INVESTIGATION ON HIGH CALCUIM FLYASH BASED GEOPOLYMER CONCRETE

T. DEEPIKA

Assistant Professor, Dept. of Civil Engineering, ARS College of Engineering,

Kanchipuram (Maraimalai Nagar), Tamil Nadu, India. Email: deepikadeeps29@gmail.com

K. KAMALARANI

Assistant Professor, Dept. of Civil Engineering, E.G.S Pillay Engineering college,

Nagaipatanam, Tamil Nadu, India. Email: kk0508699@gmail.com

ABSTRACT

Fly ash utilization in different forms in structural and non-structural concrete is an existing phenomenon in construction industries of all the countries producing fly ash, and high volume utilization is a substantial development. However class C fly ash being calcium high in composition has been used only in a restricted manner for reinforced concrete due to problem of corrosion of the reinforcing steel. Therefore an attempt is initiated through this thesis for investigation on high calcium flyash based geopolymerconcrete with the class C fly ash available as a quantum waste at the Thermal power station in Neyveli Lignite Corporation. A thorough study is made on the literature available and a formulation is arrived. Here 100% of cement is replaced by fly ash. Preliminary trial mix for M30 to M40 concrete is arrived and executed. The results obtained are encouraging.

1. INTRODUCTION

Concrete has been quit longer used in construction industries for its derived advantages like mouldbility, viability and feasibility. But the increasing demands on the strength and durability. Characteristics, tends to make concrete accompanied with some additives or admixtures or both for specific purpose. A new generation concrete having durability and in addition to strength is the current thinking of the concrete researchers.

There are two major problems

- The consumption of ordinary Portland cement (OPC) caused pollution to the environment due to the emission of co2. As such, alternative material had been introduced to replace OPC in the concrete. The reduction in the co2 emission from cement production can be contributes significantly to the turning down of the global thermostat.

- Fly ash is a by-product from the coal industry, which is widely available in the world. Moreover, the use of fly ash is more environmental friendly and save cost compare to OPC. Fly ash is rich in silicate and alumina, hence it react with alkaline solution to produced alumino silicate Gel that binds of the aggregates to produce a good concrete.

1.1 NEED OF THE STUDY

The greatest challenge for any technology looking to be adopted in the construction industry is fundamentally two –fold .They are the technological and engineering aspects and the certification of the product in the market . As Geo polymer are made from materials such as fly ash and these raw materials are vary from source to source and so they require a large investigation in formulation and certification from each source .The successful adoption of geopolymer technology in the future will be governed by a host of factors ,including the ability to add significant value of fly ash as well as the potential to significantly reduceCo2 emission compared to cement manufacture .Further GPC is a new material in india and is still need a matter of research and development investigations .The suitability of raw materials in India for production of structural grade GPC has been explored in detail .The possibility of producing structural grades of concrete using GPC mixes and conventional concreting tool has not been well established in Indian context as most of the studies have been confined to miniature specimens .The structural behavior of reinforced GPC's has been investigated to a limited extent in Australlia, Malaysiya and India .They all had done with different mix proportions and with different grades of concrete.

1.2 OBJECTIVES AND SCOPE

Class C fly ash is available in plenty at Neyveli Lignite Corporation (NLC) where structural utilization is seldom thought off. Fly utilization for structural concrete using class C fly ash is not under consideration due to the ill effects of fly ash with the reinforcing steel. Therefore, a preliminary study on utilization of such high calcium class C fly ash of NLC has proposed and initiated.

- Design a GPC mix of grade M_{30}&M_{40}
- Determine the strength properties
- Determine the durability properties

- Establish the strength relationships of the developed GPC

2.OBJECTIVES AND SCOPE

2.1 OBJECTIVES

- Literature survey of Class C flyash in GPC
- Identification of the problem
- Deciding the methodological approach
- Procuring of the constituent materials
- Determination of properties of constituent materials
- Design of GPC mix Fabrication of control specimens
- Testing for strength properties
- Analysis of test results
- Presentation of conclusions and recommendations

2.2 PROPOSED PLAN

- Determination of durability characteristics of GPC
- Analyzing the strength and durability characteristics
- Presentation of recommendations and recommendations on GPC

2.3 Materials and properties

Table 1 Materials and properties

S. No	Description	Values
1	Specific gravity of fine aggregate	2.64
2	Specific gravity of coarse aggregate	2.74
3	Specific gravity of cement	3.14
4	Specific gravity of fly ash	2.4
5	Sand confirming zone-II (IS-383-1970)	

Following are the basic materials used for the preparation of Geopolymer concrete:

- Fly ash (source material)
- Aggregates (Coarse and Fine aggregate)
- Alkaline solution (Activators)
- Water

In the present experimental work, high calcium, Class C fly ash is used and it is obtained from the thermal Power station of Neyveli Lignite Corporation. Specific gravity of fly ash 2.4.

2.4 AGGREGATES

2.4.1 Fine and Coarse Aggregate

Locally available clean river sand was used as fine aggregate in the study. Fineness modules of fine aggregate are 2.69 and Specific gravity is2.64. The fine aggregate used conforms to Zone-II as per IS: 383-1970.

The locally available crushed granite of size 12.5 mm below was used as the coarse aggregate. Specific gravity of coarse aggregate is 2.82.

2.4.2 Sodium hydroxide

NaOH with 97-98% purity ,in flake or pallet from is commercially available. Sodium hydroxide solution was prepared by mixing the required quantity of pallets of NaOH in distilled water. This solution was prepared one day before the casting of concrete to allow the exothermic process and to reduce heat because it generates more heat while mixing with water. NaOH can be varying in the range of 8 molar to 16 molars.

2.4.3 Sodium silicate

Sodium silicate is also represented as water glass or liquid glass and it is used in textile industry as a bonding agent. Here it was mixed with sodium hydroxide solution prior to batching. The chemical ingredients are Sio2-29.4% and Na2O-14.7% and water-55.9% by mass.

2.4.4 Alkaline Solution

Sodium silicate and sodium hydroxide were used to prepare alkaline solution to react with the aluminum and the silica in the fly ash. Commercially available sodium silicate was used for this experimental work with water content of 31.6%. Sodium hydroxide of 12 molars concentration solution was prepared by dissolving sodium hydroxide flakes with 97% purity in the water. The ratio of sodium silicate to sodium hydroxide solution was fixed as 2.5.

2.4.5 Mix design for GPC

Mix ratio for 1m3 of GPC concrete M30=1:1.5:3.52 M40=1:1.37:3.21

Table 2 Mix design of GPC

S. no	DESCRIPTION	QUANTITY	
		M_{30}(Kg/ m^3)	**M_{40}(Kg /m^3)**
1	Fly ash	380.69	402.92
2	Fine aggregate	554	554
3	Coarse aggregate	(12mm) 1294	(12mm) 1294
4	Na_2Sio_3/ NaOH	2.5	2.5
5	Na_2Sio_3+NaOH/Fly ash	0.45	0.37
6	Sodium silicate(Na_2Sio_3)	122.36	106.49
7	Sodium hydroxide	49	42.59
8	24 Hours Curing	Steam @60^0c	Steam @60^0c

3. RESULTS

3.1 Compressive Strength Test

The bottom of the concrete cube is placed on the platform of the compression testing machine. The load is applied gradually till the concrete cube gets failed. The corresponding reading is noted which gives the compressive strength of that cube. Similarly the compression strength values of all cubes are found.

For each mix cubes of size 100mm were cast to determine the compressive strength using a 200T capacity Compression Testing Machine (CTM). Tests were carried out an different ages on 28days, 56days and 91days respectively. Tests were conducted as per IS 516-1959

Compressive strength = P/A

Where, P = Ultimate load in N

A = Area of the cube in mm^2

Fig: 1 Experimental setup for Compressive strength

In the case of cubes, the specimen is placed in the machine in such a manner that the load is applied to opposite sides of the cubes as cast. The axis of the specimens is carefully aligned with the center of thrust of the spherically seated plate. A spherically seated block is brought to bear on the specimen; the movable portion is rotated gently by hand so that uniform seating may be obtained. The load is applied without shock and increased continuously until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load to the specimen is then recorded. The results have been obtained from the tables below.

The compressive and tensile strength test on hardened fly ash- based geopolymer concrete were performed on a 2000 KN capacity hydraulic testing machine in accordance to the relevant Indian standards. Three 100mmx100mmx100mm concrete cubes were tested for every compressive strength test.

Compressive strength=Ultimate load /Area of specimen N/mm^2

Compression test is the most common test conducted on hardened concrete partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete and qualitatively relative to its compressive strength. The compression test is carried out on specimen's cubical and cylindrical strength. The cube specimen is of the size 100mmx100mmx100mm if the largest nominal size of the aggregate does not exceed 12.5mm, testing of compressive strength of cube and cylinders are shown in figure 2. The cubes test results are shown in table 3. Cylindrical test specimens have length equal to twice the diameter. They are 100mm in diameter and 200mm long, the cylinders test results are shown in table 3.

Table 3 Compressive Strength of Geopolymer Concrete Cubes

S. No	Grade of Concrete	Area (Mm^2)	Ultimate Load (KN)	Compressive Strength (N/Mm^2)	Average Compressive Strength (N/Mm^2)
1	M 30	10000	386.5	38.65	38.5
2		10000	379	37.9	
3		10000	392	39.2	
1	M 40	10000	456	45.6	46.23
2		10000	469	46.9	
3		10000	462	46.2	

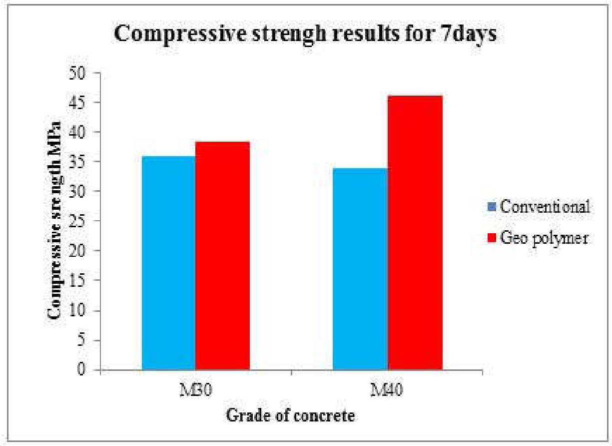

Fig: 2 Compressive strength results for 7days

3.2 Flexural Strength of Concrete

The test specimen shall confirm to all requirements of tests method C 42 or practices C 31 or C 192 applicable to beam and prism specimens and shall have a test span within 2% of being three times its depth as tested. The sides of the specimen shall be smooth and free for scars, identification, holes, or inscribed identification marks.

Flexural tests of moist-cured specimens as all be made as soon as practical after removal from moist storage. Surface drying of the specimen results in a reduction in the measured flexural strength.

Fig 3: Universal test setup for flexural

When using molded specimens, turn the specimen on its side with respect to its position as molded and center it on the support blocks. Center the loading system in relation to the applied force. Bring the load applying blocks in contact with the surface of the specimen at the third points and apply a load of between 3 and 6% of the estimated ultimate load. Using 0.004 in (0.10mm) and 0.015 in (0.38mm) leaf type feeler gages, determine whether any gap between the specimen and the load applying or support blocks is greater or less than each of gages over a length of 1 in (25mm) or more. Grind, cap, or use leather shims on the specimen contact surface to eliminate gap in excess of 0.004 in (0.10mm) in width, leather shims shall be of uniform ¼ in (6.4mm) thickness, 1 to 2 in (25 to 50mm) width, and shall extend across the full width of specimen. Gaps in excess 0.015 in (0.38mm) shall be minimized as grinded may change the physical characteristics of the specimens.

Load the specimen continuously and without shock. The load shall be applied at a constant rate to the breaking point. Apply the load at a rate that constantly increases the extreme fibers stress between 125 and 175psi/min (0.86 and 1.21 MPa/min), when calculated in accordance with 8.1 until rupture occurs.

Take the three measurement across each dimension (one at each edge and at the center) to the nearest 0.05 in.(1mm) to determine the average width average depth, and line of fracture location to the specimen at the section of failure, if fracture occurs at a capped section; include the cap thickness in measurement. If the fracture in the tension surface within middle third of the span length, calculate the modulus of rupture as follows

$$R = PL/bd^2$$

Where,

R = Modulus of rupture, psi, or MPa

P = Maximum applied load indicated by the testing machine, lbf, or N,

L = Span length, in., or mm.,

b = Average width of specimen, in., or mm, at the fracture, and

d = Average depth of specimen, in., or at the fracture

If the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5% of span length, calculate the modulus of rupture as follows

Table 4 Flexural Strength of Geopolymer Concrete Prisms

S.no	Grade Of Concrete	Ultimate Load (N)	Flexural Strength Of Prism (N/Mm^2)	Average Flexural Strength (N/Mm^2)
1	M 30	23	4.7	4.65
2		20	4.16	
3		24	5.0	
1	M 40	29	6.04	6.38
2		30	6.45	
3		32	6.66	

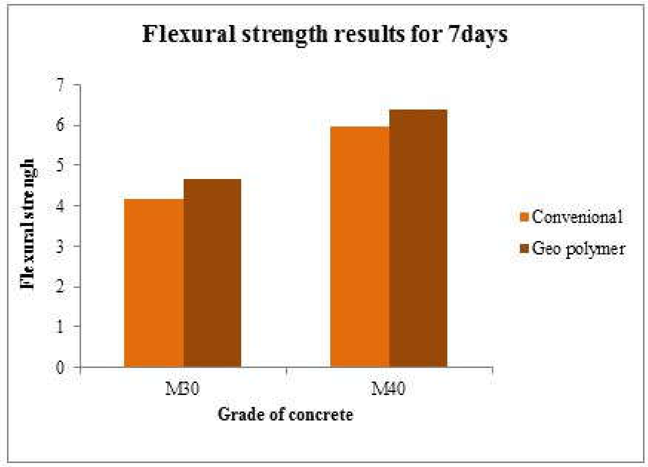

Fig 4: Flexural strength results for 7days

3.3 DURABILITY PROPERTIES

3.3.1 Water absorption test

The water absorption test was carried out by casting cubes of dimension 100mmx100mmx100mm were cast and cured for the period of 28 days. After 28 days of curing specimens were taken out and dry in oven to dry at the temperature of 105 0c to remove the moisture content using electronic weighing balance the dry weight of the specimen was measured . alternate wet and dry process was carried out the concrete specimens are taken out and expose to normal atmospheric condition so as to obtain surface dry and the average percentage of loss of weight and compressive strength were calculated.

Table: 5 WATER ABSORPTION TEST

S. NO	Grade of concrete	Weight in (kg)		Increase in weight (kg)	% of increase
		Before soaking	After soaking		
1	M30	2.318	2.376	0.058	2.50
2		2.369	2.419	0.050	2.10
3		2.329	2.356	0.027	1.96
1	M 40	2.269	2.315	0.046	2.0
2		2.297	2.335	0.038	1.60
3		2.290	2.350	0.060	1.95

Table: 6 WATER ABSORPTION TEST FOR GEO POLYMER

S. no	Grade Of Concrete	Weight In (Kg)		Increase in Weight (Kg)	% Of Increase
		Before Soaking	After Soaking		
1	M30	2.420	2.444	0.024	0.90
2		2.381	2.401	0.02	0.83
3		2.326	2.421	0.095	2.98
1	M 40	2.456	2.486	0.03	1.22
2		2.303	2.332	0.029	1.25
3		2.290	2.380	0.090	2.2

3.4 Rapid chloride penetration test

3.4.1 Specimen Preparation:

The 50 mm thick concrete disk was sliced from 100mm x 200mm height cylinder (Fig. 5)

3.4.2 Conditioning of Specimen:

The sliced specimen disk was kept in vacuum desiccators to remove air present in pore for 3 hours. Then water was allowed into desiccators for 1 hour under vacuum so that disk gets water saturated. The specimen was kept for 18 hours in water under atmospheric pressure.

3.4.3 Measurement of Charge Passing:

In this step well-conditioned disk was mounted in testing cell and chambers were filled with NaOH and NaCl solution. Then the testing cell was applied to 60 V D.C through measurement unit as shown in Fig 6., the charges were recorded by the computer.

3.4.4Rapid Chloride ion Penetration Test:

Rapid Chloride ion Penetration Test (RCPT) is essentially a measure of concrete's electrical conductivity which depends on both pore structure characteristics and pore solution chemistry (Caijun Shi, 2004). Chloride diffusion is one of the major reasons concrete.

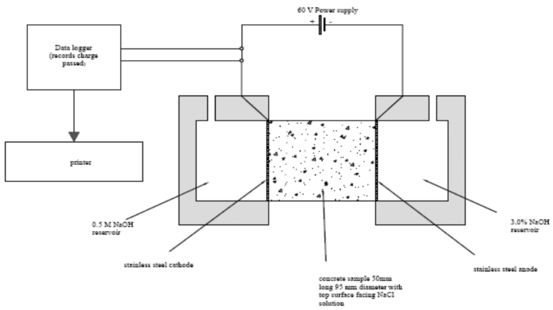

Fig 5: Line diagram for RCPT

Therefore it is necessary to study concrete for its chloride ion permeability. Alumino-silicates is the binder in the GPC, but in the conventional concretes calcium silicate hydrate (C-S-H) gel is the main binding system. The results of GPC specimens subjected to RCPT are presented in Table 6. During the RCPT the solution temperature was at 30 minutes has been extrapolated to 6 hrs RCPT to decide the chloride ion penetrability as mentioned in Table 7.

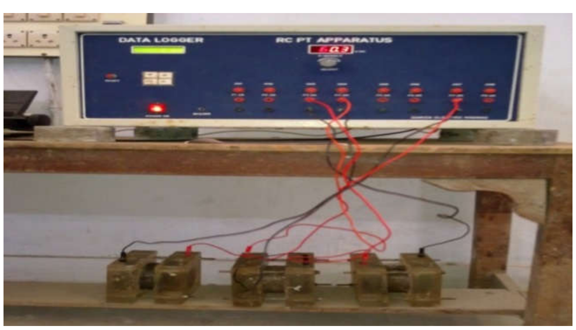

Fig 6: RCPT test

Since GPC make use of alkaline activator solutions that are highly conductive, the unreacted residual alkaline activator solutions could sometimes give a false alarm, leading to conclude that GPC are highly permeable to chlorides• As the grade of GPC increases the RCPT charges decreases. Thus we can say that RCPT of GPC is having low' chloride ion penetrability for higher grade of concrete. •

Table: 7 RCPT RESULT FOR CONVENTIONAL AND GEOPOLYMER

S. No	Grade of Concrete	Rcpt Charged Coulombs	Chloride Ion Permeability
1	M 30	3879.3	MODERATE
		1068.92	LOW
2	M40	10541.38	HIGH
		1324.78	LOW

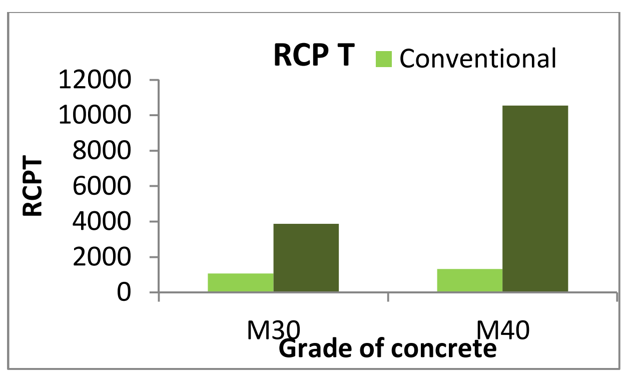

Fig 7: RCPT test for 7days

The maximum and minimum charges passed for 28 days was 1968 and 1548 Coulombs for M30 and M60 grade GPC respectively. • The maximum and minimum charges passed for 7 days was 5856 and 4956 Coulombs for M30 and M60 grade GPC respectively.

4. CONCLUSIONS AND RECOMMENDATIONS

The utilization of class C flyash as been a problem in the flyash management as be rebar corrosion problem has been identify by researches. The preliminary attend made through this thesis for M30 and M40 concrete promoting class C flyash usage in reinforced concrete in successful. Based on the investigation, the following general conclusion are derived.

1. Class C flyash can be used for reinforced concrete with the alkaline solution appropriate solution admixture.
2. The addition of alkaline solution having the combination of sodium hydroxide, and sodium silicate has improved the early strength properties class C fly ash concrete, activating, the rate of hydration.
3. The addition of alkaline solution having the combination of sodium hydroxide, and sodium silicate has improved, the durability properties of class C fly ash concrete in terms of water absorption and RCPT.
4. The quantity of alkaline solution o be added is proportional to be fraction of fly ash added o concrete for replacing cement.
5. For high early strength of fly ash based concrete the quantity of alkaline solution to be added is also proportional.

5. REFFERENCES

1 Ubollukrattanasak, kanokwanpankhet, and prinyachindapaprasirt (2011). Effect of chemical admixtures on properties of high calcium fly ash geopolymer, International journal of minerals, metallurgy and materials 18(3)pg:364.

2 Tanakornphoo - ngerkhan, prinyachindaprasirt, vanchaisatasaeng sureepangdaeng and terawatt sinsirt (2013).Properties of high calcium flyash geopolymer pastes with Portland cement as an additive, International journal of minerals ,metallurgy and materials 20(2):214-220.

3 TawatchaiTho- in, Vanchaisata, Prinyachindaprasirt, chaijaturapitakkul (2012). Previous high calcium flyash geopolymer

concrete, Construction and building materials 30 pg:366-371.

4 Venkatakrishanaiah and Mohankumar (2013) Experimental study on strength of high volume high calcium fly ash concrete, IOSR journal of mechanical and civil engineering volume (5)pg:48-54.

5 Smith sonpiriyakij(2006).Engineering properties of MAE MOH fly ash geopolymerconcrete, proceedings, International conference on pozzolano, concrete and geopolymer, khon kaen,Thailand,pp:219-215.

6 Kamhangrittirong, suwanvitaya, suwanvitaya, chindaprasirt, Green binder technology development using fly ash based geopolymer.

7 Saysuneejumrat, burachatchatveera, phadungsakrattanadecho (2011). Dielectric properties and temperature profile of fly ash based geopolymermortor, International communication in heat and mass transfer 38pg:242-248.

8 Shuxinwang and victor C. LI (2007).Engineered cementations composites with high volume fly ash, ACI Materials journal.

9 Chindaprasirt and Rattanasak (2006).A comparatively study of preparations and properties of high calcium fly ash based geopolymer ,International conference on pozzalon, concrete and geopolymer proceedings, khonkaen, Thailand,

10 Duxson, provis, lukey, van Deventer(2007).The role of inorganic polymer technology in the development of 'green concrete' .Cement concrete res;37:1590-7

11 Davidovits (1994) properties of geoplymer cements .In: Proceedings of first international conference on alkaline cements and concretes,vol.1.pg:131-49

12 Chindaprasirt , Chareerat, Hatanaka(2011).High strength geopolymer using

13 Chindaprasirt, chareerat, sirivivatananon.(2007)Workability and strength of coarse high calcium fly ash geopolymer ,cement and concrete composites; 29 pg:224-229.

14 Hardijito and Rangan. (2005)Development and properties of low-calcium fly ash based geopolymer concrete, Research Report GC ,Faculty of Engineering

,Curtin university of Technology ,Perth,Australlia,1-130.

15 Pattanapong Topark –Ngarm, Vanchaisata, Prinyachindaprasirt.(2011)

16 Workability and strength of high calcium geopolymer concrete cured at room temperature .Annual concrete conference No.7 Rayongprovince, Thailand pg:19-22.