Material Characteristics of Geopolymer Concrete Incorporated with Fly-Ash & GGBS

Dr.A.Paulmakesh[1]

[1]*Associate Professor, Department of Civil Engineering, Woliata Sodo University, Ethiopia*

Abstract - *Geopolymer concrete is such a one and in the present study, to produce the geo-polymer concrete the Portland cement is fully replaced with fly ash and Ground granulated blast-furnace slag. Fine aggregate is replaced with quarry dust and M.Sand. Coarse Aggregate (20mm) are replaced with 10mm Aggregate Alkaline liquids are used for the binding of materials. The alkaline liquids used in this study for the polymerization are the solutions of Sodium hydroxide (NaOH) and sodium silicate (Na2Sio3). The experimental results indicate that the mechanical characteristics of all the examined mixes are enhanced by increasing the GGBS content, in both plain and steel fibre reinforced geopolymer concrete. The maximum increase in strength was observed at 5%& 1.0% of incorporation of steel fibers. The addition of steel fibers had shown good increase in compressive flexural and split tensile strength. The use of fly-ash and GGBS help in reducing the air pollution by eliminating carbon- dioxide and carbon monoxide which is produced in manufacturing of cement.*

Key Words: Flyash, GGBS, Quarry dust, 10mm Aggregate, Fine Aggregate.

1. INTRODUCTION

Geopolymer concrete is a type of concrete that is made by reacting aluminate and silicate bearing materials with a caustic activator. Commonly, waste materials such as fly ash or slag from of these resources. Concrete usage around the world is second only to water. Cement is conventionally used as the primary binder to produce concrete. The environmental problems associated with the production of cement are well known [1]. The amount of the carbon dioxide released during the manufacture of cement due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of cement produced. Hence, it is imminent to find an alternative material to the existing most expensive most resource consuming Portland cement. OPC is extensively used in India due to its low cost and easy availability.

Concrete can be cast in almost any desired shape, and once hardened, can become a structural (load bearing) element. On the other hand it also affects environment, also there are many negative influence of OPC. For example emissions of airborne pollution in the form of gases, noise, dust, and vibration when operating machinery and during blasting in quarries, devouring of large quantities of fuel during manufacture and release of CO2 from the raw materials during manufacture. Due to all such reasons it is needed to be replaced by non-producing CO2 materials such as fly ash and various supplementary materials. For the construction of any structure, Concrete is the main material. Concrete usage around the world is second only to water. The main ingredient to produce concrete is Portland cement. On the other side global warming and environmental pollution are the biggest menace to the human race on this planet today. The production of cement means the production of pollution because of the emission of CO2 during its production. There are two different sources of CO2 emission during cement production. Combustion of fossil fuels to operate the rotary kiln is the largest source and other one is the chemical process of calcining limestone into lime in the cement kiln also produces CO2.In India about 2,069,738 thousands of metric tons of CO2 is emitted in the year of 2010.

The cement industry contributes about 5% of total global carbon dioxide emissions. And also, the cement is manufactured by using the raw materials such as lime stone, clay and other minerals. Quarrying of these raw materials is also causes environmental degradation. To produce 1 ton of cement, about 1.6 tons of raw materials are required and the time taken to form the lime stone is much longer than the rate at which humans use it. But the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly.

2. NEED OF GEOPOLYMER CONCRETE

To produce environmental friendly concrete, we have to replace the cement with some other binders which should not create any bad effect on environment. The use of industrial by products as binders can reduce the problem. In this respect, the new technology geo-polymer concrete is a promising technique. In terms of reducing the global warming, the geo-polymer technology could reduce the CO2 emission to the atmosphere caused by cement and aggregates industries by about

80% (Davidovits, 1994c). And also the proper usage of industrial wastes can reduce the problem of disposing the waste products into the atmosphere.

3. BENEFITS OF GEOPOLYMER CONCRETE

Geopolymer is better than normal concrete in many aspects such as compressive strength, exposure to aggressive environment, workability and exposure to high temperature. Geopolymer concrete has several economic benefits over conventional Portland cement concrete. Geopolymer concrete is cost effective against the conventional Portland cement concrete which has similar performance. It acts as a low-carbon and lesser energy consumption material and is a better alternative to traditional cement concrete and also reduces the carbon dioxide CO_2 emission and other environmental pollutions. Rock based geopolymer achieves 59% of energy needs whereas slag based geopolymer achieves 43% reduction in energy needs than a conventional concrete. Carbon emissions are also lower in geopolymer where reduction in 80% and 70% of carbon emission is achieved for rock based and slag based geopolymer respectively. Our aim is to have an alternative binder instead of Cement in Concrete. The reason is during the production of cement, higher amounts of Carbon dioxide is released into atmosphere and causes global warming. In this respect Geopolymer concrete is produced by replacing cement with Geopolymer binder which consists of Fly ash and alkaline liquids and also fine aggregate is replaced with quarry dust because it is most economical than fine aggregate.

4. LITERATURE REVIEW

DjwantoroHardjito, Steenie E Wallah, Dody M.J. Sumajouw, and B.V. Rangan (2011) describe the effects of several factors on the properties of fly ash based Geopolymer concrete, especially the compressive strength. The test variables included were the age of concrete, curing time, curing temperature, quantity geo-polymer of super-plasticizer, the rest period prior to curing, and the water content of the mix. They concluded that compressive strength of concrete does not vary with age, and curing the concrete specimens at higher temperature and longer curing period will result in higher compressive strength. They also concluded Naphthalene-based super-plasticizer improves the workability of fresh geo-polymer concrete.

D. M. J. Sumajouw D. Hardjito S. E. Wallah B. V. Rangan (2007) presents the results of experimental study and analysis on the behaviour and the strength of reinforced Geopolymer concrete slender columns. They concluded that heat-cured low-calcium fly ash-based geopolymer concrete has excellent potential for applications in the precast industry. The products currently produced by this industry can be manufactured using geopolymer concrete. The design provisions contained in the current standards and codes can be used in the case of geopolymer concrete products.

Shuguang Hu, Hongxi Wang, GaozhanZhang ,Qingjun Ding(2007) they prepared three repair materials by using cement-based, geo-polymeric, or geo-polymeric containing steel slag binders. They concluded that the geo-polymeric materials had better repair characteristics than cement-based repair materials, and the addition of steel slag could improve significantly the abrasion resistance of geopolymeric repair. By means of scanning electron microscopy (SEM) it can also be concluded that the steel slag was almost fully absorbed to take part in the alkali-activated reaction and be immobilized into the amorphous alumino silicate geopolymer matrix.

XiaoluGuo ,Huisheng Shi , Warren A. Dick(2009) they studied the compressive strength and micro structural characteristics of a class C fly ash geopolymer (CFAG) were studied. They concluded that a high compressive strength was obtained when the class C fly ash (CFA) was activated by the mixed alkali activator (sodium hydroxide and sodium silicate solution) with the optimum modulus viz., molar ratio of SiO_2/Na_2O of 1.5. When CFA is alkali activated the sphere seems to be attacked and broken due to the dissolution of alumino-silicate in the high pH alkali solution. Utilization of this fly ash in geo-polymer materials is a resource and energy saving process and it also indirectly reduces the emission of green house gas CO_2 released from cement manufacturing. This is beneficial for resource conservation and environmental protection.

SmithSongpiriyakij, TeinsakKubprasit,ChaiJaturapitakkul, PrinyaChindaprasirt(2010) they usedRice husk and bark ash as a source to partially replace fly ash in making geopolymer. They concluded that the optimum SiO_2/Al_2O_3 ratio to obtain the highest compressive strength was 15.9. Fly ash was more reactive than RHBA.

N A Lloyd and B V Rangan (2010) concluded based on the tests conducted on various short-term and long-term properties of the geo-polymer concrete and the results of the tests conducted on large-scale reinforced geo-polymer concrete members show that geo-polymer concrete is well-suited to manufacture precast concrete products that can be used in infrastructure developments. In this paper a simple method to design geo-polymer concrete mixtures has also described and illustrated by an example. The paper also includes brief details of some recent applications of geopolymer concrete

5. MATERIALS

5.1.Fly Ash

Fly ash is manufactured by the burning of coal in an electrostatic precipitator, a byproduct of industrial coal. The cementations properties of fly ash were discovered in late 19th century and it has been widely used in cement manufacture for over 100 years. In UK , fly ash is supplied as a separate component for concrete and is added at the concrete at the mixer. It generally replaces between 20 and 80 per cent of the normal Portland cement.

5.2. Ground-Granulated Blast-Furnace Slag

Ground-granulated blast-furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Ground -granulated blast furnace is highly cementations and high in CSH (calcium silicate hydrates) which is a strength enhancing compound which increases the strength, durability and appearance of the concrete.

5.3. Manufactured Sand (M-Sand)

Manufactured sand (M-Sand) is a substitute of river sand for concrete construction. Manufactured sand is produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand (M-Sand) is less than 4.75mm.

5.4. Quarry Dust

Now-a-days the natural river sand has become scarce and very costly. Hence we are forced to think of alternative materials. The Quarry dust may be used in the place of river sand fully. The world wide consumption of fine aggregate in concrete production is very high, and several developing countries have encountered difficulties in meeting the supply of natural fine aggregate in order to satisfy the increasing needs of infrastructural development in recent

5.5.10mm Coarse Aggregate

Coarse aggregates are any particles greater than 0.19 inch, but generally range between 3/8 and 1.5 inches in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.10mm crushed river aggregate to concrete production specification. Blue grey to brown in colour this aggregate can meet many job application. A hard and durable rock, washed and screened, with consistent cubic particle shape

5.6 Alkaline Activator

Alkaline activator solution used was a combination of sodium silicate solution and sodium hydroxide. An analytical grade sodium hydroxide in flakes form (NaOH with 98% purity) was used. To avoid effects of unknown contaminants in laboratory tap water, distilled water was used for preparing the activator solution. Activator solution was prepared at one day prior to its use in specimen casting.

5.7.Steel Fibres

Use of crimped steel fibres of aspect ratio (a/d) 60 is used. For the geopolymer mix we have used crimped stainless steel fibres and crimpes mild steel fibres. The use of fibres in concrete has the property to resisitance against cracking and crack propogation. The fibre composite pronounced post cracking ductility which is unheard of in ordinary concrete.

6. PROPERTIES OF MATERIALS USED FOR THE STUDY

Table 1 Chemical compositions of low calcium based fly-ash and GGBS

Particulars	Class F fly ash	GGBS
Silica(SiO_2)	65.0 %	30.74 %
Alumina(Al_2O_3)	28.9 %	16.31 %
Iron Oxide(Fe_2O_3)	3.7 %	0.572 %
Lime (CaO)	1.0 %	34.48 %
Magnesia (MgO)	1.0 %	6.81 %
Titanium Oxide (TiO_2)	0.5 %	-
Sulphur Trioxide (SO_3)	0.2 %	1.80 %
Loss on Ignition	0.32 %	2.1 %

Table 2 Physical Properties of Fly-ash class F and GGBS

Property	Fly-ash	GGBS
Specific gravity	2.23	2.87
Bulk density Kg/m^3	570-834	150-1300
Appearance	grey	Grayish white
Particle size	30 microns	25 microns
Fineness(m^2/kg)	353	400

Table 3 physical Properties of quarry dust

Property	Quarry rock dust	Test method
Specific gravity	2.60	IS 2386 (PartIII) 1963
Bulk relative density(kg/m3)	1700	IS 2386 (PartIII) 1963
Absorption (%)	1.30	IS 2386 (PartIII) 1963
Moisture Content(%)	Nil	IS 2386 (PartIII) 1963
Fineparticles less than 0.075mm (%)	14	IS 2386 (PartI) 1963
Sieve Analysis	Zone III	IS 383-1970

Table 4 chemical composition of quarry dust

constituent	Quarry Rockdust(%)	Test method
SiO2	62.48	IS: 4032-1968
Al2O3	18.72	
Fe2O3	06.54	
Cao	04.83	
Mgo	02.56	
Na2O	Nil	
K2O	03.18	

Table 5 Properties of coarse aggregate and fine Aggregates

Sno	Properties	10mm Coarse aggregate	M.sand
1.	Specific gravity	2.4	2.7
2.	Bulk Density	1530	1445
3.	Fineness modulus	6	4
4.	Water absorption	0.54%	1%

Table 6 The Properties of Steel Fibers

Material	Property
Type of Fiber	steel
Diameter	0.5 mm
Length	25mm
Aspect Ratio	50
Color	grey

Table 7 Properties of Alkaline Activators

Property	Sodium Silicate	Sodium Hydroxide
Appearance	Gel	Pellets
Density	2.5-2.9	2.13
Melting Point	1088 °C	318°C
Solubility	Insoluble In Alcohol	Insoluble In Acetone
Refractive Index	1.52	1,473-1,475

7. EXPERIMENTAL WORK

This Chapter describes the experimental work. First, Mix design of geo-polymer concrete, manufacturing and curing of the test specimens are explained. This is then followed by description of types of specimens used, test parameters, and test procedures. The conventional method used in the making of normal concrete is adopted to prepare geo-polymer concrete. First, the quarry dust, coarse aggregate and Fly a share mixed in dry condition for 3-4 minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution with super-plasticizer is added to the dry mix. The mixing is done about 6-8 minutes for proper bonding of all the materials. For the curing of geo-polymer concrete cubes, the cubes are placed in direct sun-light. For the sun light curing, the cubes are remolded after 1 day of casting and they are placed in the direct sun light for 7 days

Fig-1: Flyash Fig- 2: GGBS

Fig- 3: Sodium Silicate Fig- :4 Sodium Hydroxide

Fig- 5: Adding Alkaline solution to dry mix Fig- 6: Fresh geo-polymer concrete

8. INVESTIGATION ON MATERIAL TESTING

Tests to be conducted to determine the Mechanical properties of concrete

- ✓ Compression test
- ✓ Split Tensile test
- ✓ Flexural strength test
- ✓ Impact strength test
- ✓ Surface hardness test
- ✓ Modulus of Elasticity

Tests to be conducted to determine the Durability properties of concrete

- ✓ Water absorption test
- ✓ Sorptivity test
- ✓ Rapid chloride penetration test
- ✓ Permeability
- ✓ Acid resistance test

8.1. Compressive test

The compressive strength of concrete cubes of the different mixer are found out at the end of 21 and 28 56 days. The concrete cubes are tested for their compressive strength in the compression testing machine as per IS 516-1959 specifications. The rate of loading is applied 140 kg/sq.cm/min until the failure takes places. The ultimate loads of the concrete cubes are recorded.

8.2. Splitting tensile strength

The splitting tensile strength of concrete cylinders (150 mm dia & 300 mm ht) are tested as per IS 5816-1970 specification. The rate of loading shall be applied without shock increased continuously at rate to produce approximately a splitting tensile stress of approximately 14 to 21 kg/cm2/min until specimen failure be recorded. The splitting tensile strength τ of the specimen shall be calculated from the following formula.

τ = 2P/ πdl kg/cm2

P = maximum load in kg applied to the specimen.
D = measured diameter in cm of the specimen.
L = measured length in cm of the specimen.

8.3 Modulus of rapture

The modulus of rapture of the beam (100mm x 100mm x 500mm) is tested in UTM as per IS : 516-1959 specifications. The rate of loading applied 180 kg/sq.cm/min. the shall be increased until the specimens fails, and the maximum laod applied (P) to the specimen during the test shall be recorded.

Modulus of rapture P = M/ I = σ/ Y ;I = bd3/12; Y= D/2

Where,
M = Moment
D = measured depth in cm of the specimen at the point of failure.
I = Moment Of Inertia.
P = maximum load in kg applied to the specimen.

8.4 Preparation of Test Specimens

The ingredients for the various concrete mixtures were weighed and casting was carried out using a pan mixer. Precautions were taken to ensure uniform mixing of ingredients. The specimens were cast in steel moulds and compacted on a table vibrator by placing the concrete in the moulds in three equal layers and compacting with the table vibrator after placing each layer. The specimens were cured in sunlight on demoulding after 24 hours.

8.5 Mechanical Properties

Compressive strength tests were done on cube concrete specimens at different ages as per the procedure specified in IS:516-1959. Cylindrical concrete specimens were tested .The flexural tests were carried out on beam specimens under standard two-point loading, while the split tensile strength was determined by subjecting to diametric compression.

9. CONCLUSION

Incorporation of steel fibers had enhanced the mechanical properties of geopolymer concrete. Based on the experimental work reported in this study, the following conclusions are drawn.Higher concentration (in terms of molar) of sodium hydroxide solution results in higher compressive strength of fly ash & quarry dust based geo-polymer concrete.The mix GPC gives higher compressive strength, as it has high molarity of NaOH.We Observe that the compressive strength is increased with the increase in the molarity of the sodium hydroxide. The split tensile strength has shown better performance compared to compressive strengths.

REFERENCES

1. D. Hardijito, S. E. Wallach, and B. V. Rangan, Study on engineering properties of fly ash- based geopolymer concrete, Journal of the Australasian Ceramic Society, vol. 38, no. 1, pp. 44-47, 2002.
2. D.N.Kumar Abrasion Resistance of Polypropylene Fiber Reinforced Geopolymer Concrete. Journal of emerging technologies and innovative Research. Issue 11 vol: 4 Nov 17.
3. Specification for Course and Fine Aggregates from the Natural Sources for Concrete, Bureau of Indian Standards, IS: 383-1970. Method for Physical Tests for Hydrated Cement, Bureau of Indian Standards, IS: 4031 – 1988.
4. A.M.N.Kashyap, T. Chandrasekhara Rao, N.V.Ramana Rao Prediction of Setting and Strength Characteristic of Binary Blended Geopolymer Matrix. I-manager's Journal on Structural Engineering, 6(4), 16-22.
5. Kallempudi Murali, Meena T, Chaitanya Srikrishna T, Peta Purnachandra Sai An experimental study on factors influencing the Compressive strength of geopolymer mortar. International Journal of Civil Engineering and Technology (IJCIET) Volume 9, Issue 1, January 2018.
6. dPeta Purnachandra Sai and Meena T, A Review of Ternary Blended Hybrid Fibre Reinforced Concrete. International Journal of Civil Engineering and Technology, 9(1), 2018, pp. 314-319.