Strength studies on geopolymer concrete with GGBS and Fly ash

Ganesan Nagalingam¹ and Ramesh Babu Chokkalingam²

¹Department of Civil Engineering, Anjalai Ammal Mahalingam Engineering College, Koyilvenni – 614 403, Tiruvarur District, Tamilnadu, India
²Department of Civil Engineering, Kalasalingam Academy of Research and Education, Krishnankoil, 626126, India

E-mail: ¹civilganesan139@gmail.com

Abstract. Geopolymer concrete is a pollution controlled and eco-friendly alternate material used for construction in the recent years. This concrete has many advantages and applications. The main aim of this study is to check the effect of Fly ash and Ground Granulated Blast Furnace Slag (GGBS) on the mechanical properties of Geopolymer concrete at different replacement levels of GGBS by fly ash from 0 to 25% with 5% variation. From previous researches on Geopolymer concrete, an optimized mix is identified for testing mechanical behaviour. Sodium silicate (Na2SiO3) and sodium hydroxide (NaOH) of 12 Molarity is used as activator solution in the ratio of 1:2.5. A carboxylic based admixture called La Hypercrete S25 is added in the mix by 1% of the weight of GGBS for increasing the workability of Geopolymer concrete. Cubes of 100mm size are cast for determining the compression strength behavior. Cylinders of 100mm dia and 200mm height are cast for splitting tensile strength and beams of size 500mm length with 100mm x 100mm cross section are cast for flexural strength. The specimens are cured at ambient temperature and tested on 7 and 28 days. The test result shows the strengths gradually increases for 5, 10, 15 and 20% replacement of GGBS by fly ash. The maximum values are obtained for 20% of GGBS replacement by flyash in all the tests. The strengths reduce for replacements of above 20%. This study concludes that geopolymer concrete performs well in strength properties with GGBS and Fly ash.

1. Introduction

Many researchers have conducted studies on various industrial waste materials for replacing the aggregates in conventional concrete for minimizing the depletion of natural resources and succeeded [1]. Geopolymer based concrete is an alternative for conventional concrete. The alkaline solution used in Geopolymer concrete is mainly consists of aluminium or sodium. In this study, sodium hydroxide and sodium silicate solution is used as activator [2]. Few advantages of Geopolymer concrete include acid and fire resistance, excellent mechanical properties, less creep and shrinkage, good chemical resistance etc. [3]. Researches reveals developing GGBS based Geopolymer concrete requires ambient curing whereas production of flyash based Geopolymer concrete needs heat curing. Flyash based geopolymer concrete also exhibits good acid resistance and corrosion resistance [4, 5, 6].Since Geopolymer concrete is developed thro’ ambient curing, enormous quantity of water is saved [7]. Here an attempt is made to test the mechanical behaviour of Geopolymer concrete with GGBS and flyash.

2. Experimental Methods and Materials Used

2.1 Fine- aggregate

Fine aggregate is river sand and it passes thro’2.36 mm sieve. This belongs to Zone- II of the revised
Indian standard code IS 382-2016 [8]. Its specific gravity is 2.80 and particle size distribution (Fineness Modulus) is 3.28.

2.2 Coarse aggregate
Crushed stone with size 4.75 mm and above is utilized as coarse aggregate. The coarse aggregate confirms to the requirements with IS 383-1970. Its specific gravity is 2.808 and fineness modulus is 7.05.

2.3 Ground Granulated Blast Furnace Slag (GGBS):
GGBS is obtained as a waste in blast furnace during iron manufacture. It has the specific gravity value of 2.9. The compositions of oxides in GGBS are shown in figure 1 below. It is collected from Bangalore for this study.

![Figure 1. Chemical Analysis of GGBS](image)

2.4. Flyash
Fly ash is the byproduct obtained in thermal power stations. It is obtained from Thoothukudi thermal station. It has the specific gravity value of 2.1. The X-Ray Diffraction analysis is shown in figure 2.

![Figure 2. X-Ray Diffraction analysis](image)

2.5. Activator solution
Sodium Hydroxide (NaOH) and Sodium Silicate (Na₂SiO₃) of 1:1.25 ratio is used in this experimental study for preparing the alkaline activator solution. A 12 Molarity NaOH solution is used in the study.
2.6. Admixture
To have good workability, La- Hypercrete S25 is used in the mix.[9].

3. MIX FOR EXPERIMENTAL WORK

Proportion of materials for the study is shown in Table 1 [10]. The preparation of mix and the activator solution is shown in Figure 3 and 4 respectively.

| Materials   | GGBS | Sand   | Stone  | NaOH | Na$_2$SiO$_3$ | Admixture |
|-------------|------|--------|--------|------|---------------|-----------|
| Quantity(kg/m$^3$) | 550  | 689.1  | 1113.2 | 55   | 137.5         | 5.5       |

**Figure 3. Mix preparation**

**Figure 4. Alkaline solution**

4. EXPERIMENTAL WORK

4.1. Compression Test
Initially, geopolymer concrete mix with GGBS is prepared. Cube specimens of 100mm size are prepared to test at 7, 28 days. Cubes are also cast for the GGBS replacement by Fly ash. For easy identification, the specimens are assigned with IDs 1,2,3,4,5 and 6 for 0, 5,10,15,20 and 25% GGBS replacement and fly ash addition. After casting, cubes are dried in room temperature. Then the specimens are subjected to compression test as illustrated in figure 5 below. The test results are shown in Table 2 and the graphical representation of the test results are shown in figures 6 and 7 for 7, 28 days respectively.

**Figure 5. Compression test set up**

| Specimen ID | 1  | 2   | 3    | 4    | 5    | 6   |
|-------------|----|-----|------|------|------|-----|
| Days        |    |     |      |      |      |     |
| 7           | 38.73 | 34.42 | 35.58 | 36.53 | 37.42 | 31.45 |
| 28          | 66.59 | 61.95 | 62.56 | 64.49 | 65.60 | 60.06 |

**Table 2: Average Compressive strength results**
4.2. Split tension Test

Cylindrical specimens of 100mm dia. with height 200mm are prepared to study the splitting tensile behaviour of Geopolymer concrete. Cylinders are prepared for various flyash percentages as specified in section 4.1. After 7 and 28 days of ambient curing, the specimens are tested for split tension in Universal testing machine as shown in figure 8. The test results are tabulated in Table 3 and the graphical representation is shown in figure 9 and 10 for 7 and 28 days.
Table 3: Split tension values

| Specimen ID | 1  | 2  | 3  | 4  | 5  | 6  |
|-------------|----|----|----|----|----|----|
| Days        |    |    |    |    |    |    |
| 7           | 1.52 | 1.33 | 1.40 | 1.46 | 1.50 | 1.16 |
| 28          | 2.70 | 2.02 | 2.17 | 2.24 | 2.41 | 1.97 |

![Figure 9. 7 Days average values](image)

![Figure 10. 28 Days average values](image)

4.3. Flexure Test
For flexure test, beam specimens of length 500 mm with cross sectional area of 10000mm² are prepared. The specimens are also cast for 0 to 25% of GGBS replacement by flyash. After subjecting the specimens to ambient curing for 7, 28 days, the specimens are tested for flexure and the values are tabulated in Table 4. The graphical representation is shown in figure 11 and 12. The specimens are tested for flexural strength as illustrated in figure 13.
### Table 4: Average flexural strength values

| Specimen ID | 1    | 2    | 3    | 4    | 5    | 6    |
|-------------|------|------|------|------|------|------|
| Days        | Average values (N/mm²) |      |      |      |      |      |
| 7           | 13.65| 11.34| 12.19| 12.31| 13.08| 12.88|
| 28          | 21.67| 13.78| 15.83| 16.23| 20.50| 19.10|

**Figure 11.** 7 Days average values

**Figure 12.** 28 Days average flexure strength results
Figure 13. Specimen after failure in flexure test

5. RESULTS AND DISCUSSIONS

5.1. Compressive strength
From Table 2, it is evident that the average strength at 7 days for ID-1 specimens is 38.73 N/mm². This value increased up to 20% fly ash and starts decreasing from 25% of GGBS replacement. Similarly for 28 days, the average value of ID-1 specimens is 66.59 N/mm². This value increased up to 20% fly ash with GGBS replacement. Beyond this, the average compressive strength reduces. From the results, it is concluded that mix for ID-5 (80% GGBS and 20% Fly ash) exhibits high value and almost same as 0% GGBS replacement. The test result also shows that GGBS based Geopolymer concrete with fly ash gives excellent compressive strength values.

5.2. Splitting tensile strength
In table 3, the 7 days average split tensile strength for ID-1 specimens is 1.52 N/mm². This value is increased for further GGBS replacements up to 20% and starts decreasing from 25% of GGBS replacement. For 28 days, the average value of ID-1 specimens is 2.70 N/mm². This value reaches to 2.41 N/mm² for ID-5 specimens. Beyond this, the splitting tensile strength reduces. From these values, it is concluded, the ID-5 mix (80% GGBS and 20% Fly ash) gives better results than other replacements.

5.3. Flexural strength
Table 4 shows average flexure values of 7 and 28 days for all the mix IDs. The flexure value for ID1 specimens is 13.65 N/mm². The corresponding values for ID-5 and ID-6 specimens are 13.08 N/mm² and 12.88 N/mm² respectively. The flexural strength attaining pattern is similar to compression and split tensile tests. The values for ID-1 and ID-5 for 28 days are 21.67 N/mm² and 20.50 N/mm² respectively.

6. CONCLUSIONS

- This study proves that GGBS based Geopolymer concrete performs well in strength tests.
- This study also reveals strengths go up with age of concrete.
- It also proves GGBS and flyash based geopolymer concrete are the best alternatives for conventional concrete.

REFERENCES

[1]. B. Singh, G. Ishwarya M. Gupta and Bhattacharyya, Geopolymer concrete: A review of Some Recent Developments, Construction and Building Materials, 85(2015), pp 78-90.
[2]. N. Ganesan, C. Ramesh Babu and PL. Meyyappan, Influence of Alkaline Activator Ratio on
Compressive Strength of GGBS Based Geopolymer Concrete IOP Conf. Series: Materials Science and Engineering 561 (2019) 012083 pp1-6.

[3] C. Ramesh Babu and N. Ganesan, A Study on the Strength Development of Geopolymer Concrete Using Fly Ash International Journal of Engineering and Technology (UAE). 6 (2018), pp163-167.

[4] P. Chindaprasirt and W. Chalee, Effect of Sodium Hydroxide Concentration on Chloride Penetration and Steel Corrosion of Fly Ash Based Geopolymer Concrete Under Marine Site, Construction and Building Materials, 63 (2014), pp303-310.

[5] X. Tianyu and O. Togay, Behaviour of Low Calcium Fly and Bottom Ash Based Geopolymer Concrete Cured at Ambient Temperature, Ceramic International, 41 (2015), pp5945-5958.

[6] D. Hardjito and B. Vijayarangan B On the Development of Fly Ash Based Geopolymer Concrete, ACI Materials Journal, 101 (2004), pp467-472.

[7] N. Pradip, S. Prabir Kumar, Effect of GGBS on Setting, Workability and Early Strength Properties of Fly Ash Geopolymer Concrete Cured in Ambient Condition, Construction and Building Materials, 66 (2014), pp163-171.

[8] Indian Standard Code of Practice for specification for coarse and fine aggregates from natural sources for concrete (IS 383-1970) Bureau of Indian Standards, New Delhi, India.

[9] Indian Standard Code of Practice for specification for admixtures for concrete (IS 9103-1999) Bureau of Indian Standards, New Delhi, India.

[10] Indian Standard Code of Practice for recommended guidelines for concrete mix design (IS 10262-2009) Bureau of Indian Standards, New Delhi, India.