International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 05 | May - 2021 ISSN: 2582-3930

Properties of Geopolymer Concrete using Fly Ash

Md Mozaffar Masud[1], A K L Srivastava[2], Zeeshan Farooque[3]

[1] *Student, Department of Civil Engineering, NIT Jamshedpur*
[2] *Professor, Department of Civil Engineering, NIT Jamshedpur*
[3] *Assistant Professor, Department of Civil Engineering, MACET, Patna*

---***---

Abstract - This investigation presents the details of development of the process of making fly ash based geopolymer concrete.Therefore present study adopted a rigorous trial and error process in order to develop the geopolymer concrete using fly ash. The focus of the study was to identify the salient parameters that influence the mixture properties and the properties of fly ash-based geopolymer concrete.

Key Words: Geopolymer concrete, fly ash, compressive strength, alkaline liquid

1.INTRODUCTION

'Geopolymer Concretes' (GPC) are Inorganic polymer composites, which are prospective concretes with the potential to form a substantial element of an environmentally sustainable construction by replacing/supplementing the conventional concretes. In Geopolymer Concrete, the geopolymer binder (here, fly ash) utilises the poly-condensation of silica and alumina precursors to attain structural strength. The use of Portland cement in concrete construction is under critical review due to high amount of carbon dioxide gas released to the atmosphere during the production of cement. The climate change due to global warming, one of the greatest environmental issues has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases, such as CO_2 to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming [1].

The binders create were termed "geopolymer". Geopolymer concrete is a 'new' material that does not need the presence of Portland cement as a binder. Instead, the source of materials such as fly ash, that are rich in Silicon (Si) and aluminium (Al), are activated by alkaline liquids to produce the binder. Hence concrete with no Portland cement. Unlike ordinary Portland/pozzolanic cements, geopolymer do not form calcium-silica-hydrates (CSHs) for matrix formation and strength, but the alumina-silicate gel formed by geopolymerization binds the aggregate and provides strength to geopolymer concrete. Source materials and alkaline liquids are the two main constituents of geopolymer, the strengths of which depend on the nature of the materials and the type of liquids [2].

The chemical compositions of various fly ashes show a wide range, indicating that there is a wide variations in the coal used in power plants all over the world [3]. Fly ash that results from burning sub-bituminous coals is referred as ASTM Class C fly ash or high calcium fly ash, as it typically contains more than 20 percent of CaO. On the other hand, fly ash from the bituminous and anthracite coals is referred as ASTM Class F fly ash or low calcium fly ash. It consists of mainly an alumina-silicate glass, and has less than 10 percent of CaO. The colour of fly ash can be tan to dark grey, depending upon the chemical and mineral constituents.

The Indian low-lime fly ashes are characterized by relatively higher concentration of $SiO_2$and Al_2O_3 and lower contents of Fe_2O_3. This implies higher fusion temperature for these flyashes and, consequently, the chances of lower glass formation, if the ash is not subjected torelatively high temperature. While in the low-calcium fly ashes the silica content is almostdouble of the alumina content, in the high-calcium fly ashes the content of these two oxidesis by and large comparable or close to each other [4].

Any material that contains mostly Silicon (Si) and Aluminium (Al) in amorphous form is a possible source material for the manufacture of geopolymer. Several minerals and industrial by-product materials have been investigated in the past. Metakaolin or calcined kaolin [5] ASTM Class F fly ash (Palomo, Grutzeck et al. 1999; Swanepoel and Strydom 2002), natural Al-Si minerals (Xu and van Deventer 2000), combination of calcined mineral and non-calcined materials, combination of fly ash and metakaolin and combination of granulated blast furnace slag and metakaolin were investigated as source materials. Metakaolin is preferred by the niche geopolymer product developers due to its high rate of dissolution in the reactant solution, easier control on the Si/Al ratio and the white colour. However, for making concrete in a mass production state, metakaolin is very expensive. Low calcium (ASTM Class F) fly ash is preferred as a source material than high calcium (ASTM Class C) fly ash.The higher molecules condense in a gel form andthe alkali attack on the surface of particle, and then expand to larger hole, exposingsmaller particles whether hollow or partially filled with other yet smaller ashes to bidirectionalalkaline attack from the outside in and from the inside out. Consequently,reaction product is generated both inside and outside the shell of the sphere, until the ashparticle is completely or almost completely consumed [6].

2. Methodology

2.1 Material Used for Geopolymer Concrete

Fly Ash

Quantity and fineness of fly ash plays an important role in the activation process of geopolymer. It was already pointed out that the strength of geopolymer concrete increases with increase in quantity and fineness of fly ash [7]. Similarly higher fineness shows higher workability and strength with early duration of heating. So, the main emphasis is given on quantity and fineness of fly ash in the development of mix proportioning procedure of geopolymer concrete. Fig. 1 shows the relation between the fineness of Fly ash and density of GPC.

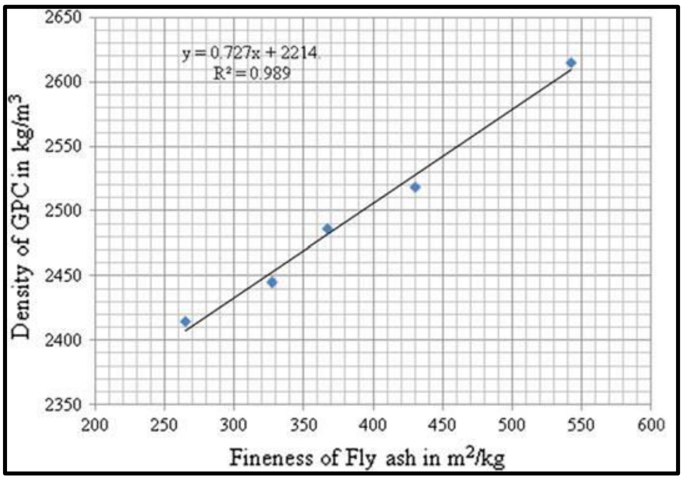


Fig -1: Relation between fineness of fly ash and density of geopolymer concrete[8]

Alkanine Activators

The combination of sodium hydroxide and sodium silicate solutions are used for the activation of fly ash based geopolymer concrete. It is observed that the compressive strength of geopolymer concrete increases with increase in concentration of sodium hydroxide solution and or sodium silicate solution with increased viscosity of fresh mix. Due to increase in concentration of sodium hydroxide solution in terms of molarity (M) makes the concrete more brittle with increased compressive strength. Sodium silicate is also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate 2.0 (ratio between Na_2O to SiO_2) is used. As per the manufacture, silicates were supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of geopolymer concrete. Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. Since our geopolymer concrete is homogenous material and its main process to activate the sodium silicate, so it is recommended to use the lowest cost i.e. up to 94% to 96% purity. In this investigation the sodium hydroxide pellets were used.

Water

From the chemical reaction, it was observe that the water comes out from the mix during the polymerization process. The role of water in the geopolymer mix is to make workable concrete in plastic state and do not contribute towards the strength in hardened state. Similarly the demand of water increases with increase in fineness of source material for same degree of workability. So, the minimum quantity of water required to achieve desired workability is selected on the basis of degree of workability, fineness of fly ash and grading of fine aggregate.

Aggregates

Aggregates are inert mineral material used as filler in concrete which occupies 70–85 % volume. So, in the preparation of geopolymer concrete, fine and coarse aggregates are mixed in such a way that it gives least voids in the concrete mass. This was done by grading of fine aggregate and selecting suitable fine-to-total aggregate ratio. Workability of geopolymer concrete is also affected by grading of fine aggregate similar to cement concrete. So, on the basis of grading of fine aggregate, fine-to-total aggregate ratio is selected in the proposed mix proportioning method.

2.2 Mix Design of M30 Geopolymer Concrete

Table-1: Mix Proportioning of Geopolymer Concrete Mixes

Mix	Total Aggregate Content (%)	Fly Ash (Kg/m³)	Coarse Aggregate (Kg/m³)		Fine Aggregate (Kg/m³)	NaOH Content (Kg/m³)		Na_2SiO_3 (Kg/m³)
			20 mm	16 mm		Pellets	Water	
Mix 1	74	427	808	435	533	14.7	41.3	141
Mix 2	76	394.52	829.92	446.88	547.20	13.6	38.5	129.63
Mix 3	78	361.69	851.76	458.64	561.60	12.5	35.05	118.83

2.3 Compressive Strength

The compressive strength of geopolymer concrete cubes at 7th day and 28th day, according to IS 516-1959.The compressive strength of geopolymer concrete with variation in days was obtained through compression testing machine.

3. RESULTS AND DISCUSSION

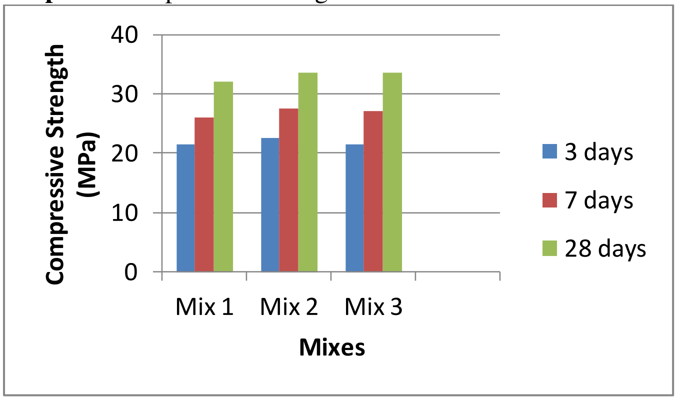
Geopolymer concrete mix is prepared using mix proportion. It was found that the fresh fly ashbased geopolymer concrete was viscous, cohesive and dark in colour and glassy appearance. Freshly mixed geopolymer concrete is viscous in nature and water comes out during polymerization process.

The cubes were then placed in an oven for thermal curing at 70 °C for a period of 24 hours. To avoid sudden variation in temperature, the concrete cubes were allowed to cool down up to room temperature. Nine cubes for each Mix were cast and tested for compressive strength after 3, 7 and 28 days of curing. Here, test period is the period considered after removing the cubes from oven till the time of testing for compressive strength. Table 2 shows the compressive strength of geopolymer concrete obtained for all three mixes after the curing period of 3, 7 and 28 days.

Table-2: Compressive Strength of All Mixes

Mixes	Compressive Strength (MPa)		
	3 days	7 days	28 days
Mix 1	21.5	26	32
Mix 2	22.5	27.5	33.5
Mix 3	21.5	27	33.5

Graph-1: Compressive Strength of All Mixes



Graph shows that the compressive strength of geopolymer concrete of varying mixes. Connecting to compressive strength after 3 days the maximum strength is obtained for Mix 2 i.e. with 76% of total aggregate.With reference to compressive strength after 7 days the maximum strength is obtained for Mix 2 i.e. with 76% of total aggregate. While in the case of 28 days maturity, the maximum strength is obtained for Mix 2 and Mix 3 i.e. with 76% and 78% of total aggregate. The results clearly shows there is an increase in strength of geoploymer concrete with increase in percentage of total aggregate up to certain limit after which the strength again decreases as total aggregate percentage increases. The increase in the percentage of total aggregates in geopolymer concrete decreases the workability of the concrete.

From the above result we found that the Mix 2 i.e. with 76% of total aggregate gives the maximum value for compressive strength at 70°C for 3 days,7 days and 28 days maturity. The above result was obtained when total aggregate percentage was varied.

4. CONCLUSIONS

From the results obtained following conclusions are made:

1. The Geopolymer concrete is found to be workable when tested for slump test. The Molar concentration of alkaline liquids does not alter the workability of Geopolymer concrete.
2. However with increase in percentage of total aggregate the workability of geopolymer concrete decreases.
3. Up to certain limit of increase in thepercentage of total aggregatesin geopolymer concrete increases the compressive strength.
4. After that certain limit (in our case – 74% total aggregate) the strength decreases with increase in the percentage of total aggregates.

REFERENCES

1. Malhotra, V.M. :High-Performance High-Volume Fly Ash Concrete,ACI ConcretInternational, (2002) 24(7), 1-5.
2. Mehta, P.K.: Reducing the Environmental Impact of Concrete, ACI Concrete International, (2001),23(10), 61-66.

3. Malhotra, Ramezanianpur, A.A.: Introduction:Sustainable Development and Concrete Technology. ACI Concrete International,(1994),24(7),22.

4.Haque, M.E.: Indian fly-ash: production and consumption scenario. International Journal of Waste Resources (IJWR), (2013),3(1), 22-25.

5. Van Deventer, J. S. J., Provis,J. L., Duxson , P., Lukey, G. C. :Reaction mechanisms in the geopolymeric conversion of inorganic waste to useful products, Journal of HazardousMaterial, A139 (2007), 506-513.

6. Pacheco-Torgal, F., Castro-Gomes, J., Jalali, S.: Alkali-activated binders: a review partI, historical background, terminology, reaction mechanisms and hydration products, J.Constr. Build. Mater., 22 (2008), 1305-1314.

7. Barbosa, V.F.F., MacKenzie, K.J.D., Thaumaturgo, C.:Synthesis and Characterisation of Materials Based on Inorganic Polymers of Alumina and Silica: Sodium Polysialate Polymers. International Journal of Inorganic Materials, (2000), 2(4), 309-317.

8. Patankar, S.V., Jamkar, S.S., Ghugal, Y.M.: Effect of water-to-geopolymer binder ratio on the production of fly ash based geopolymer concrete. Int J Adv Technol Civ Eng, (2013), 2(1), 9–83.