



## STUDY ON THE PROPERTIES OF THE GEOPOLYMER COARSE AGGREGATE

<sup>1</sup>R. Praveen Kumar, <sup>2</sup>C. Bharathi

<sup>1</sup>PG Scholar, <sup>2</sup>Assistant Professor  
Structural Engineering

<sup>1</sup>Government College of Technology Coimbatore, Tamilnadu, India

**Abstract:** The concrete is the most commonly used construction material, coarse aggregate occupies the major volume of a concrete mix at about 65% of the total volume, as the material forecasts suggest that natural coarse aggregate are getting depleted in many regions of the world and a shortage of the coarse aggregate is predicted in the near future, an alternative for that is to developed hence a geopolymer aggregate is manufactured with fly ash and kaolin along with alkali activators sodium hydroxide (molarity 8) and sodium silicate with varying proportion is trialed to obtain an optimum proportion for the preparation of geopolymer coarse aggregate, in this paper the manufacturing method and the properties of the geopolymer aggregate is investigated and compared with the natural coarse aggregate properties and the surface characteristics of the aggregate is studied with the help of SEM analysis

**Index Terms – Geopolymer aggregate, Sodium hydroxide (8 Molarity), Fly ash, SEM analysis**

### I. INTRODUCTION

Natural aggregates are those that are taken from naturally occurring rocks by breaking and sieving them in to desired size it imparts major properties to concrete and in simple terms aggregate forms the skeleton system of concrete, hence annually 4.5 billion tons of coarse aggregate are produced worldwide. The usage of natural aggregates has become serious issue, due to the over use of these materials in this developing infrastructure era Considering the high demand, depletion of the natural resources in production of aggregate and the environmental effects in obtaining the natural aggregate create a need in, developing concrete with non-conventional aggregates is an essential sustainable approach. There are many alternatives being developed for coarse aggregate, among them is the Geopolymer coarse aggregate (GPA), where polymerization of the basic ingredients plays the major role in imparting the physical and mechanical properties of the concrete. Geopolymer aggregate will be light in weight and will possess good mechanical and physical properties.

### II. SIGNIFICANCE OF THE WORK

The concrete industry needs to explore alternative for natural coarse aggregate hence this develops an alternative for the natural coarse aggregate and reducing the environmental impacts due to the production of natural aggregate. Utilization of fly ash in the production Geopolymer aggregate act as a method of Fly ash disposal. In addition, usage of one ton fly ash earns approximately one carbon credit that has significant redemption value. The aggregate so produced will be light in weight when compared to the natural aggregate indirectly reducing the weight of the concrete being produced hence reducing the dead weight of the structure.

### III. MATERIAL USED

The material used in the production of the geopolymer aggregate are Fly ash of class F, kaolin, sodium hydroxide of molarity 8 the lower molarity is used so as to enhance the inertness of the aggregate being produced and the molarity is determined based on the experimental results, sodium silicate is also used as another alkali activator so as to increase the strength and toughness of the Geopolymer aggregate . Fly ash 80% and Kaolin is 20% and the ratio to cementitious material and alkali activator is kept as 2.5 for workability constraints and the ratio of sodium silicate to sodium hydroxide is varied 2.25, 2.5 and 2.75, the purpose of using fly ash and kaolin is that the chemical composition of fly ash and kaolin are similar to that of the chemical composition of a natural aggregate. The fineness of fly ash and kaolin are 8% and 6% which indicate their blending capacity both the materials will blend and fuse together easily. The sodium hydroxide solution has to be prepared 24 hours prior to its use sodium hydroxide pellets are to be mixed in 1 liter of water, the quantity of water to be added for 320g is (1000-320=680g) 680g of water is to be added i.e. 680ml and mixed well if the total quantity doesn't add up to 1 litre, remaining quantity of water is to added to reach the 1 liter quantity of solution

$$\frac{\text{Cementitious material}}{\text{Alkali activator}} = 2.5$$

$$\frac{\text{Sodium Silicate}}{\text{Sodium Hydroxide}} = 2.25, 2.5, 2.75$$

#### IV. MANUFACTURING OF GEOPOLYMER AGGREGATE

The cubical shape of the samples are preferred for the production of geopolymer aggregate, as the cylindrical samples have curved surfaces which do not aid in the production of the angular aggregate, The optimum proportion of the raw materials is obtained based on the compressive strength results at 28 days, cubical samples of size 100mm x 100mm x 100mm is casted for obtaining the compressive strength and the same samples are casted for obtaining the geopolymer aggregate. Hand mixing of the samples are preferred over machine mixing as there is loss in material for machine mixing, the geopolymer paste is filled in the moulds in layers, with each layer being given even amount of pressure and vibrators are used to remove the entrapped in air in the geopolymeric paste. Ambient curing is followed as the thermal curing will affect the thermal conductivity of the aggregate so formed from it.



Figure 1 Various steps in the manufacturing of Geopolymer Aggregate

The trial proportion of 80% fly ash 20% kaolin and sodium silicate sodium hydroxide ratio 2.5 gave a compressive strength of 54MPa at 28 days, the ratio of 2.5 gave better strength and the geopolymeric past was at a good workable consistency, for the production of the geopolymer aggregate the cubical samples are casted for the above optimum proportion and ambient cured for 28 days and then crushed with the help of pulverizer the aggregate of size 20mm was obtained after crushing from the crusher.



Figure 2 Geopolymer Coarse Aggregate

#### V. GEOPOLYMER AGGREGATE

##### 5.1 Properties of the Geopolymer Aggregate

The Geopolymer aggregate so formed as a rough surface and has small pores over it, the crushed aggregate is angular in shape, the rough surface will aid in the bonding with the cement paste, the properties of the geopolymer aggregate are studied and compared with that of the natural aggregate. The properties of the geopolymer aggregate are shown in the Table 4.1

- i. The specific gravity of the geopolymer aggregate is lower than that of the natural aggregate, indicating that the aggregate is lighter in weight and slightly absorptive in nature
- ii. The Bulk density of the Geopolymer aggregate indicate that they are lighter than the natural aggregate, hence the structures formed from them will tend be lighter in weight.
- iii. The soundness test determines an aggregate's resistance to disintegration by weathering, magnesium sulphate solution was used for the test and tests were performed in cycles, the overall loss in weight are within the limit indicating that the geopolymer aggregate is durable in nature.
- iv. The water absorption of the geopolymer aggregate is slightly higher than that of the natural aggregate, small pores are present on the surface and are randomly scattered over the surface, the pores and nature of the parent material may tend to increase the water absorption
- v. The aggregate impact value and crushing value of the Geopolymer aggregate are less than that of the conventional aggregate indicate that the aggregate so obtained is tough in nature and possesses a good strength.
- vi. The angularity number is around 9, which is well within the range 0-11 the more nearing to 11 the more is the angularity of the aggregate, which will enhance the interlocking of the aggregate, reducing the voids.

Table 1 Properties of the Geopolymer aggregate and Natural aggregate

S.NO	Tests	Geopolymer coarse aggregate	Natural coarse aggregate
1	Aggregate Impact value	17%	20%
2	Aggregate Crushing Value	20%	26.65%
3	Compacted Bulk Density	1167 kg/m <sup>3</sup>	1622.6kg/m <sup>3</sup>
4	Loose Bulk Density	1057 kg/m <sup>3</sup>	1457kg/m <sup>3</sup>
5	Specific gravity test	2.31	2.68
6	Soundness test (Magnesium sulphate)	11%	8%
7	Angularity number	9	10
8	Water absorption	1%	0.5%

## 5.2 Surface Characteristic of Geopolymer Aggregate

The Geopolymer Aggregate surface morphology is studied with the help of SEM images with a scale up to a 100 micrometer and a image type of 8 bit the figure 3.a and 3.b below shows the SEM image of the Geopolymer aggregate

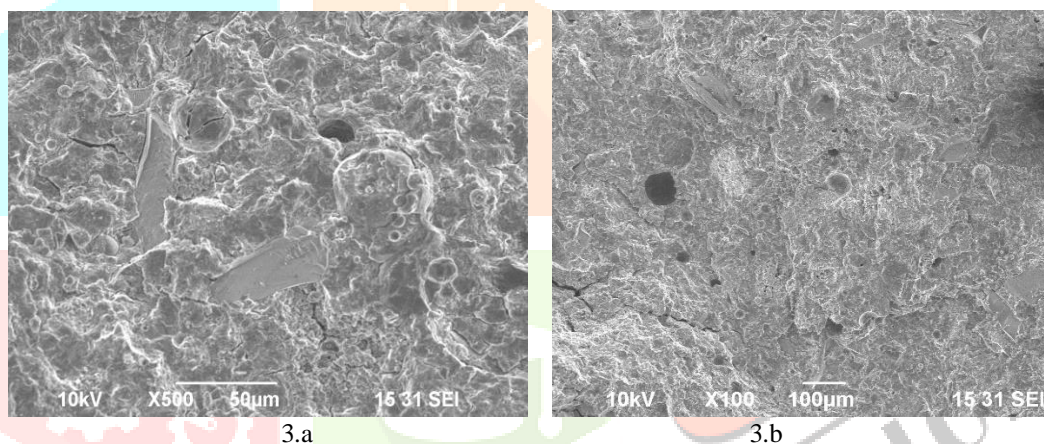


Figure 3.a and 3.b represent the surface of the geopolymer coarse aggregate

- The surface of the geopolymer aggregate is porous in nature, the pore distribution is not even, it is distributed randomly over the surface of the aggregate the size of the pores varies from one another, ImageJ software is used to further study the pores on the surface, The approximate size of the largest pore visible on the image is approximately around 77 micro meters ( $7.7 \times 10^{-5}$  m) and the medium size pore is of length approximately about 30 micrometers ( $3.0 \times 10^{-5}$  m).
- Cracks are visible on the surface of the geopolymer aggregate and they are also not distributed throughout the aggregate they are developed at random points with shorter lengths. The surface of the aggregate contains cracks over few regions especially on the edges of the aggregate it may be due to the crushing action of the jaw crusher the cracks are short in length and they do not propagate throughout the surface of the aggregate and there aren't many cracks when compared to that of the pores

## VI. CONCLUSION

- The geopolymer aggregate can be produced from fly ash and kaolin with alkali activators sodium hydroxide 8M and sodium silicate with ambient curing of the samples
- The Geopolymer aggregate so obtained has rough and uneven surface and will aid in proper bonding with the cement paste and better interlocking reducing the when used during the process of concreting.
- The geopolymer aggregate so produced is light in weight it can be seen from the specific gravity value and bulk density value of the geopolymer aggregate
- The water absorption is slightly higher than the natural aggregate, that might be due to the pores present on the geopolymer aggregate, when used in concrete the pores might be filled with cement paste aiding in better bonding of the aggregate.
- The Impact and crushing strength properties showed better result than the conventional aggregate and they are within the permissible limits of the code, hence the geopolymer aggregate is tough in nature and at the same time light in weight.
- The surface characteristics of the geopolymer coarse aggregate is slightly porous in nature with small cracks over some regions, especially on the edges, they may help in binding with the cement paste when used in the process of concreting.
- Further research has to be done to study the behavior of the geopolymer aggregate when used in concreting process.

## REFERENCES

1. Chamila Gunasekera Sujeeva Setunge, David W. Law “Effect of Geopolymer Aggregate on Strength and Microstructure of Concrete” ACI Materials Journal, November 2018
2. A Abdullah, M M A B Abdulla, K Hussin, S Junaid and M F M Tahir “Effect of fly ash/alkaline activator ratio on fly ash geopolymer artificial aggregate” AIP Conference Proceedings, December 2018.
3. Waleed Abbas Wasan Khalil, and Ibtessam Nasser “Production of lightweight Geopolymer concrete using artificial local lightweight aggregate” MATEC Web of Conferences, 2018
4. Yliniemi, Paiva, Ferreria, Tiainen and Illikainen “Development and incorporation of Light weight waste-based Geopolymer aggregate in mortar and concrete” Construction and Building Materials (Elsevier) , November 2016
5. M.M.A. Abdullah, H. Kamarudin, H. Mohammed, Khairul Nizar, R. Rafiza and Y. Zarina” The relationship of NaOH Molarity, Na<sub>2</sub>SiO<sub>3</sub>/NaOH Ratio, Fly Ash/Alkaline Activator Ratio, and Curing Temperature to the Strength of Fly Ash-Based Geopolymer “Advanced Materials Research 2011.
6. S. Mesgari, A. Akbarnezhad , Z. Xiao “ Recycled geopolymer aggregates as coarse aggregates for Portland cement concrete and geopolymer concrete: Effects on mechanical properties“ Construction and building materials 2019.
7. S. Kox, G. Vanroelen, J. Van Herck, H. de Kerm, B. Vandoren “Experimental evaluation of the high-grade properties of recycled aggregates and their application in concrete road pavement construction” Elsevier Case studies in Construction Material, August 2019.

