MICROSTRUCTURE INVESTIGATION OF FLY ASH F AND FLY ASH C GEPOLYMER CONCRETE USING SYNERGY OF RECYCLE AGGREGATES

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Abstract

Microstructure studies in concrete are unique techniques for understanding the morphological features of concrete. In this research work, four mixture of concrete has been prepared by replacement of normal cement with geopolymer in 0 %, 50%, 80% and 100% of different ratio with recycled aggregates. Both class of fly ash F and C has been used with an alkaline activator (NaOH and Na₂SiO₃). In each mixture, the alkaline liquid, sodium hydroxide (Noah), and sodium silicate were dependent on the amount of fly ash, while the ratio of NaOH to Na₂SiO₃ is maintained 2.5 for all concrete. After costing twelve cylinders 150mm x 300 mm and twelve 152.4 mm x 152.4 mm x 609.6 mm concrete beams were cured for 28 days at a normal temperature of 27°C water. The physical and chemical properties have been investigated in this research. The SEM and XRF analysis of all samples has been compared with the controlled sample. Which all samples have been compared with a controlled sample, to identify the changing of compressive and flexural strength in each sample.

Keyword: Microstructure, Geopolymer, Normal cement, SEM, XRF

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I. Introduction

Concrete is long-established material all over the world, because of its properties concrete is used vastly [VIII]. The production of cement has been increased day by day because of the rate of CO₂ has been increased during the formation of cement all over the world. The cement industry is responsible for 7% of the total emission of carbon dioxide in all over the world [VI]. In general, the physical properties of concrete depend on the microstructure of concrete. The mechanical properties of concrete like compressive strength and flexural strength, etc, can be improved by changing of binding material, coarse aggregate and fine aggregate, etc [I]. Since the high emission of CO₂ and getting high quality of concrete which is responsible for high durability, high density and good in morphology structure the new environment friendly concrete has been introduced by Davidovits in 1975 which is called geopolymer concrete.

Geopolymer concrete is environment-friendly concrete which generally reduces 80% of CO₂ emission as compared to ordinary Portland cement [VII]. Geopolymer is the combination of source material (Metakaolin, low-calcium ASTM Class F fly ash, the combination of fly ash and metakaolin, etc) and alkaline liquid (sodium hydroxide, sodium silicate). Combination of sodium hydroxide and sodium silicate used in fly ash based concrete, the strength of geopolymer concrete is directly proportional to the concentration of sodium hydroxide due to increase in the concentration of sodium hydroxide solution in terms of molarities (M) makes the concrete more brittle [VIII].

As we know that synergy between cement and polymer concrete improves the sustainability of construction. Except that it improves the property and application of concrete especially the durability of concrete [XIII]. The aim of this study, to utilize the class c fly ash in geopolymer concrete, and its synergy with OPC cement concrete with different ratio has been studied. The cement has been replaced with middle-class fly ash geopolymer concrete. The effect of middle class geopolymer with cement was good up to a certain limit.

II. Literature Review

According to the literature review, the cement has been replaced by several types of silica bound material like rice husk ash, GGBS, etc which gives good results in form strength and as well as other properties. 15% replacement of cement by rice husk ash is given high compressive strength. According to SEM analysis, the well compacted and low pores concrete is got on 15% replacement of cement on rice husk ash [II]. Utilization of coal bottom ash as fine aggregate in concrete is not given badly compressive strength while according to SEM and XRD analysis showed that the concrete was less uniform as compared to normal concrete [X]. Another effort has been done, using the waste foundry sand and bottom ash used equally by the replacement of natural sand in concrete (0% to 60%). The compressive strength has been improved when natural material replaced by industrial product aggregate up to 30%. From the SEM analysis, the formation of calcium silica hydrate gel was good.

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from 20% to 50%. This gave a monolithic concrete sample [XIV]. The glass powder has been used with ultra-high performance concrete. After SEM analysis it has been noted that the hydration process was accelerated which give result in form of good monolithic microstructure. The use of glass powder showed good achievement and increased compressive strength [XII]. In 2000 by replacing cement with silt and clay in concrete. Which improves the strength of concrete and as well as reduced permeability and sorptivity of concrete [III]. In 2004 the nano-silica has been used with cement, to investigate the microstructure analysis of cement mortar. Nano silica was not only used as filler in mortar while they also act as an activator in a mortar, which causes good compacted and uniform microstructure of cement past [V]. Changing in properties of concrete is directly proportional to changes in the microstructure of concrete. While the microstructure of concrete can be changed due to time, environmental condition likes temperate acidity attack, etc. so the microstructure of concrete can be improved by replacement of ingredient of concrete with other waste and by-product material, to give the high performance of concrete [XII].

Assumption and Limitation

➢ It has been assuming that Fly ash-c have the same property as like fly ash-f.
➢ The amount of both class fly ash will be equal in each ratio.
➢ The amount of alkaline liquid must not be increased then the amount of w/c ratio.

Experimental Work

The concrete mixed design has been done from a literature review which gave ratio 1:1.5:3 with a 0.57 water-cement ratio. Fly ash f, fly ash c, sodium hydroxide, sodium silicate, ordinary Portland cement, fine aggregate, and course recycle aggregate have been got from the local market. All materials were meet to his specific standard. The finesse modules of fine aggregate were 2.70 while specific gravity, water abortion, and bulk density of recycled coarse aggregate were 2.670,1.30% and 1505.37 respectively. The amount of sodium hydroxide (NaOH) and sodium silicate has been calculated from the amount of fly ash for all mixture. The calculation for all mixtures has been showing in table 1.

| MIXTURE | RATIO | CEMENT (KG) | FLY ASH F (KG) | FLY ASH C (KG) | NAOH (KG) | Na2SiO3 (KG) | SAND (KG) | C.A (KG) |
|---------|-------|-------------|----------------|----------------|-----------|-------------|-----------|---------|
| 1       | 1:1.5:3 | 23.37       | 0              | 0              | 0         | 0           | 36.87     | 73.74   |
| 2       | 1:1.5:3 | 11.68       | 5.84           | 5.84           | 2.33      | 3.505       | 36.87     | 73.74   |
| 3       | 1:1.5:3 | 4.674       | 9.348          | 9.348          | 3.739     | 5.602       | 36.87     | 73.74   |
| 4       | 1:1.5:3 | 0           | 11.68          | 11.68          | 4.674     | 6.954       | 36.87     | 73.74   |

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The concrete has cost in all mold of beams and cylinders. After 24 hours the all sample has cured at room temperature for 28 days. After 28 days, the flexural and compression test has been done of all samples.

After flexural and compression text the SEM and XRF analysis has been done after 60 days. The Scanning Electronic Microscope (SEM) test has been done for three mixture (1, 2, and 4) with different magnification, which showed differently and cleared morphology of concrete. Similarly, XRF analysis has been done for the same mixture, which showed different elements and components of samples.

**Result and Discussion**

**Compressive Test Result**

The concrete was design for 20.68 Mpa. The compressive result was calculated after tested of 12 cylinders in UTM, 3 cylinders for each mixture. The result of all samples is below in table 2.
Table 2: Compressive Test Result

| MIXTURE | CEMENT : GEOPOLYMER | CYLINDER/No | STRENGTH (Mpa) | LOSS OF STRENGTH IN PERCENTAGE |
|---------|----------------------|-------------|----------------|--------------------------------|
| 1       | 100% : 0%            | 1           | 12.31          | 33.35                          |
|         |                      | 2           | 12.45          |                                |
|         |                      | 3           | 16.36          |                                |
| 2       | 50% : 50%            | 4           | 6.54           | 70.11                          |
|         |                      | 5           | 5.96           |                                |
|         |                      | 6           | 6.06           |                                |
| 3       | 20% : 80%            | 7           | 2.56           | 85.63                          |
|         |                      | 8           | 3.06           |                                |
|         |                      | 9           | 3.29           |                                |
| 4       | 0% : 100%            | 10          | 2.53           | 89.31                          |
|         |                      | 11          | 2.22           |                                |
|         |                      | 12          | 1.90           |                                |

According to the compressive test result, the compressive strength was reduced when the amount of Geopolymer was increased. The cause of failure of compressive strength got in SEM analysis. All the result is shown in the below graphs.

![Fig. 5: Mixture-1 Graph of cylinder](image1)

![Fig. 6: Mixture-2 Graph of cylinders](image2)

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Fig. 7: Mixture-3 Graph of cylinders  
Fig. 8: Mixture-4 Graph of cylinder

**Flexural Test Result**

Similarly designed for 71.17 KN. Three beams have been tested for each mixture. Geopolymer with cement was good up to a certain percentage all the result has been showing in table 3.

| MIXTURE | CEMENT : GEOPOLYMER | BEAM/No | STRENGTH (KN) | LOSS OF STRENGTH IN PERCENTAGE |
|---------|---------------------|---------|---------------|--------------------------------|
| 1       | 100% : 0%           | 1       | 76.65         | Zero % lost                    |
|         |                     | 2       | 84.04         |                                |
|         |                     | 3       | 63.65         |                                |
| 2       | 50% : 50%           | 4       | 69.99         | 17.76                          |
|         |                     | 5       | 59.61         |                                |
|         |                     | 6       | 46.02         |                                |
| 3       | 20% : 80%           | 7       | 20.12         | 64.35                          |
|         |                     | 8       | 24.94         |                                |
|         |                     | 9       | 31.05         |                                |
| 4       | 0% :100%            | 10      | 37.16         | 52.43                          |
|         |                     | 11      | 33.97         |                                |
|         |                     | 12      | 34.43         |                                |

The flexural strength of beams was also decreased with an increasing amount of geopolymer in the mixture. For each mixture, three beams have been tested and then expressed the result in one graph for each mixture. All the flexural result is shown in the below graphs.

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Fig. 9: Mixture-1 graph of beam

Fig. 10: Mixture-2 graph of beam

Fig. 11: Mixture-3 graph of beam

Fig. 12: Mixture-4 graph of beam
**Scanning Electron Microscope SEM Analysis**

The microstructure of the control sample and different batch of geopolymer sample has been observed. From the SEM analysis density of concrete was reduced when the amount of geopolymer increased in concrete. Because of low density, more cracks and voids have been found in pure Geopolymer Mixture-4 and Mixture-2. Which is shown in the figure.

![SEM Image](image1)

**Fig. 13:** Mixture-4 SEM analyses with 150 Magnification show less density

![SEM Image](image2)

**Fig. 14:** Mixture-2 SEM analyses with 150 Magnifications show more densify

![SEM Image](image3)

**Fig. 15:** Mixture-4 SEM analyses with 150 Magnifications for voids & cracks

![SEM Image](image4)

**Fig. 16:** Mixture-2 SEM analyses with 150 Magnifications for voids & cracks

As we know that the strength is directly depending upon the chemical reaction of binding materials with water and other liquid. Because of using fly ash –c most of the raw material didn’t take part in the chemical reaction in mixture-4 and convert it in crystal form which is shown in the figure.

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Fig. 17: Mixture-2 SEM analyses with 150 Magnifications show crystals

Xrf Analysis for All Batches

To find out different elements and composition in all batches of concrete, the XRF has been done. The different element is showing in the below graph.

The different compounds in all samples are shown in the graph. Which affects the strength of samples. From the above graphs, it’s showed that the amount of CaO decreased when the amount of Geopolymer increased so as we know that CaO is responsible for strength, so the strength was decreased after decreasing the amount of CaO. Except for this when the amount of Geopolymer increased, the initial setting time was decreased as compared to the mixture-1 sample because the amount of Al₂O₃ increased.

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Conclusion
➢ Using both class fly ash in a geopolymer with normal cement concrete was not given the best result in both compressive and flexural strength.
➢ Because of Using both class fly ash, most of the raw material didn’t take part in a chemical reaction which causes decreasing strength with increasing geopolymer contents with cement.
➢ From the microstructure of concrete, the voids, crack, and separation of aggregates were increased when the amount of geopolymer increased with cement concrete.

Recommendation
➢ Using natural aggregate instead of recycling aggregate with mixture -2 may improve the flexural strength of concrete.
➢ Using of one class fly ash in Geopolymer with a changing in ratio with cement concrete may change the strength of concrete.

Conflict of Interest :
Authors declared : No conflict of interest regarding this article.

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