coarse aggregate |
|---|---|---|
| Specific gravity | 2.70 | 2.68 |
| Silt content | 0.82 | Nil |
| Moisture content | Nil | Nil |
| Fineness modulus | 2.81 | 3.25 |

### Mix proportions and mixing methods

The M30 grade concrete mix design is done by using IS: 10262-2009. The cement is replaced by GGBFS by 0%, 50% and 60% by weight of cement. Water content for cement is that sufficient to obtained a slump of 100mm. Water binder ratio of 0.38 was selected for ascertaining strength properties of different curing methods. The 150mm size cubes were cured one day in the moulds, unmoulded and immersed in various curing techniques, until to get maximum compressive strength. Cubes were tested after curing. Curing by water curing, steam curing, steam curing with high pressure, compound curing, lime water curing and curing by super absorbent polymers was carried out.

**Test methods**

Fresh properties of the concrete mixes were investigated in term of slump, compacting factor and vee bee degree. From each batch of mix, a total of 18 numbers of 150 x 150 x 150 mm cubes were casted in accordance to the procedure in I.S.516: 1959 [13], total 54 cubes were casted during entire experiment process. Concrete mix were cured in the mould for 24 hours and after demoulding placed in various curing methods till age of test.

## III. RESULTS AND DISCUSSION

**Workability of concrete**

The workability of concrete with 0%, 50% and 60% of GGBFS is determined by slump test, compaction factor test and vee bee degree test. Table 4 shows the results of the workability tests of control and HVGGBFS concrete mixtures. Adding of GGBFS to concrete mixtures increases slump and compaction factor values but decreases the vee bee time.

***Table 4. Workability test results***

| Description of concrete | Slump (mm) | Compaction factor | VB degree (Sec) |
|---|---|---|---|
| Concrete with 0% replacement of cement by GGBFS | 95 | 0.85 | 9 |
| HVGGBFS concrete with 50% replacement of cement by GGBFS | 100 | 0.89 | 8 |
| HVGGBFS concrete with 60% replacement of cement by GGBFS | 100 | 0.90 | 7 |

**Compressive strength test**

Compressive strength test results for various curing techniques, a cube specimens of size 150 x 150 x 150 mm were casted using steel moulds for 0%, 50% and 60% replacement of OPC cement with GGBFS. The cubes were removed from the moulds 24 hours after they were cast. They were labeled appropriately with respect to the curing methods used and dates their compressive strengths were to be determined. Immediately after, the cubes were cured using the designated curing methods, and for the designated periods. Compressive strength at required periods were determined for each of the curing methods used. The average of three compressive strength results, for each curing period and for each of the curing methods, was determined. The average compressive strength for different curing techniques chosen for this study is given in table 5. Also the variation of compressive strength with respect to different curing techniques is shown in the figure 1.

From the table it is clear that, The average compressive strength of concrete at 28 days, in case of compound curing is minimum where as it is maximum for lime water curing technique. The percentage in the increase in the compressive strength at 0% replacement of cement to GGBFS (reference concrete) is found to be 15.77% in lime water curing and 5.69% in SAP curing techniques with respect to water curing technique.

The average compressive strength of concrete at 28 days, in case of compound curing is minimum where as it is maximum for lime water curing technique. The percentage in the increase in the compressive strength at 50% replacement of cement to GGBFS is found to be 21.42% in lime water curing and 9.63% in SAP curing techniques with respect to water curing technique.

Also the average compressive strength of 60% replacement of cement by GGBFS under the influence of same six types of curing techniques at 28 days, the results of compound curing is minimum where as it is maximum for lime water curing technique. The percentage of increase in the compressive strength at 60% replacement of GGBFS to cement is found to be 13.32% in lime water curing and 3.09% in SAP curing techniques with respect to water curing technique.

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***Table 5. Compressive strength test results***

| Description of curing | Compressive strength (MPa) for | | | | | |
|---|---|---|---|---|---|---|
| | Concrete with 0% replacement of cement by GGBFS (Reference concrete) | Percentage increase or decrease of compressive strength with respect to water curing technique | HVGGBFS concrete with 50% replacement of cement | Percentage increase or decrease of compressive strength with respect to water curing technique | HVGGBFS concrete with 60% replacement of cement | Percentage increase or decrease of compressive strength with respect to water curing technique |
| Water curing | 42.67 | ---- | 48.37 | ---- | 40.77 | ---- |
| Steam curing | 35.00 | -17.97 | 36.83 | -23.86 | 33.63 | -17.51 |
| Steam curing with high pressure | 40.50 | -5.08 | 42.12 | -12.92 | 37.93 | -6.96 |
| Compound curing | 32.23 | -24.47 | 35.17 | -27.29 | 31.70 | -22.25 |
| Lime water curing | 49.40 | +15.77 | 58.73 | +21.42 | 46.20 | +13.32 |
| SAP curing | 45.10 | +5.69 | 53.03 | +9.63 | 42.03 | +3.09 |

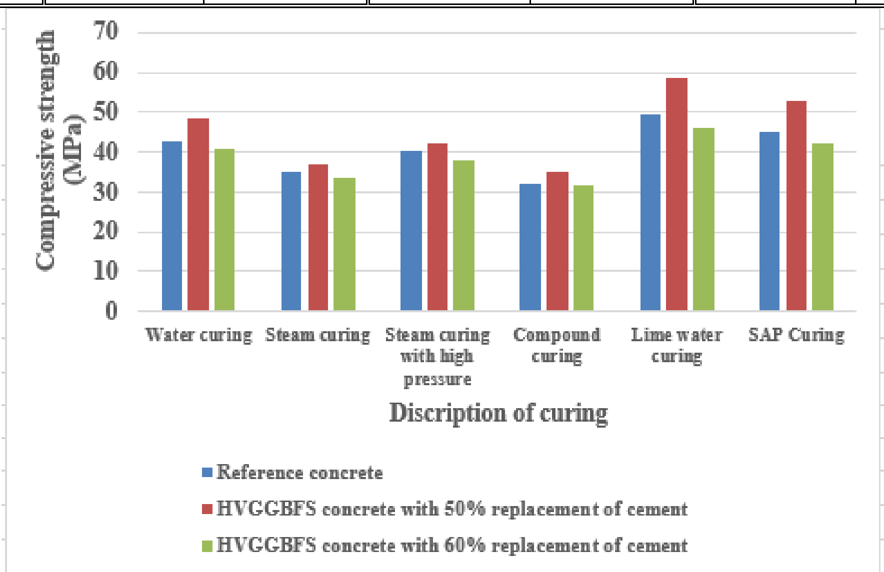


***Figure 1 Variation of compressive strength***

 

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## IV. CONCLUSION

The workability of concrete is measured from slump, compaction factor is increasing with increasing in GGBFS and vee bee time is decreasing as the proportion of replacement of GGBFS in place of cement increases.

Lime water curing method is a good alternative curing technique compared to water curing technique for HVGGBFS concrete and it gives 15.77%, 21.42% and 13.32% increased strength in order to 0%, 50% and 60% OPC cement with GGBFS compared to water curing method.

Curing by using SAP method is a another one alternative curing technique compared to water curing technique for HVGGBFS concrete and it produces 5.69%, 9.63% and 3.09% increased strength in order to 0%, 50% and 60% OPC cement with GGBFS compared to water curing method.

GGBFS is a good alternative for cement for M30 grade of concrete and it gives more strength in order of 13.36%, 5.23%, 4%, 9.12%, 18.88% and 17.58% increase for 50% replacement of cement by GGBFS in water curing, steam curing, steam curing with high pressure, compound curing, lime water curing and curing by SAP techniques.

Partial replacement of cement with GGBFS by 50% has given more compressive strength.

On replacement of cement by 50% GGBFS helps to reduce the cement content of concrete, thereby reducing the cost of concrete.

Reuse of the slag helps to protect the environment from pollution.

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