INVESTIGATE CURING BEHAVIOR OF FLY ASH BASED POLYMERIC FERROCEMENT CONCRETE

AMALE V.R.[1] **DR. HAKE S.L.**[2]

[1]*P.G. Student, Department of Civil Engineering, Dr. V.V. Patil College of Engineering, Ahmednagar, Pin-414111, Maharashtra, India.*

[2]*Associate Professor, Department of Civil Engineering, Dr. V.V. Patil College of Engineering, Ahmednagar, Pin-414111, Maharashtra, India .*

Email -vishalamale41@gmail.com

ABSTRACT

This paper represents Investigation of curing behavior of fly ash based polymeric ferrocement concrete. Ferrocement is a form of reinforced concrete that differs from conventional reinforced or prestressed concrete primarily by the manner in which the reinforcing elements are dispersed and arranged. It consists of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar. The name geopolymer was formed by a French Professor Davidovits in 1978 to represent a broad range of materials characterized by networks of inorganic molecules. Geopolymer is a new development in the world of concrete in which cement is totally replaced by pozzoloanic materials like fly ash and activated by highly alkaline solutions to act as a binder in the concrete mix.

In this study instead of cement mortor geopolymer mortor is used. Alkaline activators are also used sodium hydroxide and sodium silicate. In this experiment investigation on behavior of fly ash based geopolymer ferrocement, curing condition such as oven, steam, membrane, accelerated and natural sunlight curing for ferrocement geopolymer mortar, analyse effect of chicken mesh layer on flexural or bending behavior determined. The wire chicken mesh with thickness of 0.7mm i.e.22 gauge is used. The geopolymer mix is prepared by mixing fly ash and sand with the proportion by weight 1:3.Testing is done by a specially made frame for 1m x 1m size with thickness 50mm. The slab is simply supported and the load is applied to the slab is uniformly distributed load. The loading is done by 50 kg cement bags. The slab is kept on the frame and linear variable differential transducer.

Keywords: *Ferrocement, fly ash, Geopolymer, mortor, Curing, chicken wire mesh, sodium hydroxide, sodium silicate.*

I. INTRODUCTION

"Ferro cement is a type of thin wall reinforced concrete, commonly constructed of hydraulic cement mortar, reinforced with closely spaced layers of continuous and relatively small size wire mesh. The mesh may be made of metallic or other suitable materials"

Ferro cement or Ferro-cement (also called thin-shell concrete or Ferro-concrete) is a system of reinforced mortar or plaster (lime or cement, sand and water) applied over layer of metal mesh, woven expanded-metal or metal-fibers and closely spaced thin steel rods such as rebar. The metal commonly used is iron or some type of steel.

Ferrocement is a form of reinforced concrete that differs from conventional reinforced or prestressed concrete primarily by the manner in which the reinforcing elements are dispersed and arranged. It consists of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar. A composite material is formed that behaves differently from conventional reinforced concrete in strength, deformation, and potential applications, and thus is classified as a separate and distinct material.

It is used to construct relatively thin, hard, strong surfaces and structures in many shapes such as hulls for boats, shell roofs, and water tanks. Ferro cement originated in the 1840s in France and is the origin of reinforced concrete. It has a wide range of other uses including sculpture and prefabricated building components. The term "ferrocement" has been applied by extension to other composite materials, including some containing no cement and no ferrous material.

Cement and concrete are used interchangeably but there are technical distinctions and the meaning of cement has changed since the mid-nineteenth century when ferrocement originated. Ferro- means iron although metal commonly used in ferro-cement is the iron alloy steel. Cement in the nineteenth century and earlier meant mortar or broken stone or tile mixed with lime and water to form a strong mortar. Today cement usually means Portland cement, Mortar is a paste of a binder (usually Portland cement), sand and water; and concrete is a fluid mixture of Portland cement, sand, water and crushed stone aggregate which is poured into formwork.

The name geopolymer was formed by a French Professor Davidovits in 1978 to represent a broad range of materials characterized by networks of inorganic molecules.

Geopolymer is a new development in the world of concrete in which cement is totally replaced by pozzoloanic materials like fly ash and activated by highly alkaline solutions to act as a binder in the concrete mix. For the selection of suitable ingredients of geopolymer concrete to achieve desire strength at required workability, an experimental investigation has been carried out for the gradation of geopolymer concrete and a mix design procedure is proposed on the basis of quantity and fineness of fly ash, quantity of water, grading of fine aggregate, and fine to total aggregate ratio.

Geopolymers can meet a "zero waste" objective because they can be produced from materials that are themselves waste products, such as fly ash, blast furnace slag, rice husk ash, metakaoline etc. The properties of alkali-activated fly ash are influenced, by a set of factors related to the proportioning of ingredients of the mixture and the curing conditions. Also, the earlier studies have manifested the high potential of these materials that could be used in the near future in the construction industry, especially in the pre-cast industry. The development of fly ash-based geopolymer mortar is one of the needs to the „greener" mortar for sustainable development. Fly ash based geopolymer mortar has excellent compressive strength and is suitable for structural applications.

II. LITERATURE REVIEW

V. Sreevidya et al (2012) are investigated “Experimental study on geopolymer ferro cement slab using various wire meshes”. The purpose of this experimental investigation is to study the flexural behavior of fly ash-based geopolymer ferrocement elements. Compressive strength of fly ash based geopolymer mortar was found to depend on the strength of the geopolymer binder and excellent bonding between the geopolymer binder and fine aggregate.

S. Nagan et al (2014) are explained in “Behaviour of Geopolymer Ferrocement Slabs Subjected to Impact”. This paper presents the experimental investigations of the resistance of geopolymer mortar slabs to impact loading. In all the impact test specimens the damage is found localized, i.e. at the point of impact of load, and the failure is characterized by formation of cracks initially at the bottom surface of the specimen, propagating to the top surface and then widening further.

A. Sofi et al (2016) describes “Geopolymer ferrocement slabs-An experimental investigation “The aim of this research is to examine a potential mix design process for this emerging product. This work is a largely experimental investigation into mixture proportion and strength relationships, attempting to detail a large amount of data which will be utilised at the core of the process to be investigated.

Swapna S.Yedshikar (2015) et al concluded in their research under title “Comparison of geopolymer and ferrocement mortar with varying volume percentage and specific surface of mesh”. Experimental investigation has been carried out to study the effect of different volume fraction %of steel mesh on compressive strength and split tensile strength of ferrocement and geopolymer. Tests results shows that compressive strength and split tensile strength of geopolymer mortor increases with increase in volume fraction percentage and specific surface of steel mesh as compared to ferrocement mortor.

Prof (Dr). S.K Patra et al describes “Ferrocement-A review” Ferrocement element can be used as a plate or walling units or as a fire resisting unit. Though there has been many experiments done on the strength (basically Flexural, compressive) by taking different section of ferrocement plates as well as beams, this paper has given an importance on the shear behavior of ferrocement elements.

Sakthivel, P.B. et al (2013) under title “Ferrocement Construction Technology and its Applications – A Review” This paper attempts to review the literature on ferrocement and bring out the salient features of construction, material properties and the special techniques of applying cement mortar on to the reinforcing mesh. This study brings out the importance of using ferrocement in swimming pools and water tanks, silos, corrugated roofs, shell and dome structures, and also in the repair of old/ deteriorated RCC structures.

Nagesh M.Kulkarni et al (2013) analyzed in their paper titled “Analysis and design of ferrocement panels an experimental study” This paper describes the various experiments conducted on ferrocement panels in literature review and the conclusions and remarks drawn by the authors. The results obtained are going to help in the project work to investigate the behavior of ferrocement panels for various parameters and loading.

N Ranjith Kumar et al (2016) concluded that under title “Behaviour of geopolymer concrete with ferrocement” This paper presents the experimental investigations of the resistance of Geopolymer mortar slabs to impact loading for the specimens of size 200mmx210mmx100mm.

K. Sasiekalaa et al (2012) studied “A Review Report On Mechanical Properties of Ferrocement with Cementitious Materials” This paper focuses on the materials, advantages, mechanical properties, practical design parameters, recommendations, research and development in ferrocement.

M. I. Abdul Aleem et al (2012) analysed "Geopolymer concrete- a review" Flyash is rich in silica and alumina reacted with alkaline solution produced aluminosilicate gel that acted as the binding material for the concrete. It is an excellent alternative construction material to the existing plain cement.

III.MATERIAL AND METHODS:

Materials used: - Following material are employed in work

1. Fine aggregate
2. Fly ash
3. Sodium Hydroxide (NaOH)
4. Sodium Silicate (Na2SiO3)
5. Wire chicken mesh
6. Water
7. Lime

1. Fine aggregate: -

Locally available river sand conforming to grading zone II of IS: 383 – 1970 was used as fine aggregate. Fine aggregate used is the ordinary river sand passing through sieve no.8 (2.36 mm) with a specific gravity of 2.72, dry density of 1.6 g/cc and having a fineness modulus of 2.56 as per I.S: 383 1970.

2. Fly ash: -

Pozzocrete 60 is a high efficiency pozzolonic material, used as cement component with Portland clinker (i.e. as a partial replacement of Portland cement). It is obtained by selection, processing and testing of power station fly ash resulting from the combustion of coal used at electricity generating power stations. It confirms to IS 3812-Part 1 fly ash and its low loss-on-ignition is an advantage. It is subjected to strict quality control.

General information:
Finely divided dry powder. Colour:
Light grey
Bulk weight: 1.0 tonne /m3
Specific density: 2.3
Fineness: <18%retained on 45-micron sieve
Loss on ignition: <2.5%
Particle shape: Spherical Package:
30 Kg bags

Recommended uses:

- Concrete:

General purpose plain and reinforced structural concrete with 28 days' strength up to 50 mpa. Special purpose concrete, such as mass concrete, pre-cast concrete, pumpable concrete, selfcompacting and self-levelling concrete.

 Cement:

Blended cements, with pozzocrete 60 content up to 50%, such as sulfate and chloride resistant and low/very low heat cements.

 Mortar:

General purpose mortar for plastering /rendering, brickwork/blockwork. Specialised mortars for floor/wall titles. Flowable mortars for use as structural fill in earthworks.

 Grout:

General purpose grouts for use in earthworks for the treatment of rock cracks. Grouts for earthwork to be used in anchors.

3. Sodium Hydroxide:

Generally, Sodium hydroxide are available in solid state by means of pellets and flakes. It is highly soluble in water. When dissolved in water or neutralized with acids liberates substantial heat. Higher concentration of NaOH solution resulted in higher flow for alkaline solution to fly ash ratio of 0.350.40.

4. Sodium Silicate:

Sodium silicate also called as water glass or liquid glass. Sodium silicates are stable in neutral and alkaline solution. In acidic solution the silicate ions react with hydrogen ions to form silicate acids, which tend to decompose into hydrated silicate gel. Heated to drive of the water, the result is hard translucence substance called silica gel, widely used as desiccant. The largest application of sodium silicate solutions is a cement for producing cardboards. Concrete treated with sodium silicate solution helps to reduce porosity in most masonry products such as concrete, stucco, and plasters.

5. Wire chicken mesh reinforcement: -

The wire woven chicken mesh with thickness of 0.7mm i.e.22 gauge are used. Ultimate strength of chicken mesh 270 N/mm^2.

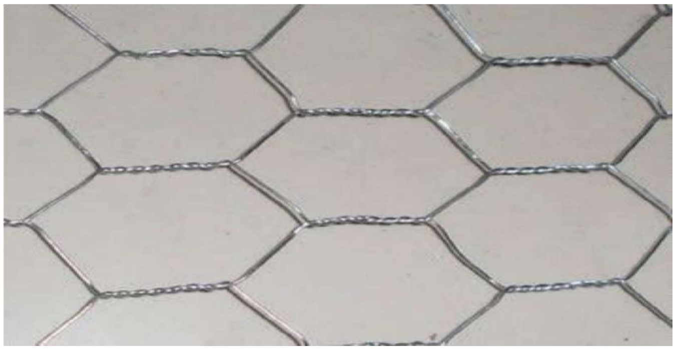


Fig.2 Wire chicken mesh

6. Water: -The fresh potable water is used

7. Lime: -

Lime is a calcium containing inorganic mineral composed primarily of oxides and hydroxides, usually calcium oxide and /or calcium hydroxide. Lime used in building materials is broadly classified as "pure", "hydraulic", and "poor" lime; can be natural or artificial; and may be further identified by its magnesium content.

Preparation of sodium hydroxide solution: -

The sodium hydroxide (NaOH) solids were dissolved in water to make the solution.The mass of NaOH solids varied depending on the concentration of solution in terms of molar,M.
NaOH solution for with a concentration of 15M consisted of 15×40=600 grams of NaOH solids per liter of the solution, where 40 molecular weight of NaOH. The sodium silicate solution and sodium hydroxide solution were mixed together at least one day prior to use to prepare the alkaline liquid.

Geopolymer mortar: -

Geopolymer is a combination of the following compounds,

- Pozzolans (fly ash, silica fumes, GGBS etc.,)
- Fine aggregate
- Activator solution (Hydroxides and Silicates of sodium or potassium)
- Distilled water.

The pozzolan used here is the low calcium fly ash of Pozzocrete P60, the chemical composition of fly ash as shown in table below, the geopolymer mortar used in this study is composed of fly ash and alkaline solution composed of sodium hydroxide, sodium silicate combinations.

Composition	Mass (%)
SiO_2	20-60
Al_2O_3	5-35
Fe_2O_3	10-40
CaO	1-12
LOI	0-15

Table 1 Chemical composition of fly ash

In order to avoid the effect of unknown contaminants in the mixing water, the sodium hydroxide pellets were dissolved in distilled water. The activator solution was prepared at least one day prior to its use.

3.1 Mix proportion:

The geopolymer mix is prepared by mixing fly ash and sand with the proportion by weight 1:3. The specimen were casted for 0.45 W/B ratio. Cube of this proportion casted and cured for 7 days to achieve strength.

3.2 Testing:

Alkaline solution of Sodium hydroxide and sodium silicate are used. Mortor cube 150×150×150mm and cylinders of 150mm dia., 300mm height were tested.

IV. Result and discussion:

Compressive Strength Test:-

Compressive strength is one of the important properties of concrete. Concrete cubes of size 150mmx150mmx150mm were cast with and without of fly ash. After 24 hours, the specimens were demoulded and subjected to water curing. After 28 days of curing specimens were taken and allowed to dry and tested in compressive strength testing machine.

Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Sample No	Load (KN)	Comp Strength (N/mm^2)	Average (N/mm^2)
60°C	18	7	O1	135	6.00	6.15
			O2	120	5.33	
			O3	160	7.11	
90°C			O4	900	40.00	40.74
			O5	930	41.33	
			O6	920	40.89	
120°C			O7	1260	56.00	59.26
			O8	1430	63.56	
			O9	1310	58.22	
150°C			O10	360	16.00	14.67
			O11	300	13.33	

Table1: The temp. effect of oven cured geopolymer concrete.

Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Sample No	Load (KN)	Comp Strength (N/mm^2)	Average (N/mm^2)
60°C	18	7	A1	500	22.22	30.07
			A2	780	34.67	
			A3	750	33.33	
80°C			A4	1550	68.89	65.93
			A5	1420	63.11	
			A6	1480	65.78	
100°C			A7	620	27.56	33.04
			A8	860	38.22	
			A9	750	33.33	

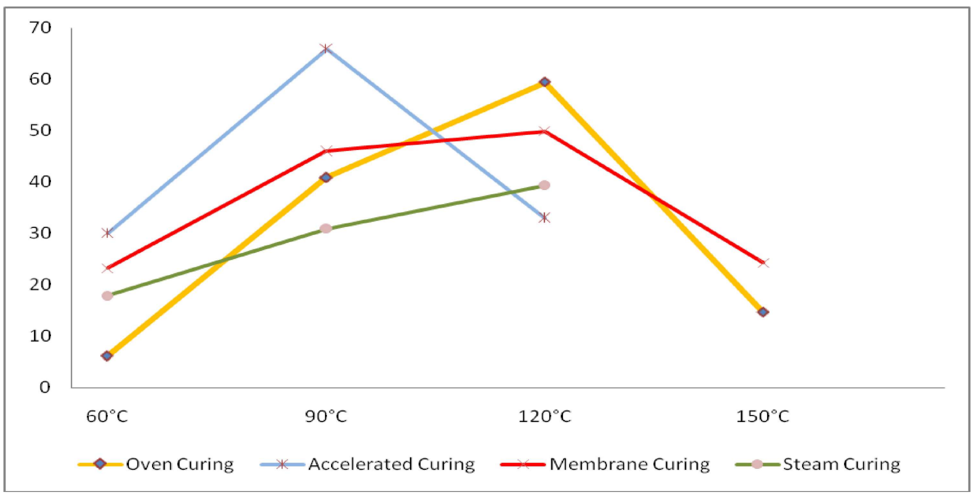
Table2: The temp. effect of Accelerated cured geopolymer concrete.

Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Sample No	Load (KN)	Comp Strength (N/mm^2)	Average (N/mm^2)
60°C	18	7	M1	550	24.44	23.26
			M2	540	24.00	
			M3	480	21.33	
90°C			M4	1050	46.67	46.07
			M5	1090	48.44	
			M6	970	43.11	
120°C			M7	1120	49.78	49.93
			M8	1100	48.89	
			M9	1150	51.11	
150°C			M10	530	23.56	24.30
			M11	540	24.00	
			M12	570	25.33	

Table3: The temp. effect of Membrane cured geopolymer concrete.

Sr.No.	Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Sample No	Load (KN)	Comp Strength (N/mm²)	Average (N/mm²)
12	60°C	18	7	S1	430	19.11	17.93
				S2	370	16.44	
				S3	410	18.22	
13	80°C			S4	730	32.44	30.96
				S5	690	30.67	
				S6	670	29.78	
14	100°C			S7	880	39.11	39.41
				S8	860	38.22	
				S9	920	40.89	

Table4: The temp. effect of Steam cured geopolymer concrete.



Graph 1 Temperature Vs Comp. strength

In the geopolymerisation process of geopolymer concrete, water is given out during the chemical reaction and this water tends to vaporize as the specimens were subjected to heat during the curing process. Table shows various different types of curing. Oven heat curing the temperature varies from 60 ^{0} C to 150 ^{0} C the optimum result we get at 90 ^{0}C with consideration of energy for heating.

In Accelerated curing the effect of temperature on geopolymer concrete will show the optimum result at 80 ^{0}C.

Also in membrane curing the effect of temperature varies from 60 ^{0} C to 150 ^{0} C the optimum result we get at 90 ^{0}C. In case of Steam curing the temperature optimize at 100^{0}C.

V. Conclusion:-

In this paper various methods of curing of geopolymer ferrocement concrete are investigated. Different types of curing methods such as oven heating, membrane curing, steam curing, water curing are discussed.

Flexural strength increases in number of wire mesh used. The use of mesh in ferrocement structures gives more strength .The use of fly ash in geopolymer slabs leads to reduce environmental pollution.

In polymerisation process heat is required to geopolymer concrete.

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