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Strength Assessment on Flyash Based Geopolymer Concrete

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***Abstract*: Ordinary Portland Cement (OPC) is used for construction globally whose production is an extremely energy-intensive process. Waste material has gained attention among researchers as replacement cement to fly ash in concrete making. The sense of using waste materials in concrete not only of the economic factor but the more significant aspect is to protect the environment since more solid waste are produced day by day. This causes the pollution in water bodies and loss of productive land.**

Geo Polymer composites are possible alternates to OPC and other blended cements. This is due to the high early strength and improved durability evidenced by resistance against acid and sulphate attack, apart from environmental effects (CO_2 let into atmosphere in case of OPC). In various parts of the world, considerable researches in the field of Geo-polymer composites are conducted. Hence the experimental investigations are executed to study the effect of use of fly ash and Geo polymer as a replacement of cement.

The material properties were studied, based on their properties, reference mix M_{25} and M_{30} were designed. 12 specimens tested for workability test and compressive strength. Also, we have replaced cement to fly ash with 40, 60 percentages. For each mix, workability test and strength test was conducted for 9 specimens.

Keywords: Concrete, OPC, Geo-polymer, fly ash, workability, strength

I. INTRODUCTION

Fly ash is the by-product of thermal power stations which use pulverized coal as fuel. The major source of fly ash in our country is thermal power plants which is around 125 in number. The research works has shown good results with respect to strength and durability by replacement of cement with fly ash. Since fly ash has been used there is need of use of certain chemicals such as sodium hydroxide and sodium silicate. For an instant it can considered that fly ash is a dead materials which doesn't have any binding properties which we are making it to behave as a cementitious properties. We need chemicals for such reaction. Recent Development Geo-polymer composites are possible alternates to OPC and other blended cements.

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Unlike Portland Cements, it consumes no energy which is required for clinker formation in OPC. It has no environmental effects. OPC performs poor in adverse conditions which is attributed to the high CaO content in acids and also forms gypsum and ettringite when exposed to sulphates. Since Geo-polymer relies on alumina silicate, rather than calcium silica hydrate as bonds for structural integrity, they have been reported as being acid resistant. Adding fly ash in Geo-polymers improves durability by reducing permeability, improves strength with aging, improves workability and is environment friendly. Fly ash based Geo-polymers have attracted much attention for the past two decades.

II. MATERIALS AND PROPERTIES

B. Fly Ash

Table-I shows the chemical composition of Fly Ash. Fly ash is fine powdered particles with spherical shape, glassy and amorphous. The particle size is less than 0.075mm and specific gravity is about 2.1 to 3.0 with colour tan grey to black depending upon the presence of unburnt carbon in the ash.

Table-I: Chemical Composition of Fly Ash

Chemical Composition	% Weightof Fly Ash
Silicon dioxide,SiO2	55.3
Aluminium oxide, Al2O	25.7
Ferric oxide,Fe2O2	5.3
Calcium oxide, CaO	5.6
Magnesium oxide, MgO	2.1
Titanium oxide, TiO2	1.3
Potassium oxide, K2O	0.6
Sodium oxide, Na2O	0.4
Sulphur trioxide, SO2	1.4
LOI (1000°C)	1.9

Fly ash sand –lime –Gypsum cement/ bricks/ blocks, Fly ash tiles, Interlocking pavers, Glass and ceramics, Geotechnical application, Soil stabilizer, Structural fill, Pavement construction, Embankment, Agricultural application, Soil amendments, Fly ash and Low cost adsorbents

C-S-H gel is produced as the reaction due to the high amount of silica and alumina that binds aggregates together to the strength which prevents deterioration and corrosion.

Fly ash contains reactive elements which converts free lime into reactive C-S-H gel resulting in less heat of hydration, thermal cracks in concrete and improves workability of concrete. The spherical shape of fine particles of fly ash gives better concrete finish making the mix homogenous thus reduces bleeding and segregation. The cost of fly ash is generally less than Portland cement.

C. Geo Polymer

Geo-polymers are inorganic polymeric binding materials which involve a chemical reaction between solid alumino-silicate oxides and alkali metal silicate solution under highly alkaline condition yielding amorphous to semi-crystalline three dimensional polymeric structures, which consist of Si-O- A1 bonds. The Geo-polymerisation is exothermic and takes place under atmospheric pressure at temperature below 1000◦c. The exact mechanism by which Geo- polymer setting and hardening occurs is not fully understood.The polymerization by the alkaline can be shown as:

$$n(Si_2O_5,Al_2O_2)+2nSiO_2+4nH_2O \rightarrow n(OH)_3\text{-}Si\text{-}O\text{-}Al\text{-}O\text{-}Si\text{-}(OH)_3$$

$$n(OH)_3\text{-}Si\text{-}O\text{-}Al\text{-}O\text{-}Si\text{-}(OH)_3 \rightarrow (Na,K)\text{-}(Si\text{-}O\text{-}Al\text{-}O\text{-}Si\text{-}O)+4nH_2O$$

A combination of sodium silicate solution and sodium hydroxide pellets can be used for preparing the alkaline liquid. The NaOH solution is made in different molars.

The sodium silicate solution is commercially available in different grades. The sodium silicate solution with SiO_2-to-Na_2O ratio by mass of approximately, SiO_2 = 15.89%, Na_2O = 4.37%, and water =79.74% by mass. The sodium hydroxide with 97-98% purity, in flake or pellet form, is commercially available. Table-II shows the properties of Sodium Silicate solution and Table –III shows the properties of Sodium Hydroxide

Table-II: Properties of Sodium Silicate solution

Parameter	Value
Sodium oxide, Na_2o	4.37%
Silicate, SiO_2	15.89%
Appearance	Liquid(Gel)
Colour	Light yellow liquid(Gel)
Molecular Weight	184.04

Table -III: Properties of Sodium Hydroxide

Chemical Properties	Percentage by Mass
Carbonate(Na_2CO_3)	2%
Chloride (Cl)	0.01%
Sulphate (SO_4)	0.05%
Potassium (K)	0.1%
Silicate (SiO_2)	0.05%
Zinc (Zn)	0.02%
Heavy metals (as Pb)	0.002%
Iron (Fe)	0.002%
Minimum assay	97.0%
Molarity	16

III. PERIMARY INVESTIGATIONS

A. Materials Used

- Cement-Ultratech brand, OPC 53 grade cement Fine
- Aggregate-River sand from kollidam river bed
- Coarse Aggregate-Hard blue granite of size 20 mm and 12.5mm of angular shape.
- Water-Tap water with pH value satisfying the IS code.
- Fly Ash- Fly ash obtained from NLC at Neyveli.
- Alkaline Activators-Sodium Hydroxide and Sodium Silicate obtained from Jayalakshmi Chemical Centre at Trichy.

B. Properties of Materials Used

- Fineness modulus of cement = 8.3
- Specific gravity of cement = 3.15
- Fineness modulus of fine aggregate = 3.00
- Specific gravity of Fine Aggregate = 2.625
- Water absorption of Fine Aggregate = 1%
- Fineness modulus of coarse aggregate = 7.3
- Specific gravity of coarse aggregate = 2.62
- Water absorption of coarse Aggregate = 0.06%
- Aggregate-River sand from kollidam river bed
- Based on the preliminary tests the mix design for M_{25} and M_{30} grade of concrete were designed in the following chapter.

C. Concrete Mix Design Ratio

Table –IV shows the concrete mix design ratios for M_{25} and M_{30} grade of concrete.

Table -IV: Concrete Mix Design Ratio

Grade of Concrete	W/C	Cement	Fine Aggregate	Coarse Aggregate
M25	0.4271	1	1.18	2.62
M30	0.3758	1	0.972	2.272

D. Geo-polymer Concrete Mix Design Ratio

Table –V shows the Geo-polymer concrete mix design ratios for M_{25} and M_{30} grade of concrete.

Table -V: Geo-polymer Concrete Mix Design Ratio

Grade of Concrete	Fly Ash	FA	CA	Extra Water	NaOH	Na_2SiO_3
M_{25}	1	1.081	2.34	0.03	0.1714	0.42
M_{30}	1	0.8	1.73	0.03	0.1743	0.436

E. Geo-polymer Specimen details for M25 Grade

Table-VI shows the Geo-polymer specimen details for M25 Grade concrete

Table-VI: Specimen details for M25 Grade

Mix	Type of specimen	Dimension (mm)	Numbers	Type of curing
M30	Cube	150x150x150	6	Water
R+40% Fly Ash (M30-GC40)	Cube	150x150x150	3	Steam
R+60% Fly Ash (M30-GC60)	Cube	150x150x150	3	Steam

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F. Geo-polymer Specimen details for M30 Grade

Table-VII shows the Geo-polymer specimen details for M30 Grade concrete.

Table-VII: Specimen details for M30 Grade

Mix	Type of specimen	Dimension (mm)	Numbers	Type of curing
M30	Cube	150x150x150	6	Water
R+60% Fly Ash (M25-GC100)	Cube	150x150x150	3	Steam

G. Steam Curing

We can cure specimens in Steam Curing with temperature 60°C - 90°C. On curing GPC with 60°C for 24 hours, the results are satisfactory for GC-40, GC-60, when compared to 7days curing of Reference Concrete. On curing GPC with 60°C for 24 hours, the results are satisfactory for GC-40 and GC-60, when compared to 28 days curing of Reference Concrete. So it is necessary to increase the time for Steam Curing.

IV. TEST RESULTS AND DISCUSSIONS

Experimental tests were carried out on series of mixes to evaluate the workability and strength characteristics based on adding fly ash and Geo Polymer.

A. Results of slump cone test

Table –VIII and Table-IX shows the Slump Value For M_{30} Grade and M_{25}Grade Concrete. Concrete mix with 40%, 60% of Fly Ash and Geo Polymer (1:2.5) shows good workability.

Table -VIII: Slump Value For M_{30} Grade

Grade of Concrete	Identification	Slump Value in mm
M30	RC_{30}	123
R+40% Fly Ash (M30-GC40)	G40	195
R+60% Fly Ash (M30-GC60)	G60	200

Table-IX: Slump value for M_{25}Grade

Grade of Concrete	Identification	Slump Value in mm
M30	RC_{30}	123
R+40% Fly Ash (M30-GC40)	G40	195

B. Compressive strength in 7 days, 28 days and 24 hours curing

After 24 hour's compressive strength results found that GC40, GC60 show the highest strength when compared with 7 days of control concrete. After 24 hours compressive strength results found that GC40 and GC60 show the highest strength when compared with 28 days of control concrete.

Figure.1 and 2 shows the variations in Compressive Strength after 7 days and 28 days after 24 hours curing for M_{30} grade of concrete.

Table –X and Table-XI shows Compressive strength in 7 days, 28 days and 24 hours curing for M_{30} and M_{25}Grade Concrete.

Table-X: Compressive strength in 7 days, 28 days and 24 hours curing(M_{30})

Percentage of fly ash	Average Compressive strength in 7 days and 24 hours (N/mm²)
M_{30} – R	22.05
R+40% Fly Ash (M_{30}-GC40)	41.42
R+60% Fly Ash (M_{30}-GC60)	30.31
Percentage of fly ash	**Average Compressive strength in 28 days and 24 hours (N/mm²)**
M_{30} – R	30.02
R+40% Fly Ash (M_{30}-GC40)	41.42
R+60% Fly Ash (M_{30}-GC60)	30.31

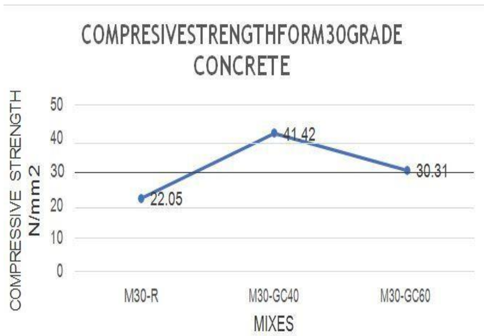

Fig.1. Variations in Compressive Strength after 7 days and 24 hours curing

Fig.2. Variations in Compressive Strength after 28 days and 24 hours curing

After 24 hour's compressive strength results found that GC60 show the highest strength when compared with 7 days of control concrete. Figure.3 and 4 shows the variations in Compressive Strength after 7 days and 28 days after 24 hours curing for M_{25} grade of concrete.

Table-XI: Compressive strength in 7 days, 28 days and 24 hours curing(M25)

Percentage of fly ash	Average Compressive strength in 7 days and 24 hours (N/mm^2)
M_{25}-R	19.50
R+60% Fly Ash (M_{25}-GC60)	22.02
Percentage of fly ash	**Average compressive strength in 28 days and 24 (N/mm^2)**
M_{25}-R	26.10
R+60% Fly Ash (M25-GC60)	22.02

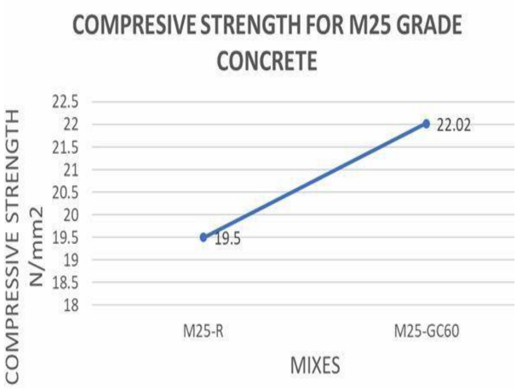

Fig.3. Variations in Compressive Strength after 7 days and 24 hours curing

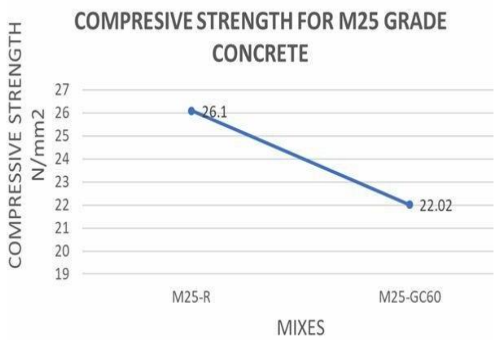

Fig.4. Variations in Compressive Strength after 28 days and 24 hours curing

C. Compressive strength of M_{30} concrete cube casted

Table–XII and Table-XIII shows Compressive strength results at 7 days and GC-40 for M_{30} grade concrete

Table-XII: Compressive strength results at 7 days M30 (RC)

Cube mark	Ultimate Load (KN)	Compressive Strength (N/mm^2)	Average Value (N/mm^2)	Corresp o- nding weight of cube in Kg
C_{25}-1	345	15.33	19.50	8.28
C_{25}-2	375	16.66		8.40
C_{25}-3	330	14.66		8.29
Compressive strength test results at 28 days M25 (RC)				
C_{25}-1	580	25.77	26.10	8.5
C_{25}-2	600	26.27		8.4
C_{25}-3	570	25.33		8.65

Table-XIII: Compressive strength of GC-40(24 hrs)

Cube mark	Ultimate Load (kgf)	Compressive Strength (N/mm^2)	Average Value (N/mm^2)	Corresponding weight of cube in Kg
GC40-1	95616.72	41.69	41.42	8.32
GC40-2	94597.35	41.24		8.45
GC40-3	94801.22	41.33		8.20
Compressive strength results at 28 days M30 (RC)				
C_{30}-1	680	30.22	30.02	8.5
C_{30}-2	675	31.11		8.3
C_{30}-3	690	30.66		8.5

Table–XIV shows Compressive strength results for GC-60(24 hrs) of M_{30} concrete cube

Table-XIV: Compressive strength of GC-60(24 hrs)

Cube mark	Ultimate Load (kgf)	Compressive Strength (N/mm^2)	Average Value (N/mm^2)	Correspon ding weight of cube in Kg
GC60-1	68600	29.91	30.31	8.42
GC60-2	70400	30.69		8.33
GC60-3	69600	30.35		8.20

D. Compressive strength of M_{25} concrete cube casted

Table–XII and Table-XIII shows Compressive strength results at 7 days and GC-60 for M_{25} grade concrete.

Table-XV: Compressive strength of M25 at 7 days (24 hrs)

Cube mark	Ultimate Load (KN)	Compressive Strength (N/mm^2)	Avg. Value N/mm^2	Correspondin g weight of cube in Kg
C_{30}-1	435	19.383	22.05	8.4
C_{30}-2	390	17.33		8.62
C_{30}-3	410	18.22		8.63

Table-XV: Compressive strength for M25 of GC-60(24 hrs)

Cube mark	Ultimate Load (kgf)	Compressive Strength (N/mm^2)	Avg. Value N/mm^2	Correspondi- ng weight of cube in Kg
G60-25-1	50000	21.80	22.02	8.00
G60-25-2	50600	22.06		8.31
G60-25-3	51000	22.24		8.10

E. Cost Analysis

Rate of material per cubic feet is considered. Table-XVII and Table-XVIII shows the rate of different materials used and the rate of materials per kg

Table-XVII: Rate of Materials

Materials	Quantity	Rate in"Rs."
Cement	1 bag	340
Fine aggregate	Per cft	43
Coarse aggregate	Per cft	40
NaOH	1 Kg	55
Na_2SiO_3	1litre	15

Table-XVIII: Rate of materials per kg

Materials	Rate in "Rs."
Cement	6.80
Fine aggregate	1.52
Coarse aggregate	1.42
Fly Ash	0.50
NaOH	35
Na_2SiO_3	15

V. CONCLUSION

The molarity and ratio of chemicals must be reduced, which will reduce the cost for chemicals. The workability for all the GC is twice when compared to Reference Concrete. So sand can be replaced with M-Sand or Bottom Ash, which will reduce the cost for sand. By increasing the time and temperature of steam curing, the strength of GC increases. By considering the above three points, we can increase the strength of GC and reduce the cost when compared to Reference concrete.

Steam cured low calcium fly ash with geo-polymer gives several benefits over OPC including strength, environmental and economical benefits. In this project the experimental investigations carried out to study the effect of use of fly ash and geo polymer as a replacement of cement on the workability and compressive strength of concrete.

Concrete mix with 40%, 60% of fly ash and Geo polymer shows good workability. Compressive strength results found that GC40, GC60 show the highest strength when compared with 7 days and 28 days of control concrete.

Geo-polymer concreting comparatively needs further research and can be one of the best replacements to the cement in the near future. Finding of our study shows that there is a lot of future scope in the field of Geo-polymer concreting and its uses in civil engineering structures and the developing the countries infrastructures.

REFERENCES

1. **Hardijito** and **Rangan** 'Development and properties of low calcium fly ash based Geo-polymer concrete'. Research Report GC 1 Faculty of engineering, curtin university of Technology,Australia
2. **Djwantoro Hardjito et al.** "factor influencing the compressive strength fly ash based geo polymer concrete" Civil engineering dimension volume VII No.2, 88-93, September 2004. Specification for fly ash for use as pozzalana and admixture'.IS:3812-1981
3. IS: 383-1970,"Specification for coarse and fine aggregates from natural resources for concrete".
4. IS: 456:2000,"Plain and reinforced concrete-code practice".
5. IS: 2386 (part III) / 1963,"Methods of test for strength of concrete .part3 specific gravity, density, voids, absorption and bulking".
6. IS: 10262-1982, "Recommended guide lines for concrete mix design".
7. **M. S. Shetty** Concrete Technology Theory and Practice, 2008. Portland Cement,en.wikipedia.org/wiki/Portland-cement
8. **Abebe Dinku** Construction Materials Laboratory Manual, Addis Ababa University Printing Press, 2002.

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Seena Simon, working as Assistant Professor at R. M. K. Engineering College, Kavaraipettai. She completed B.Tech in Civil Engineering from Calicut University in 2009. She obtained M.E in Structural Engineering from Anna University in 2012. She has guided many under graduate projects and published papers in International journals and Conferences. She has attended several National and International Conferences, Workshops, Faculty Development and Training programs. She is a life time member of ISTE.

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