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Review on Palm Fuel Ash – Based Geopolymer Concrete with Out Portland cement

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***Abstract*— The construction industry is increasingly turning to the use of environmentally friendly materials in order to meet the sustainable aspect required by modern infrastructures. Geopolymer is an emerging alternative binder for concrete that uses materials that are normally considered and waste or by products of low value. In geopolymerization, a material that is rich in Silicon (Si) and Aluminium (Al) reacts in an alkaline solution (medium) to produce the binder. Materials such as Fly ash, Metakaolin, slimes, and Palm fuel ash can are used to make Geopolymer concrete. Slag based Geopolymer concrete has advantages like faster strength gain, ambient curing, low concentration of KOH and so on. Here Palm fuel ash based Geopolymer has been developed and highlighted. It is generally seen that addition of palm fuel ash results in an increased viscosity of the mix, the mix tends to be stickier in nature, demanding a higher water content or workability aiding admixtures. Incorporation of palm fuel ash tends to marginally increase the strength developed and also better durability performance. This paper present results of an experimental study on the flexural, tensile and compressive strength of Geopolymer concrete. The experiments were conducted on palm fuel ash based Geopolymer concrete by varying the types of curing namely ambient curing and hot curing. In the present study, 8M on potassium hydroxide are to be used as well as potassium silicates are to be used based on the quantity of concrete.**

***Index Terms*— Geopolymer concrete, Fly ash, palm fuel ash, Molarity, Curing, Strength.**

I. INTRODUCTION

Concrete is the most consumed material on the earth next to water. The global demand of cement for construction of infrastructures is continuously increasing in order to maintain the ongoing growth and accommodate the needs of the increasing population. OPC has been traditionally used as the binder in concrete. Therefore, development of alternative binders utilising industrial by-products is necessary to reduce the carbon footprint of the construction industry.

Palm fuel ash is an ash obtained by burning of palm fibres and palm kernel shells after extraction of palm oil in palm industry. It is a finely ground waste material having size less than 90μ.

Palm fuel ash has been successfully used as an cement source (partial replacement) in Portland cement concrete. The Palm fuel consists mainly of calcium aluminosilicate glass with crystal inclusions of larnite and melilite. Similarly to FA materials, the micron-in homogeneities and the existence of multi phases within the structure of glassy matters are possible,but not frequent .The three main oxide compositions of Palm fuel ash are CaO (58 weight %) ,SiO2 (14.16 weight%) and Al2O3 (0.35%)with the particles size distribution in the range 2.8μm to 17.5μm.

Geo polymer concrete is no fine (cement) concrete. Palm fuel ash is to replace totally manufactured cement to make concrete- like material. This will turn the construction material to the new era. Normally there are two main constituents of Geopolymers, namely the source material and the alkaline liquids. The Source materials for Geopolymer based on alumina-silicate should be rich in silicon (Si) and aluminum (Al) the material of geological origin or by-product materials such as palm fuel ash. The alkaline solution, which is a combination of potassium silicate solution and potassium hydroxide solution, reacts with the silicon and aluminium in the palm fuel ash form the paste which binds the loose coarse and fine aggregates, to produce the Geopolymer concrete.

Geopolymer was first introduced by Davidovits (1). Utilization of such a material to produce the valuable-added products is of considerable commercial interest. The results in the paper demonstrate that heat-cured low-calcium fly ash-based geopolymer concrete has excellent potential for applications in the precast industry (2). The use of by-product material, i.e. fly ash, as a base material for concrete binder to totally replace the use of Portland cement through geopolymerisation process has been attracting a lot of attention globally (3). Geopolymer is used as the binder, instead of cement paste, to produce concrete. The geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete (4). Longer curing time, in the range of 24 to 72 hours (4 days), produces higher compressive strength of fly ash-based geopolymer concrete. However, the increase in strength beyond 48 hours is not significant (5).

This paper present results of an experimental study on the flexural, tensile and compressive strength of palm fuel ash based Geopolymer concrete with different types of curing.

II. EXPERIMENTAL PROGRAM

Normally the Geopolymer concrete can be manufactured by Palm fuel ash is a ash obtained by burning of palm fibres and palm kernel shells after extraction of palm oil in palm industry. It is a finely ground waste material having size less than 90µ. Palm oil fuel ash has been successfully used as an cement source (partial replacement) in Portland cement concrete. Only Palm fuel ash is used as a replacement material for OPC. Palm fuel ash has been used to synthesize alkali activated cement and geo polymers. Palm fuel ash ash has good shear strength properties and relatively less compressibility.

Fine Aggregate (sand) used is clean dry river sand. The sand is sieved using 4.75 mm sieve to remove all the pebbles. Fine aggregate, having a specific gravity of 2.69, bulk density of 1701.84 kg/m3 and fineness modulus of fine aggregate is 3.99, was used. Coarse aggregates of 20 mm maximum size having specific gravity of 2.74 were used. Water conforming to the requirements of water for concreting and curing was used throughout.

Alkaline liquids are used in geopolymerization. In the present investigation, a combination of potassium hydroxide solution and potassium silicate solution was used as alkaline solution. Potassium hydroxide is available commercially in flakes or pellets form. For the present study, potassium hydroxide flakes with 98% purity were used for the preparation of alkaline solution. Potassium silicate is available commercially in solution form and hence it can be used as such. The chemical composition of potassium silicate is: Na2O-14.7%, SiO2-29.4% and Water -55.9% by mass.

The major chemical compositions of palm fuel ash are silica (SiO2), Aluminium (Al2O3) and Iron Oxide (Fe2O3) with smaller amount of calcium (CaO), Magnesium (MgO) and Sulphur (SO3). The constituents most likely to affect the index and engineering properties of palm fuel ash are silica, free lime, Iron and carbon.

III. MIX DESIGN OF GEOPOLYMER CONCRETE

In the design of Geopolymer concrete mix, coarse and fine aggregates together were taken as 77% of entire mixture by mass. This value is similar to that used in OPC concrete in which it will be in the range of 75 to 80% of the entire mixture by mass. Fine aggregate was taken as 30% of the total aggregates. From the past literatures it is clear that the average density of palm fuel ash-based Geopolymer concrete is similar to that of OPC concrete (2400 kg/m3). Knowing the density of concrete, the combined mass of alkaline liquid and palm fuel ash can is arrived at. The mix was designed as M25 grade and the mix proportions are given in below Table 1.

Table – 1 Mix proportions of Palm fuel ash based Geopolymer concrete

Alkaline liquid to fly ash ratio	Palm fuel ash (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	KOH solution (Kg/m^3)	K_2SiO_3 solution (Kg/m^3)	Total water (Kg/m^3)
0.4	394.3	554.4	1293.4	45.1	112.6	136.3

A. Preparation of Geopolymer Concrete

The potassium hydroxide solution thus prepared is mixed with potassium silicate solution one day before making the geopolymer concrete to get the desired alkaline solution. The solids constituents of the fly wet mixing was done for 4 min. Twelve cubes of size 150 mm x 150 mm x 150 mm were cast and compaction was done by mechanical vibration using a table vibrator.

B. Curing of Geo polymer Concrete

After casting the specimens, they were kept in rest period for five days and then they were demoulded.

The term 'Rest Period' was coined to indicate the time taken from the completion of casting of test specimens to the start of curing at an elevated temperature. This may be important in certain practical applications. For instance, when palm fuel ash-based geopolymer concrete is used in precast concrete industry, there must be sufficient time available between casting of products and sending them to the curing chamber. At the end of the Rest Period, six test specimens were kept under ambient conditions for curing at room temperature. Remaining six specimens were kept at 60oC in hot oven for 24 hrs

IV. RESULTS AND DISCUSSION

A. Density of Geopolymer Concrete

Variation of density of Geopolymer concrete after 7 and 28 days of curing is presented in Table 3.1. Density values range from 2251 to 2400 kg/m3. The density of Geopolymer concrete was found approximately equivalent to that of conventional concrete. As the age of concrete increases, there is a slight increase in density as shown in Table 2. Variation of density is not much significant with respect to age of concrete and type of curing.

Table no2: variation of density with age of concrete

Density of Geopolymer concrete				
Type Of curing	Density of sample (Kg/m^3)			
	7 days	Avg.	28 days	Avg.
Ambient Curing	2293.65	2301.27	2340.74	2357.98
	2298.30		2393.87	
	2311.87		2339.34	
Hot Oven Curing	2367.10	2364.54	2450.41	2403.93
	2376.55		2344.39	
	2349.99		2417.00	

B. Compressive Strength

The compressive strength after 7 and 28 days of curing is presented in Figure 3.1 which shows a graphical representation of variation of compressive strength for 7 days and 28 days of curing.

Table2: compressive strength of geopolymer concrete

Type of curing	Ultimate Load (N)		Compressive Strength (N/mm^2)			
	7 days	28 days	7 days	Average	28 days	Average
Ambient Curing	75000	195000	7.5	6.67	19.5	18.5
	70000	170000	7.0		17.0	
	55000	190000	5.5		19.0	
Hot Oven Curing	33000	460000	37.0	37.5	46.0	44.5
	37500	425000	37.5		42.5	
	33000	450000	38.0		45.0	

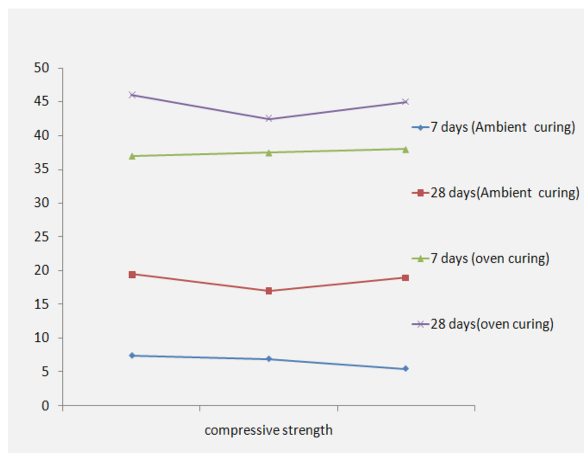

Fig.1.Graphical Representation of Compressive Strength of Geopolymer Concrete

Compressive strength of hot cured specimens is more than that of ambient cured specimens both for 7 and 28 days. 28 days compressive strength of hot cured specimens was about 2 times more than that of ambient cured specimens. 7 days compressive strength of hot cured specimens was around 7 times more than that of ambient cured specimens. In ambient curing the 28 days compressive strength is about 4.5 times the 7 days compressive strength. In hot curing the 28 days compressive strength is about 1.2 times the 7 days compressive strength.

C. Split Tensile Strength of Concrete

The split tensile strength after 28 days of curing is presented in Figure 3.2 which shows a graphical representation of variation of split tensile strength for 28 days of curing.

Table3: split tensile strength of geopolymer concrete

Type of curing	Applied Load (N)	Tensile strength (N/mm²)	Average (N/mm²)
Ambient Curing	66000	2.101	2.015
	59000	1.870	
	62000	1.970	
Hot Oven	96000	3.050	3.020
	93000	2.960	
	96000	3.050	

The split tensile strength of hot cured specimens is more than that of ambient cured specimens for 28 days. The split tensile strength is satisfies the ordinary concrete.

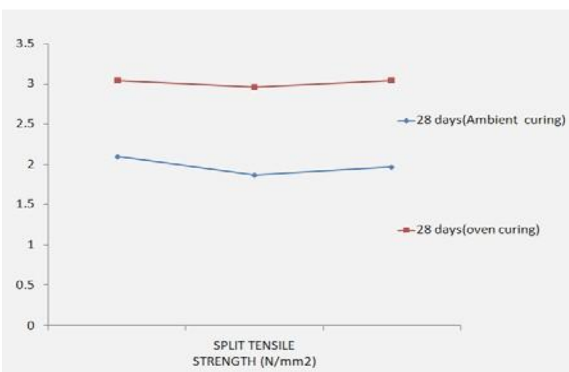

Fig.2.Graphical Representation of split tensile Strength of Geopolymer Concrete

D. Flexural Strength

The flexural strength after 7 and 28 days of curing is presented in Figure 3.3 which shows a graphical representation of variation of flexural strength for 7 days and 28 days of curing. In reinforced concrete construction the strength of the concrete in compression is only taken into consideration. But the design of concrete beams is often based on flexural strength of the concrete. Therefore, it is necessary to access the flexural strength of the concrete. Here we are calculating the flexural strength of the autoclave aerated concrete. The specimen is tested under two point loads in a testing frame with 50 tonne capacities. The specimen sizes are 1200 x 100 x 150 mm.

Flexural strength $= P \times L / (b \times d2)$

Where,

P = Maximum load in KN applied to the specimen

b = Breadth of the specimen in mm

d = Depth of specimen in mm

Table4: Flextural strength of palm fuel based geopolymer concrete

Sl no.	Temperature(°c)	Flexural Strength(N/mm²) (After 28 days)	
		Ambient curing	Hot Oven curing
1	60⁰c	4.32	9.92
2		3.01	10.67
3		3.84	11.84

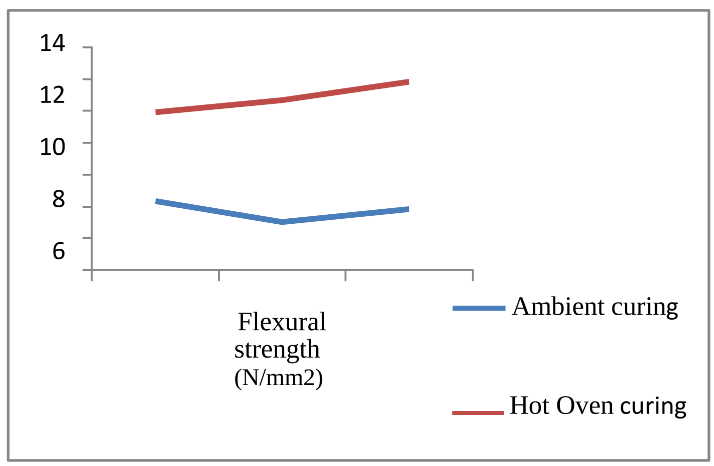

Fig.3.Graphical Representation of Flexural Strength of Geopolymer Concrete

The Flexural strength of hot cured specimens is 2 times more than that of ambient cured specimens for 28 days. The Flexural strength is satisfies the ordinary concrete.

V. CONCLUSION

From the results, the following conclusions can be drawn.

- The slump value of the fresh palm fuel ash based Geopolymer increase with the increase of extra water added to mixture.
- The compressive strength of hot cured concrete is much higher than that of ambient cured concrete. In ambient curing, the compressive strength increases as the age of concrete increases from 7 days to 28 days. The compressive strength of hot cured palm fuel ash based geo polymer concrete has not increased substantially after 7 days. The compressive strength of hot cured palm fuel ash based Geopolymer concrete does not depend on age.
- The splitting tensile strength is satisfies the ordinary concrete. Density values range from 2251 to 2400 kg/m3.
- The density of geopolymer concrete was found approximately equivalent to that of conventional concrete.
- Variation of density is not much significant with respect to age of concrete and type of curing. The average density of palm fuel ash based geopolymer concrete is similar to that of OPC concrete.
- The Flexural strength of hot cured specimens is 2 times more than that of ambient cured specimens for 28 days. The Flexural strength is satisfies the ordinary concrete.
- Palm fuel ash based Geopolymer concrete is more eco-friendly and has the potential to replace Ordinary Portland Cement concrete in many appliances such as precast units. It can thus be concluded that Geopolymer concrete possesses excellent mechanical property and durability for aggressive environment.

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