IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Geopolymer Concrete for Rigid Pavement by Using Fly Ash of Unchahar Thermal Plant

[1]Upendra Pratap Singh, [2]Vaibhav Dubey

[1]Student, Transportation Engineering (Civil Engineering), Rama University, Kanpur, Uttar Pradesh, India

[2]Assistant Professor, Civil Engineering Department, Rama University, Kanpur, Uttar Pradesh, India

Abstract: Geopolymer concrete is the new development in the field of building constructions in which cement is totally replaced by pozzolanic material like fly ash and activated by alkaline solution. In this thesis the effect of concentration of sodium hydroxide, temperature, and duration of oven heating on compressive strength of fly ash-based geopolymer concrete were studied. Sodium silicate solution (Na2SiO3) containing NaO of 16.45%, SiO of 34.35%, and H O of 49.20% and sodium hydroxide solution of 3M, 4M, 7M,8M,16M,and18M. Moles concentrations were used as alkaline activators. Geopolymer mortar mixes were prepared by considering solution-to-fly ash ratio of 0.35, 0.40, and 0.45. The temperature of oven curing was maintained at 60°C, 90°C, and 120°C each for a heating period of 24 hours and tested for compressive strength at the age of 7 & 28 days as test period after specified degree of heating. Test results show that the workability and compressive strength both increase with increase in concentration of sodium hydroxide solution for all solution-to-fly ash ratios. Degree of heating also plays vital role in accelerating the strength**.** In this thesis presents the development of fly ash-based geopolymer concrete. In geopolymer concrete, a by-product material rich in silicon and aluminum, such as lowcalcium Class F fly ash, is chemically activated by a high-alkaline solution to form a paste that binds the loose coarse and fine aggregates and other unreacted materials in the mixture. The test results presented in this thesis show the effects of various parameters on the properties of geopolymer concrete.

Index Terms **- Geopolymer, Concrete, Fly Ash, Dr. Fixit, Pozzolanic, Unchahar, NTPC**

Introduction

Concrete is the building material that is widely used by communities around the world and the cement industry needs a lot of energy. Concrete is a versatile, durable and reliable building material. Ordinary concrete is made of good and strong adhesives, water, standard Portland cement (OPC) and chemical compounds. Ordinary Portland Cement (OPC) is an important asset in the production of concrete that covers all components. Cement production (production) will increase from 3.0 billion tons / year in 2013 to 4.0 billion tons by 2050 (Dr. Martin, 2011). India is the second largest producer of cement after China. In India, cumulative growth in cement production was 6.7% in April-Nov. 2012-2013 compared to its growth of 4.8% over the same period of 2011-2012. (Ministry of Commerce Industries Gov. of India. November 2012). The geopolymer technology proposed by Davidovits (1988) in this great promise for use in the concrete industry as an integral part of ordinary Portland cement (OPC). Reducing global warming with geopolymer technology can reduce carbon dioxide emissions from cement plants and plant vegetation by about 70-80% (Davidovits 1994b). The impact is significant in India with the current annual production of about 99 million tons of cement and the release of more than 91 million tons of carbon dioxide. On the other hand it is important to develop new technologies and processes for other cement and concrete materials in order to reduce the increase in carbon dioxide emissions caused by increased cement production in Portland. In addition, these new technologies will reduce the shrinkage of raw materials (especially limestone) and the natural gas (Coal) used to produce cement. In this project a study of fly ash-based geopolymer concrete, which focuses on the formation of three-phase alloys namely lower, middle and upper layers has been developed and tested for compressive strength. Fly ash is found in the burning of charcoal in industrial boilers or in electric boilers. There are four types of coal-fired boilers: (i) sharp charcoal (PC), (ii) stoves, (iii) hurricanes, and (iv) flammable bed boilers. Crushed coal boiler is the most widely used mainly to produce large units of electricity. Some boilers are widely used in industrial or mixed areas. Fly ash is collected in exhaust gases using electrostatic precipitator collectors. The chemical and physical properties of fly ash depend on (i) combustion methods, (ii) coal source, and (iii) particle shape. The impact is significant in India with the current annual production of about 99 million ton of cement and the consequent release of over 91 million ton of carbon dioxide. In other hand it is essential to develops new technologies and practices for alternative cement and concrete compositions in order to curtail the rising carbon dioxide emissions caused by increased Portland cement production. Furthermore, these new technologies will slow down the depletion of raw material (mainly limestone) and fossil fuel (Coal) used for cement production. In this project the study on fly ash-based geopolymer concrete, focused on mix design for three grades i.e. low and medium grades have been arrived and tested for compressive strength.

For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

1.1 Properties of Fly Ashes.

Properties:

1. Color: Gray Cement
2. Bulk density: 1550 Kg / m^3
3. Unit Weight: 2.6 - 3.0 Kg.
4. Water Absorption: 12 - 16%
5. Crush Power: 80 - 120 Kg / m^2

UTILIZATION OF FLY ASH IN CIVIL ENGINEERING WORKS

1. Fly ashes as cement production equipment.
2. Fly ash in the construction of the Embankment
3. Apply ash to flexible areas
4. Use of ash on concrete (pre-mixed concrete)
5. Fly ash is used to make lightweight aggregates.
6. Use of Fly ash as a waste disposal site.
7. Using ashes to strengthen the road.

1.2 FLY ASH CLASSIFICATION

Manz and others (1982) have suggested that high-calcium fly ashes (the socalled Class C ashes) are best distinguished from the low-calcium (Class F) ashes by their cementing properties. Thus, a general term 'mineral admixtures' has been suggested to describe all classes of slugs, ashes, pozzolans and other cement supplements, with a further distinct on being drawn on the basis of their self-cementing capabilities.

1.3 FINENESS

Puri (1975) has stated that fineness is one of the principal parameters to be considered for fly ash to be added to cement, as it influences the rate of development of mechanical strength and relative values to be attained. However, there is an optimal fineness above which the increase in strength becomes less significant, due to the increase in the specific surface.

1.4 CHEMICAL COMPOSITION OF FLY ASH

Table No. 1, Chemical composition of fly ash

Chemical composition	Percentage %
Silica (SiO_2)	49-67
Alumina (Al_2O_3)	16-29
Iron Oxide (Fe_2O_3)	4-10
Calcium Oxide (CaO)	1-4
Magnesium Oxide (MgO)	0.2-2
Sulphur (SO_3)	0.1-2
Loss of Ignition	0.5-3.0

1.5 SOURCE MATERIALS AND ALKALINE LIQUIDS

There are two main constituents of geopolymers, namely the source materials and the alkaline liquids. The source materials for geopolymers based on alumino-silicate should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, micas, andalousite, spinel, etc whose empirical formula contains Si, Al, and oxygen (O) (Davidovits, 1988c). Alternatively, by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc could be used as source materials. The choice of the source materials for making geopolymers depends on factors such as availability, cost, and type of application and specific demand of the end users. The alkaline liquids are from soluble alkali metals that are usually sodium or potassium based.

1.6 PROPERTIES OF GEOPOLYMERS

Previous studies have reported that geopolymers possess high early strength, low shrinkage, freeze-thaw resistance, sulfate resistance, corrosion resistance, acid resistance, fire resistance, and no dangerous alkali-aggregate reaction.

Based on laboratory tests, Davidovits (1988b) reported that geopolymer cement can harden rapidly at room temperature and gain the compressive strength in the range of 20 Mpa after only 4 hours at 20^{o}C and about 70-100 Mpa after 28 days. **Comrie et.al, (1988)** conducted tests on geopolymer mortars and reported that most of the 28-day strength was gained during the first 2 days of curing.

Subhas v. Patankar et.al., 2013 the compressive strength of geopolymer concrete is inversely proportional to water to geopolymer- binder- ratio similar to water –to- cement ratio in cement ratio in cement concrete. Suitable range of water-to-geopolymer binder ratio is in the range of 0.25 to 035. Higher ratio gives segregated mix while lower ratio gives viscous and dry mix.

The slump value of the fresh fly ash based Geopolymer concrete decreases with increases in fly ash content of the mixture. The flexural strength of the fly ash based Geopolymer concrete is a fraction of the compressive strength, as in the case of OPC based concrete. The measured values are higher than recommended values in IS: 456-2000. Geopolymeric cement was superior to Portland cement in terms of heat and fire resistance, as the Portland cement experienced a rapid deterioration in compressive strength at 300°C, whereas the geopolymeric cements were stable up to 600°C (Davidovits, 1988b; 1994b). It has also been shown that compared to portland cement, geopolymeric cement has extremely low shrinkage.

2. OBJECTIVES OF THE PROPOSED STUDY

i. To check suitability of fly ash available abundantly in India (Sarni thermal power plant M.P) for making concrete using recent Geopolymer technology.
ii. To establish some graphical relationship between Alkaline Liquids, temperature, workability and strength of fly-ash based geopolymer Concrete.
iii. To ascertain design parameters like alkaline liquid to fly ash ratio for development of the Geopolymer concrete.
iv. To carry out cost benefit analysis on normal concrete with the similar products using Geopolymer Concrete using maximum utilization of fly ash.

3. RESEARCH METHODOLOGY

This section of study describes the proposed experimental work. First, the materials, mixture proportions, manufacturing and curing of the test specimens are explained. This is then followed by the proposed tests to be conducted, expected outcome and plan about time scheduling of research.

EXPERIMENT NO.1

DESIGN MIX OF G 40. (For 1m^3 volume of geopolymer concrete)

Density of aggregate of concrete = 2400 kg/m3. (As per IS: 456)
Mass of solid aggregate = 72-82 % (consider 0.77%) = 2400 x 0.77% = 1848 kg/m3
Mass of solid aggregate = 1848 kg/m3
Mass of Fly ash and alkaline Liquid = 2400-1848 = 552 kg/m3 Take alkaline liquid to fly ash ratio as 0.4,
Now the mass of fly ash = (552)/(1+0.4) = 394.29 kg/m3 Mass of alkaline liquid = 552-394.29 = 157.22 kg/m3
Consider the ratio of sodium hydroxide to sodium silicate solution, as 2.5.
Now mass of sodium hydroxide (NaoH) solution = (157.22)/(1+2.5) = 45.059 kg/m3
Mass of sodium silicate solution (Na_2sio_3) solution = 157.22- 45.059 = 112.63 kg/m3
Mass of Coarse aggregate = 1202.19 kg
Calculating the total amount of mass of water and mass of solids in the sodium hydroxide and sodium silicate solution,
Sodium Hydroxide solution (NaoH) Consider 16M concentration, in the solution consists of 44% of solids and 62% of water.
Mass of solids = (44.4/100) x (45.06) = 20.01 Kg Mass of water = 45.06 - 20.00 = 25.07 Kg.

Sodium Silicate Solution (Na2sio3):
The water percentage in the silicate solution in observed as 64%. So the Mass of Water = (63/100) x (112.63) = 71 Kg
Mass of solids = 112.63 – 71 = 41.63 Kg
Total mass of water:
Mass of water in Sodium Hydroxide solution and mass of water in Na_2sio3. Solution = 25.06 + 71 = 96.56Kg.
Total mass of solids:
Mass of solids in sodium hydroxide solution and Mass of solids in sodium silicate solution and Mass of Fly ash = 20.00 + 41.63 + 394.29 = 456 Kg.
Ratio of water to Geopolymer Solids: Ratio = (96.56) / (456) = 0.22.

EXPERIMENT NO.2

DESIGN MIX OF G 40.
Design data-
Total volume of 3 cube and 1 slump cone geopolymer concrete = 0.025m^3
Molarity = 18M
The ratio of sodium silicate to sodium hydroxide = 2.5 Ratio of Fine aggregate to total Aggregate = 0.35
Calculations of quantity of materials-
Mass of combined aggregates = 1848 x 0.025 = 46.2 kg Mass of fly ash = 394.28 x 0.025 = 9.857 kg
Mass of alkaline liquid = 157.21 x 0.025 = 3.93 kg Mass of NaOH solution = 45.06 x 0.025 = 1.126 kg Mass of N_2Sio_3 solution = 112.64 x 0.025 = 2.816 kg
Considering 16M concentration, where in the solution consists of 44.4% of solids (pallets) and 63.5% of water.
Mass of solids = (44.4/100) x (1.126) = 0.499 Kg Mass of water = 1.126 – 0.499 = 0.627 Kg
Sodium Silicate Solution (Na_2sio_3)
The water content in the silicate solution in observed as 63.5%. So, the Mass of Water = (63.5/100) x (2.816) = 1.788 Kg
Mass of solids = 2.816– 1.788 = 1.028 Kg.

Total mass of water:
Mass of water in NaoH solution and mass of water in Na_2sio3. Solution = 0.627+1.788 =2.415Kg.
Total mass of solids:
Mass of solids in NaoH solution and mass of solids in Na_2sio_3 solution and mass of Fly ash = 0.499 + 1.028 + 9.857 = 11.384 Kg.
Fine Aggregates = 646.8 x 0.025 = 16.17 kg
Coarse aggregates = 1201 x 0.025 = 30 kg.

3.1 EXPERIMENTAL PROCEDURE OF SOLUTION

The sodium hydroxide (NaOH) solid were mixed in fresh distilled water to make a solution with a required concentration at least one or two days before to use. The aggregates and fly ash are first mixed together in a mixer for 3 or 4 minutes. The sodium hydroxide and the sodium silicate solutions were mixed together with super-plasticizer just before use and the extra water and other dry materials and mixed for four minutes. The fresh concrete was cast into the molds immediately after mixing, in three layers and compacted with 25 blows per layers with vibrating machine. After that, the specimens were cured at 60°C for 24 hours. After that curing was applied heat curing or ambient curing? For heat curing, the specimens were cured in an oven. The heat cured specimens were kept in air dry in the laboratory for the next seven days until testing on the 7th day and 28th day.
Each grade of Geopolymer concrete mix 4 mixture proportions were tested and optimized by taking the mix which is giving maximum compressive strength at 28 days under Heat curing or oven curing. Based on earlier project work conducted in Materials testing lab by me.

4.2 TESTING

After preparation of samples following tests are proposed to be carried out on the specimen as per relevant BIS codes on concrete

a) **Compressive strength test**

The compressive strength is the ratio of maximum load applied to the specimen till failure and surface area of one cubes and the bearing capacity of a material to withstand loads tending to reduce size. It can be find out by applied force against deformation in a testing machine.

Proportion of materials: - fly ash: sand: agg = 1: 1.64: 3.06 Quantity of fly ash = 9.8 kg
Quantity of sand = 16.kg Quantity of aggregate = 30 kg
Quantity of solids (Na2sio3) = 1.028 Kg Quantity of solids (NaOH) = 0.499 Kg

Table No.-2, Compressive strength result of specimen Cube

Sample no.	Grade	Age(days)	Surface area (mm)	Compressive strength
1.	G40	7	150x150	22.23
	G40	14	150x150	28.45
	G40	28	150x150	36.04
Heat cured specimens @ 60^{0}C,for 24hrs				
Slump value (true slump)				10mm
Compaction factor				0.86

5. RESULTS

On the basis of the experimental procedure carried out on low and medium strength geopolymer concrete the obtaining data can be explain in the given form.

Fig 5.1: Geopolymer concrete cubes ready for testing

Fig 5.2: Geopolymer concrete cube during heat curing in oven

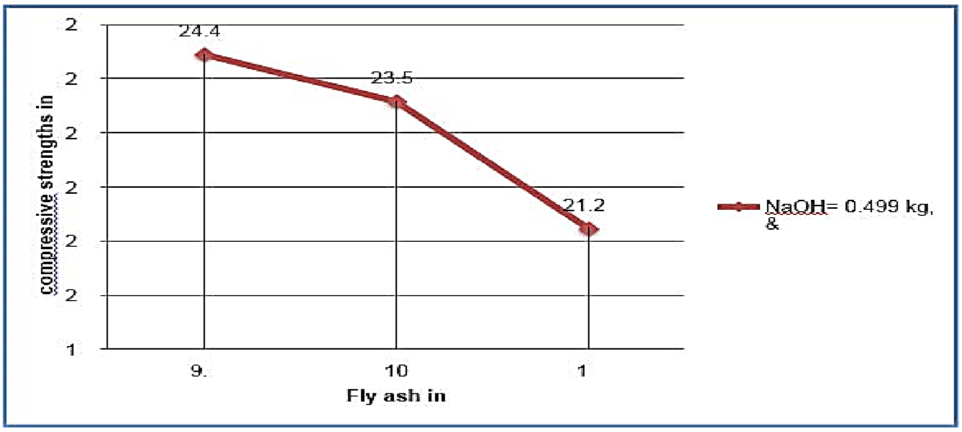
Table No. 3 Design data for fly ash based geopolymer concrete mixtures

Description	**Present work**		**Previous work**	
Compressive Strength, N/mm^2	20	40	20	40
Alk. liquid/ Flyash ratio	0.50	0.40	-----	0.40
Water/ Geopoly mer solids ratio	0.28	0.21	-----	0.21
Workability (Slump)	High	Mode rate	------	Mode rate

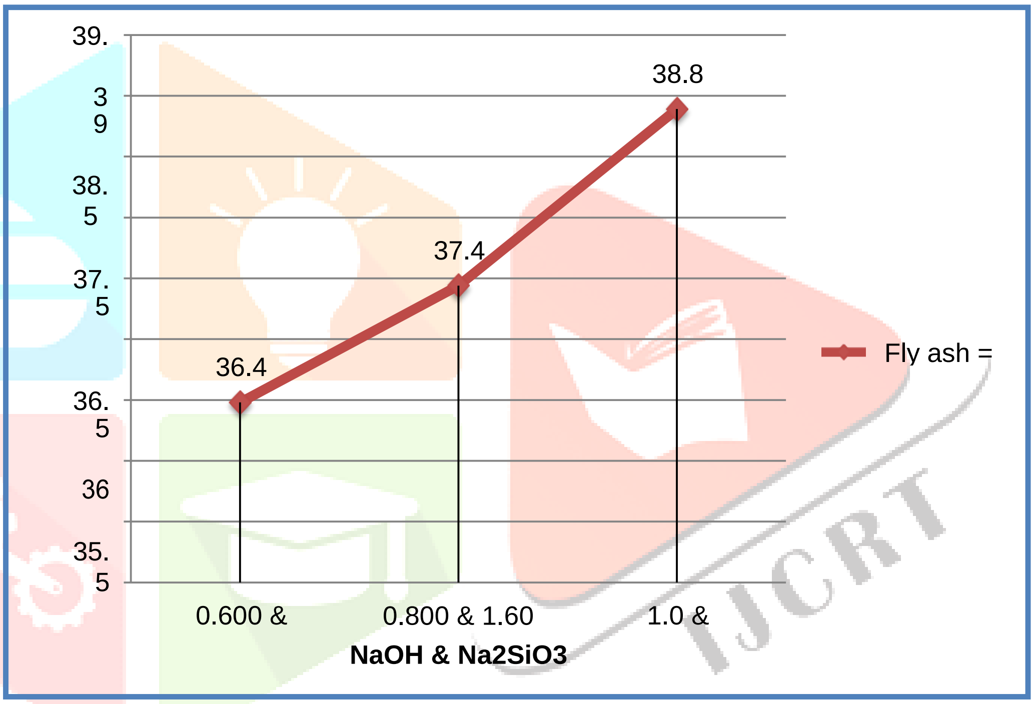
Compressive strength tests were performed on the age of 3 days, 7 days and 28 days in one thousand (1000 KN) compression testing machine (CTM) with uniform rate of 14 N/mm^2 per minutes load applied for Geopolymer concrete mixes . From the results it was seen that the compressive strength increases with increase in the fly ash content and decrease of water to geopolymer solids ratio for G20 and G40. It is also seen that 85% - 90 % of strength is obtain within 7 days and there is not much variation in strength after 7 days under heat cured conditions.

The nature of geopolymer concrete for all grades is similar to the conventional mixes. The effect of alkaline liquid to fly ash ratio and molar concentrations of sodium hydroxide (NaOH) on the compressive strengths geopolymer concretes for low and medium grades are shown in graphs.

Graph no.-1 Graphical relationship between alkaline liquids, workability and strength of fly- ash based geopolymer concrete



Graph no.-2 ***Graph of G40 for 28 days compressive strength***



6. CONCLUSION

1. From the above result it is seen that for water to binder ratio and alkaline liquid to fly ash ratio are the important factors in designing the Geopolymer mix design (GMD) for different grades. The water to binder ratios of 0.28, 0.21 & 0.16 and Alkaline liquid to fly ash ratios of 0.50, 0.40 &0.35 are suggested for G20 and G40.
2. The decrease in water content favors the formation of geopolymerization process which demands for increase of concentration of Sodium hydroxide and sodium silicates. Hence increase in concentration of sodium hydroxide (NaOH) results in increase of compressive strength. Hence it is recommended 6M, 16M and 18M concentrations for Low medium and higher grades respectively.
3. It is recommended to added Super plasticizers for high strength Geopolymer concretes (GPC). This is analogous to Conventional concrete of higher grades to secure required workability.
4. For Lower grade of geopolymer concrete definite mix design procedure is not available in the past literature which was incorporated in the present work.

Geopolymer concrete has outstanding properties as discussed earlier so it can be very useful for rehabilitation and retrofitting works. It can also be used in road works because of its very early attainment of strength. The financial benefits and involvement of geopolymer concrete to sustainable development have also been outlined. The geopolymer concrete is a whole new concept of structural concrete with a new technology and since no Indian Standards are available so a detailed study on the chemistry behind the polymerization is desired. So a new method can be there rather than the conservative mixing procedure which is obtained for the mixing of geopolymer concrete.

REFERENCE

1. Andi Arham Adam, Horianto (2014) "The effect of temperature and duration of curing on the strength of fly ash based geopolymer mortar" Procedia Engineering.
2. ASTM (1985) -"ASTM standard test method for unconfined compressive strength of soil." ASTM D216 – Philadelphia.
3. Balaguru Al (1997) reported the results of the investigation on using geopolymers,
4. Behzad Nematollahi, Jay Sanjayan (2014) "Effect of different super plasticizers and activator combinations" Materials and Design 57, Elsevier 667–672.
5. Chandan Kumar, Krishna Murari, C.R.Sharma (2014) "Strength Characteristics of low calcium fly ash based Geopolymer Concrete" IOSR Journal of Engineering, ISSN 2250-3021, ISSN 2278-8719, Vol. 04, Issue 05,.
6. Cheng and Chiu (2003) restudy of making fire-resistant geopolymer concrete using granulated blast furnace slag.
7. Comrie et.al (1988) "Conducted tests on geopolymer mortars and reported that the 28 day strength was gained during the first 2 days of curing."
8. Davidovits, J. (1988) "Soft Mineralurgy and Geopolymers. Paper presented at the Geopolymer "88, First European Conference on Soft Mineralogy France."
9. International Conference on Recent Advances in Concrete Technology, Las Vegas, USA.
10. IS: 516-1959 – Methods of tests for strength of concrete.
11. IS: 456 – 2000 Indian Standard Plain and Reinforced Concrete code of Practice
12. IS: 516-1959, "Method of test for strength of Concrete", Bureau of Indian Standards, New Delhi
13. IS-2386-1963,"Method of test for Aggregate concrete, Bureau of Indian Standards, New Delhi.
14. Report of Central Energy Agency (CEA) GOI, December 2012.
15. Report of International Energy Agency (IEA),2012
16. Effect of molarity in geopolymer concrete.
17. Fly ash- based geopolymer mortar incorporating bottom ash.
18. Geopolymer materials based on fly ash.
19. Strength and setting time of lao calcium fly ash – based geopolymer mortar.
20. Is geopolymer concrete a suitable alternative to traditional concrete?
21. Effect of NaOH concentration in manufacture of geopolymer fly ash building bricks.
22. Carbon dioxide equivalent (CO 2 -e) emissions: A comparison between geopolymer and OPC cement concrete.