EXPERIMENTAL INVESTIGATION ON GEO-POLYMER CONCRETE BY USING STEEL SLAG AT HIGHER TEMPERATURE

J Sanghamitra¹*, P Ramakanta², B Sushree Ananya³

¹Assistant Professor, Department of Civil Engineering, VSSUT, Burla, 768018, Odisha, India
²Associate Professor, Department of Civil Engineering, VSSUT, Burla, 768018, Odisha, India
³M.Tech Dual Degree student, Department of Civil Engineering, VSSUT, Burla, 768018, Odisha, India,

Email: sanghamitrajena1987@gmail.com

Abstract. Concrete is the most durable, versatile and reliable construction material after water. Its requirement is very large so the need of ordinary portland cement is also high. Due to such large production of OPC our environment is getting polluted as carbon dioxide is emitted. Geo-polymer is the alternative to control the pollution and its an innovative construction material. It can be prepared by using fly ash, the secondary product of thermal coal and steel slag which is the by product of the production of steel in an electric arc. Another thing required to prepare the geopolymer concrete (GPC) is curing temperature. In this study mechanical properties of GPC is examined with curing temperature 70°C with a replacement of steel slag as coarse aggregate as 0%, 10%, 20%, 30% and 40%. Here the strength of GPC is increasing up to 30% replacement of steel slag as coarse aggregate.

Keywords: Geopolymer concrete, Compressive Strength, Rebound Number

1. Introduction

Green house gases are the main factor for the increasing global warming and also pollution of our environment. About 65% of global warming is due to emission of CO₂ which is also a green house gas. Our cement industry contributes round six percent of carbon dioxide emission to environment. The impact of cement industry has an adverse effect on the environment. In such situation it is necessary to think an alternative to traditional concrete and geo-polymer concrete is such an innovative way so that emission of CO₂ can be controlled. GPC can be prepared by mixing activated industrial waste materials like fly-ash, coal ash and alkaline solution. Fly ash (FA) is employed as binder and almost every research on GPC has concluded that ash is the appropriate alternative to traditional method. But the only difficulty to prepare the GPC is it requires external temperature for curing. The optimum temperature for thermal curing of FAbased GPC is oven curing at 75°C for 18-24 hr [1]. During preparation addition of water can improve workability around 200% and reduces the rest GPC properties up to 27% and optimum molarity of NaOH solution is 16M [2]. Here steel slag is used as aggregate i.e with partial replacement of coarse aggregate as 10, 20, 30 40%. The compressive strength of GPC with steel slag substitution was higher compared to GPC with gravel aggregate [3].

2. Experimental Procedure

2.1 Materials

Firstly the binder for GPC mixture is class F FA confirming to IS: 3812(2003) Part-I [4] which is main source of aluminosilicates. It contains CaO less than 10% and sourced from Hindalco Industries Ltd, Burla, Odisha. It has nearly 100% particles finer than 90 microns. Ground granulated blast furnace slag (GGBS) was collected from ACC cement, Raipur. Then steel slag which is used as aggregate of 10mm and 20 mm. It was collected from Bhushan Power & Steel Ltd, Jharsuguda, Odisha. Similarly natural coarse aggregate of 10mm and 20mm are used. As fine aggregate natural sand is used. Mixture of NaOH solution and Na₂SiO₃ solution is used as alkaline activator and ratio of Na₂SiO₃ to NaOH is 2.5 [5]. Chemical compositions of FA and GGBS are given in Table 1 obtained by X-ray fluorescence (XRF) analysis. Table 2 shows the properties of materials.
Table 1 Chemical compositions of Fly ash and FS were obtained by XRF

| Contents | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO | MgO | Na$_2$O | K$_2$O | Cr$_2$O$_3$ | SO$_3$ | P$_2$O$_5$ | MnO |
|----------|---------|-------------|-------------|------|-----|---------|-------|-----------|-------|---------|-----|
| FA       | 53.5    | 21.7        | 6.9         | 3.42 | 0.82| 0.24    | 0.7   | 1.1       | 0.015 | 0.12    |     |
| GGBS     | 32.36   | 13.4        | 1.3         | 42.9 | 3.7 | 0.21    | 0.32  | 3.76      | 0.02  |         |     |

Fig 1. Bulk Image of Fly Ash

Fig 2. NCA

Fig 3. Steel Slag

Table 2 Properties of Materials

| Materials | Specific Gravity | Impact Value | Zone | Water Absorption | Los Angeles Abrasion Value |
|-----------|------------------|--------------|------|------------------|----------------------------|
| NCA       | 2.85             | 15.7%        | -    | 0.8%             | 19.6%                      |
| Fly Ash   | 2.45             | -            | -    | -                | -                          |
| Sand      | 2.38             | -            | H    | 1.25%            | -                          |
| Steel Slag| 3.25             | 25%          | -    | 1.75%            | 26.5%                      |
2.2 Specimen Preparation

First 14 M Sodium hydroxide solution has to be prepared by dissolving (14 x 40) i.e 560 g of Sodium hydroxide pellets in 1L water as molecular weight of NaOH is 40gm [5]. Then according to the ration 2.5 times Sodium silicate solution was added to it. It should be prepared a day before. Alkaline solution to binder ratio was considered as 0.5. On the other hand, all the solids were mixed together up-to 3 minutes after quantified and then alkaline solution was added to it which was mixed for 4minutes. Then GPC mixture was casted and compacted to moulds of (100 ×100 × 100) mm. After completing the previous step moulds were put in oven for curing at 70°C for 24hours. Table 3 shows the mix design proportion and slump values.

| Mix  | NaOH+Na₂SiO₃ (kg/m³) | Fly Ash (kg/m³) | Steel Slag (kg/m³) | NCA (kg/m³) | Sand (kg) | Slump values (mm) |
|------|----------------------|-----------------|-------------------|------------|----------|------------------|
| S-10 | 250                  | 500             | 133.33            | 1200       | 720      | 74               |
| S-20 | 250                  | 500             | 267.67            | 1067.67    | 720      | 68               |
| S-30 | 250                  | 500             | 400               | 933.33     | 720      | 60               |
| S-40 | 250                  | 500             | 533.33            | 800        | 720      | 55               |

3. Result & Discussion

3.1 Compressive Strength

For different ratio of GPC mixtures samples were kept for 7, 14 and 28 days & after that samples were tested to check the compressive strength. Fig. 4 shows the compressive strength variation with respect to different percentages of steel slag.

Fig. 4 Compressive strength variation

Development of high volume fly ash based GPC can show extremely good mechanical properties with higher compressive strength and longer durability [6]. Also Steel slag substitution as an aggregate can increase the strength...
of GPC up to 46% than natural coarse aggregate [7]. From the above result it is noted that the strength is increasing upto 30% replacement of steel slag as coarse aggregate and then it decreases.

3.2 Rebound Number

This non destructive test was carried out through the moulds of size 100 × 100 × 100 mm. The test is done to check the homogeneous microstructure of the GPC sample. Table 2 shows the rebound number values of different GPC mixes.

| Mix | Rebound No. |
|-----|-------------|
| S-0 | 29          |
| S-10| 31          |
| S-20| 35          |
| S-30| 40          |
| S-40| 28          |

4. Conclusion

The study deals with the detailed investigation on partial replacement of steel slag as natural coarse aggregate which was cured at 70°C. So it is concluded that,

- Partial use of steel slag as coarse aggregate gave high compressive strength.
- Replacement of steel slag as coarse aggregate improves 46% the strength up to 30% and accordingly rebound number also increases.

Future work,

- All Mechanical properties can be studied by using steel slag with the replacement of natural coarse aggregate.
- Durability properties can be studied with steel slag.

5. References

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