International Journal of Engineering Research And Advanced Technology (IJERAT)
DOI: http://dx.doi.org/10.7324/ IJERAT.3118
E-ISSN : 2454-6135
Vol.3 (8) Aug -2017

# Durability of Partially mixed GGBS concrete exposed to acid and base attack

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## ABSTRACT:
*This thesis investigates the effects of aggressive Hydrochloric acid attack and sodium sulfate attack on the concrete mixtures prepared by partial replacement of cement with* Ground granulated blast furnace slag *GGBS at 20%, 35% and 50% replacement levels. The Hydrochloric acid solutions and sodium sulfate solutions with concentrations of 3% were used for examining behaviour of concrete for a total exposure period of 3days, 7days and 28 days. The performance of the degraded specimens was evaluated by measuring change in compressive strenght, tensile strength, flexural strength and visual assessment. The mixtures with ternary binders of OPC and GGBS experienced the lowest strength loss after exposure to high concentrations of Hydrochloric acid attack and sodium sulfate attack.*

*Keywords:* Acid attack , Compressive strength , Ground granulated blast furnace slag *(GGBS),* Sulphate attack.

## I. INTRODUCTION
Concrete is probably the most extensively used construction material in the world with about six billion tones being produced every year. Concrete is the composition of many material such as aggregates, cement and water .In addition to this some pozzolonic material and admixtures are used to enhance the properties of concrete.

During the recent past , the problem of early deterioration of concrete structures has assumed serious proportion all over the world. In India also , this problem is being witnessed in the past few years , especially in coastal and industrial areas as well as in other aggressive environments. Durable concrete can be defined as one that is designed, constructed and maintained to perform satisfactorily in the expected environment for the specified designed life. Some of the significant factors that govern the strength and durability of concrete structures are mix design , structural design , reinforcement detailing , form work , concrete cover , quality of materials used , compaction , curing , and supervision . Inadequate attention to these factors and the presence of chlorides causes the corrosion of reinforcement ,moisture , carbonation , sulfate attack , alkali aggregate reaction leading to the deterioration of concrete structures.

### 1. 1. Acid Attack:

Acid attack involves conversion of calcium compound to calcium salts after attacking acid. The structure of the hardened concrete destroyed by acid attack, the rate of deterioration depends not only on the strength of the reactants but also upon the solubility of the resultant salts and their transport. The acids like sulfuric acid , hydrochloric acid , nitric acid etc…., destroy concrete by converting hardened concrete, and its pore system. Impermeability of concrete is of little consequence in this case. In this paper we used HCL for the curing of concrete for 7 and 28 days . It leads to loss in the mass of the concrete and strength of the concrete ,which leads to early deterioration of concrete structures.

### 1. 2.Sulphate Attack :

Sulphate attack is on only aluminate compounds, calcium and hydroxyl of hardened Portland cement forming ettringite and gypsum. In the presence of sufficient water, these reactions of delayed ettringite formation cause expansion of concrete leading to irregular cracking. The cracking of concrete provides further access to penetrating substances and to progressive deterioration. The effects of sulphate on concrete depend upon the severity of attack, accessibility (Permeability and Cracking), presence of water and susceptibility of cement- Concrete can be protected against sulphate attack by limiting the aluminates between 3 to 8%.

## 2. MATERIALS AND METHODS

### 2.1 Cement

Cement is universally accepted binding material which are used to bond aggregates together.
In this present work Ramco OPC 53g grade has been tested and used as per IS 4031:1988 and confirmed to IS 269-2015;

**Table 1 .physical properties of cement**

| | | | |
|---|---|---|---|
| 1. | Normal consistencyin (%) | 29 | - |
| 2. | Specific gravity | 3.11 | - |
| 3. | Initial setting time in min | 1.53 | Not less than 30 min |
| 4. | Final setting time in min | 2.77 | Not less than 600 min |

### 2.2Water

Water is the key ingredient, which when mixed with cement, forms a paste that binds the aggregates together. The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products.

### 2.3 Fine Aggregates

Fine aggregate Here manufactured sand has been used as fine aggregate and tested the same as per IS 2386- 1963. The results are tabulated in Table 2.

**Table 2. Physical properties of FA**

| | | |
|---|---|---|
| 1. | Specific gravity | 2.56 |
| 2. | Water absorption(%) | 3.8 |
| 3. | Zone | II |

### 2.4 Coarse Aggregate

In this investigation 20mm downsize of coarse aggregate were used and they were tested as per IS 2386-1963. The results are shown in Table 3

**Table 3. Physical properties of CA**

| | | |
|---|---|---|
| 1. | Specific gravity | 2.62 |
| 2. | Water absorption(%) | 0.7 |
| 3. | Impact value (%) | 18.46 |
| 4. | Crushing value (%) | 20.73 |
| 5. | Flakiness index (%) | 18.63 |
| 6. | Elongation index (%) | 19.48 |

### 2.5 Ground granulated blast furnace slag (GGBS )

The GGBS is a by-product in the manufacture of iron and the amounts of iron and slag obtained are of the same order. Iron ore, coke and limestone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about 1500°C to 1600°C. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then water-quenched rapidly, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size, which is known as GGBS. The GGBS required in this study obtained from Ispats steel plant Surat. The GGBS which is used passes, 90% through 90 micron sieve. The aim of this work is to ascertain the performance of concrete mix containing GGBS as replacement of OPC and to compare it with the plain concrete mix of M30 grades.

## 3. EXPERIMENTAL PROGRAMME

- Aquiring of materials ( cement , aggregates ,GGBS , admixtures ) for the project .
- After acquiring the required amount of materials ,the materials were tested foe their physical properties .
- Preparing mix design for the mix by replacing GGBS in different proportion .

a) Mix 1: 100% cement
b) Mix 2: 80% cement + 20% ggbs
c) Mix 3: 50% cement + 50% ggbs
d) Mix 4 : 65% cement + 35% ggbs

- The specimens are casted and cured for 3, 7 and 28 days .
- The specimens are kept in the 5% HCL and 5% Sodium sulpate solutions.
- The specimens are tested for strength values at 3 , 7 and 28 days comparison of the specimens with control sample.

**Mix Design of M30 grade concrete by using IS10262-2009 .**

**Table 4 : mix design of M30 grade concrete**

| Particulars | M30 100% | M30 80%+20% | M30 65%+35% | M 30 50%+50% |
|---|---|---|---|---|
| Cement(kg/m$^3$) | 340 | 300 | 265 | 220 |
| GGBS(kg/m$^3$) | - | 75 | 145 | 220 |
| Water(kg/m$^3$) | 152 | 152 | 152 | 152 |
| Fine aggregates(kg/m$^3$) | 813 | 799 | 784 | 720 |
| 20mm aggregates(kg/m$^3$) | 662 | 650 | 638 | 627 |
| 12.5mm aggregates(kg/m$^3$) | 441 | 434 | 425 | 418 |
| w/c ratio | 0.45 | 0.41 | 0.37 | 0.35 |
| Admixture in % | 0.40 | 0.40 | 0.45 | 0.45 |

### 3.1. Casting and testing of specimens:

Concrete cubes of size 150mm x 150mm x 150mm ; cylinder of size 150mm dia and 300mmlength and prism of size 100mm x 100mm x 500mm is casted and curried in normal water curing tank; 3% concentration hydrochloric acid curing tank and 3 % concentration sodium sulfate curing tank for a period of 3 days , 7days and 28 days; after respective days of curing compressive strength, tensile strength and flexural strength are carried out to the concrete specimens

## 4. RESULTS

### 4.1 Comparison of compressive strength of all four proportion under Normal curing

**Table 5 : Compressive strength comparison in normal curing.**

| Sl no | Age of curing | Compressive strength in N/mm2 | | | |
|---|---|---|---|---|---|
| | | 100% | 80%+20% | 65%+35% | 50%+50% |
| 1 | 3 days | 23.67 | 22.71 | 23.17 | 20.53 |
| 2 | 7 days | 31.23 | 29.08 | 32.31 | 29.32 |
| 3 | 28 days | 42.99 | 40.33 | 44.24 | 41.85 |

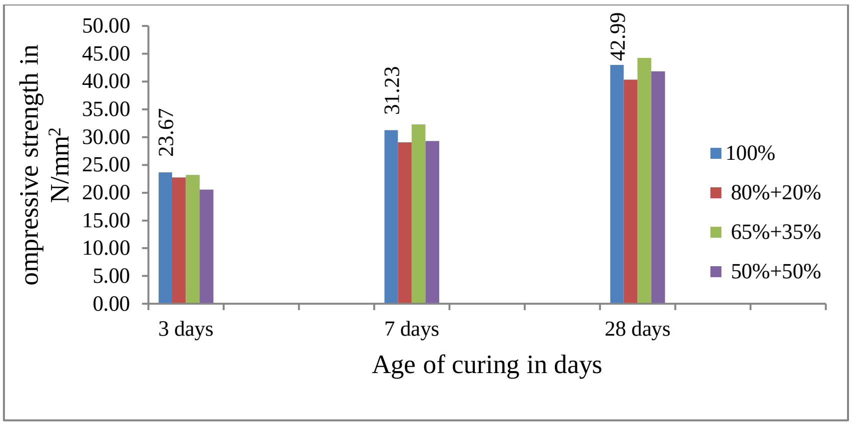


**Figure 1 : Compressive strength comparison in normal curing.**

The compressive strength of the concrete cubes under normal curing is maximum at 35% of replacement of cement with GGBS than the other proportions of mix. Hence , the mix (65%+35%) is better than other proportions.

**Comparison of compressive strength of all four proportion under Acid curing**

**Table 6 : Compressive strength comparison in Acid curing**

| Sl no | Age of curing | Compressive strength in N/mm2 | | | |
|---|---|---|---|---|---|
| | | 100% | 80%+20% | 65%+35% | 50%+50% |
| 1 | 3 days | 19.07 | 20.87 | 21.99 | 19.53 |
| 2 | 7 days | 23.50 | 24.61 | 26.52 | 23.78 |
| 3 | 28 days | 35.08 | 35.99 | 37.97 | 35.90 |

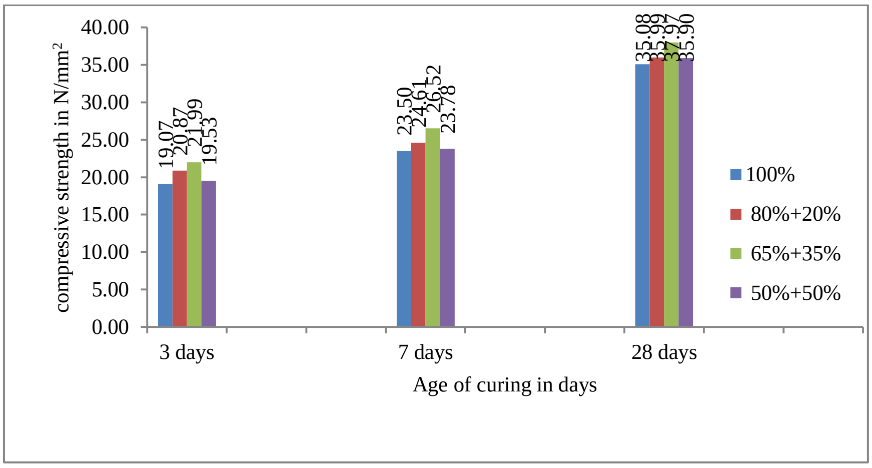


**Figure 2: Compressive strength comparison in Acid curing**

The compressive strength of the concrete cubes under acid curing is maximum at 35% of replacement of cement with GGBS than the other proportions of mix. Hence , the mix (65%+35%) is better than other proportions

**Comparison of compressive strength of all four proportion under Base curing**

**Table 7 : Compressive strength comparison in Base curing**

| Sl no | Age of curing | Compressive strength in N/mm2 | | | |
|---|---|---|---|---|---|
| | | 100% | 80%+20% | 65%+35% | 50%+50% |
| 1 | 3 days | 22.87 | 21.91 | 22.86 | 20.28 |
| 2 | 7 days | 26.95 | 27.45 | 28.86 | 27.29 |
| 3 | 28 days | 37.10 | 38.76 | 39.60 | 38.47 |

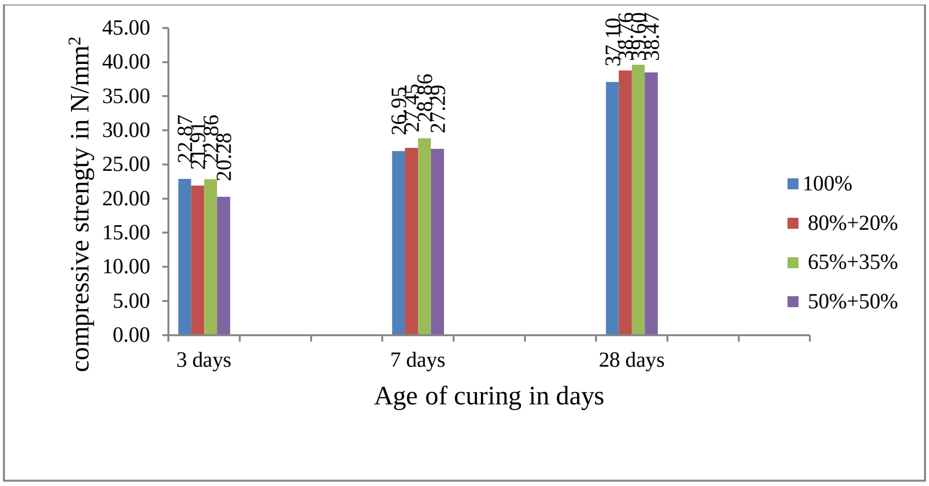


**Chart 3 : Compressive strength comparison in Acid curing**

The compressive strength of the concrete cubes under base curing is maximum at 35% of replacement of cement with GGBS than the other proportions of mix. Hence , the mix (65%+35%) is better than other proportions.

**B . Comparison of tensile strength of all four proportion under Normal curing**

**Table 8: Tensile strength comparison in normal curing**

| Sl no | Age of curing | Tensile strength in N/mm2 | | | |
|---|---|---|---|---|---|
| | | 100% | 80%+20% | 65%+35% | 50%+50% |
| 1 | 3 days | 1.76 | 1.68 | 1.52 | 1.21 |
| 2 | 7 days | 2.23 | 2.16 | 2.33 | 1.89 |
| 3 | 28 days | 2.77 | 2.89 | 3.09 | 2.65 |

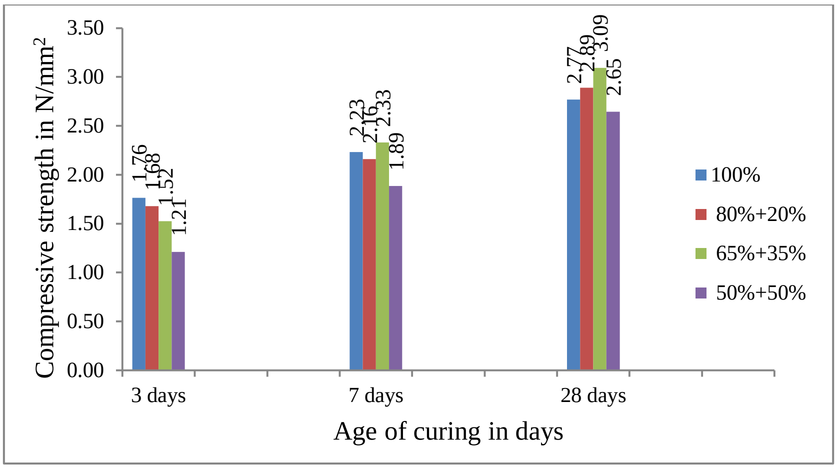


**Figure 4: Tensile strength comparison in normal curing**

The tensile strength of the concrete cubes under normal curing is maximum at 35% of replacement of cement with GGBS than the other proportions of mix. Hence , the mix (65%+35%) is better than other proportions.

**Comparison of tensile strength of all four proportion under Acid curing**

**Table 9: Tensile strength comparison in acid curing**

| Sl no | Age of curing | Tensile strength in N/mm2 | | | |
|---|---|---|---|---|---|
| | | 100% | 80%+20% | 65%+35% | 50%+50% |
| 1 | 3 days | 1.61 | 1.49 | 1.42 | 1.05 |
| 2 | 7 days | 2.04 | 1.96 | 2.09 | 1.71 |
| 3 | 28 days | 2.50 | 2.58 | 2.67 | 2.63 |

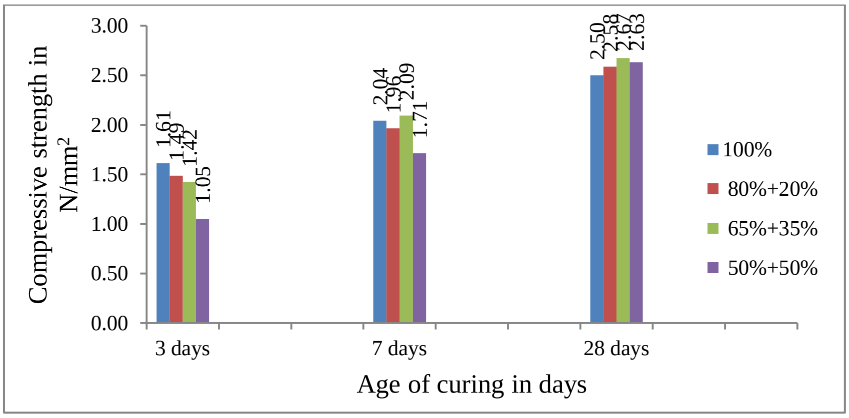


**Figure 5: Tensile strength comparison in acid curing**

The Tensile strength of the concrete cubes under acid curing is maximum at 35% of replacement of cement with GGBS than the other proportions of mix. Hence , the mix (65%+35%) is better than other proportions .

**Comparison of tensile strength of all four proportion under Base curing**

**Table 10: Tensile strength comparison in base curing**

| Sl no | Age of curing | Tensile strength in N/mm2 | | | |
|---|---|---|---|---|---|
| | | 100% | 80%+20% | 65%+35% | 50%+50% |
| 1 | 3 days | 1.73 | 1.57 | 1.56 | 1.07 |
| 2 | 7 days | 2.16 | 1.98 | 2.21 | 1.73 |
| 3 | 28 days | 2.69 | 2.70 | 2.91 | 2.67 |

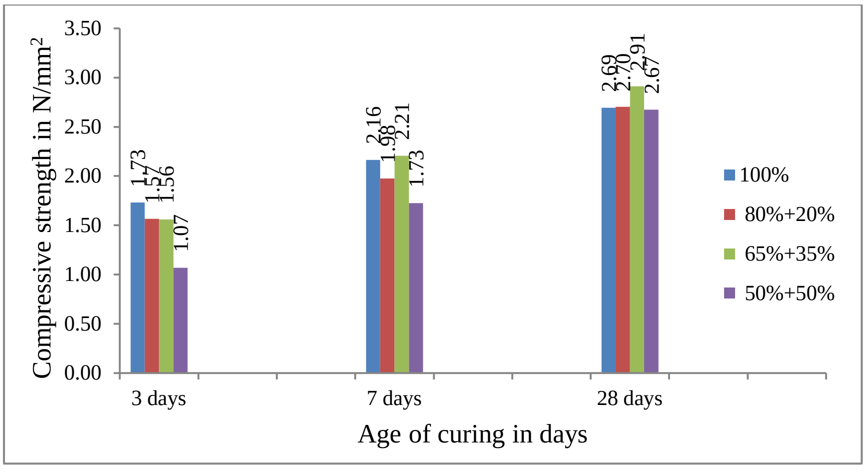


**Figure 6 5: Tensile strength comparison in acid curing**

The tensile strength of the concrete cubes under base curing is maximum at 35% of replacement of cement with GGBS than the other proportions of mix. Hence , the mix (65%+35%) is better than other proportions .

**C . Comparison of flexural strength of all four proportion under normal curing**

**Table 11: Flexural strength comparison in normal curing**

| Sl no | Age of curing | Flexural strength in N/mm2 | | | |
|---|---|---|---|---|---|
| | | 100% | 80%+20% | 65%+35% | 50%+50% |
| 1 | 3 days | 1.90 | 1.60 | 1.66 | 1.60 |
| 2 | 7 days | 3.20 | 2.37 | 2.49 | 2.43 |
| 3 | 28 days | 3.73 | 3.85 | 3.97 | 3.73 |

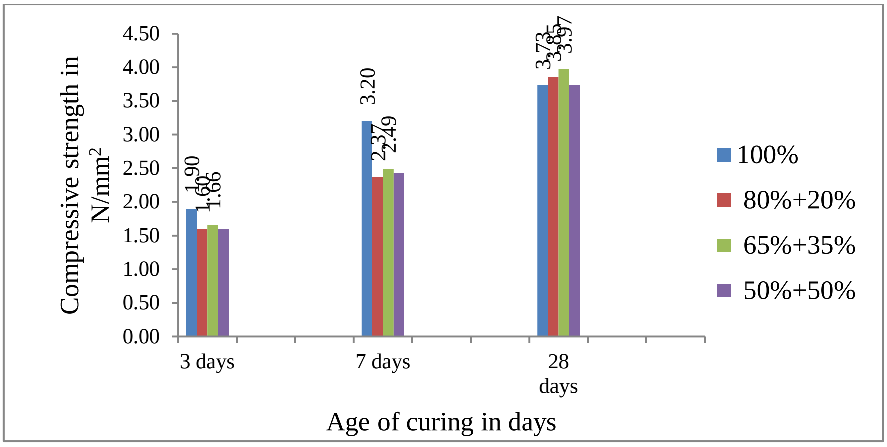


**Figure 7: Flexural strength comparison in normal curing**

The flexural strength of the concrete cubes under normal curing is maximum at 35% of replacement of cement with GGBS than the other proportions of mix. Hence , the mix (65%+35%) is better than other proportions .

**Comparison of flexural strength of all four proportion under base curing**

**Table 12: Flexural strength comparison in base curing**

| Sl no | Age of curing | Flexural strength in N/mm2 | | | |
|---|---|---|---|---|---|
| | | 100% | 80%+20% | 65%+35% | 50%+50% |
| 1 | 3 days | 1.72 | 1.48 | 1.72 | 1.13 |
| 2 | 7 days | 2.96 | 2.25 | 2.31 | 2.25 |
| 3 | 28 days | 3.32 | 3.50 | 3.85 | 3.14 |

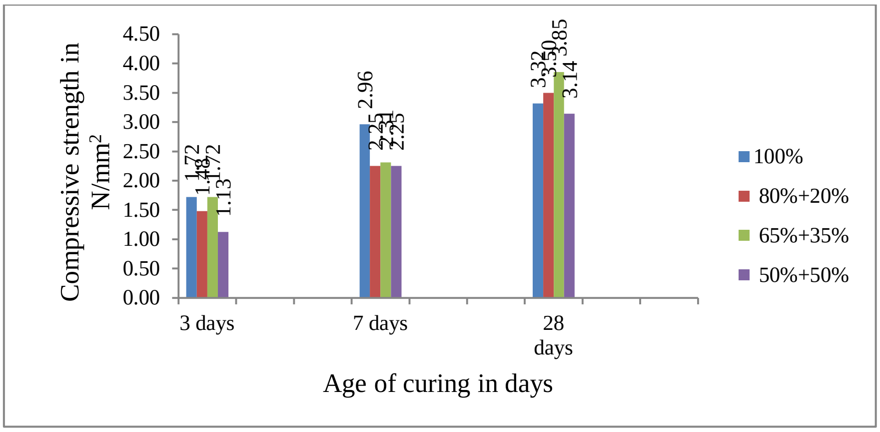


**Figure 8: Flexural strength comparison in base curing**

The flexural strength of the concrete cubes under base curing is maximum at 35% of replacement of cement with GGBS than the other proportions of mix. Hence , the mix (65%+35%) is better than other proportions

**Comparison of flexural strength of all four proportion under acid curing**

**Table 13: Flexural strength comparison in acid curing**

| Sl no | Age of curing | Flexural strength in N/mm2 | | | |
|---|---|---|---|---|---|
| | | 100% | 80%+20% | 65%+35% | 50%+50% |
| 1 | 3 days | 1.42 | 1.48 | 1.54 | 1.07 |
| 2 | 7 days | 2.31 | 2.07 | 2.25 | 2.02 |
| 3 | 28 days | 3.02 | 2.90 | 3.26 | 2.96 |

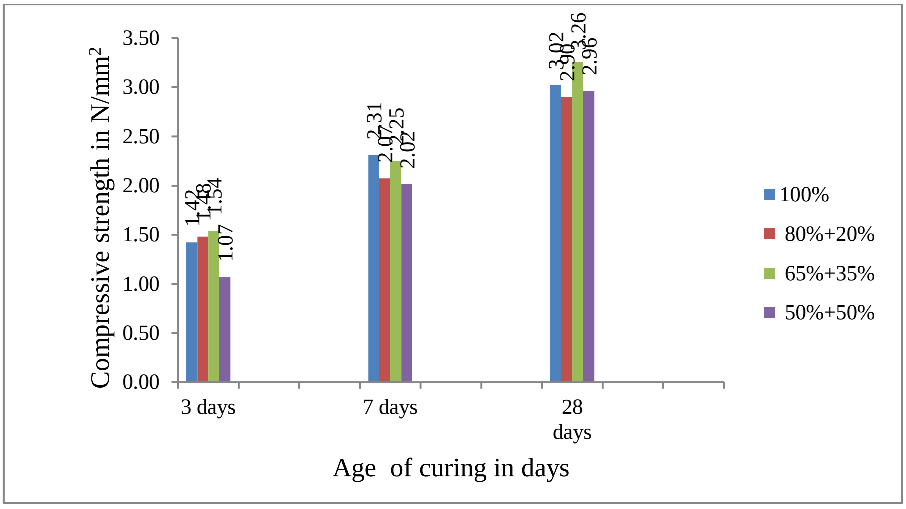


**Figure 9: Flexural strength comparison in acid curing**

The flexural strength of the concrete cubes under acid curing is maximum at 35% of replacement of cement with GGBS than the other proportions of mix. Hence , the mix (65%+35%) is better than other proportions .

## 5. CONCLUSION

In this paper, the concrete specimens are casted and curing is done in different methods like normal water curing, 3% concentration hydrochloric acid curing tank and 3 % concentration sodium sulfate curing tank.

i. In this paper, the cement is partially replaced by the Groung granulated blast furnace slag (GGBS) in 20% , 35% , and 50% .
ii. The replacement of cement by the GGBS reduces the quantity of cement and cost of the paper.
iii. After the casting of the specimens, the specimens were cured in different ways i.e.,Normal water curing ,acid curing (3% acid ) ,base curing ( 3% base ) at 3, 7 and 28 days.
iv. The compressive strength of concrete specimen under normal curing is more compared to cubes under acid curing and base curing.
v. The results of this paper shows that, when concrete is subjected to any acid and base, losses its some properties and strength.
vi. In both Acid and base curing maximum compressive, tensile and flexural strength has been obtained for replacement of cement by 35% GGBS.
vii. Hence , we can conclude that the cement can be replaced by 35% of the Ground granulated blast furnace slag (GGBS).

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