Low Calcium Fly Ash Based Geopolymer Concrete Reinforced with Steel Fibers

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Abstract- Concrete usage around the globe is second only to water. An important ingredient in the conventional concrete is the Portland cement. The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere. Moreover, cement production is not only highly energy-intensive, next to steel and Aluminium, but also consumes significant amount of natural resources. In order to meet infrastructure developments, the usage of concrete is on the increase. Do we build additional cement plants to meet this increase in demand for concrete, or find alternative binders to make concrete? We have conducted some research on the manufacture and behavior, of "Low-Calcium Fly Ash-Based Geopolymer Concrete Reinforced with steel fibres". This concrete uses no Portland cement; instead, we use the low-calcium fly ash from a local coal burning power station as a source material to make the binder necessary to manufacture concrete. This study is aimed to know the compressive strength of concrete using the basic materials like Fine Aggregate, Coarse Aggregate and the binder material as fly ash the flexural strength study between the geopolymer concrete with and without steel fiber. Various properties like Workability, Initial setting time, compressive strength and Split tensile Strength has been studied are to be compared with geopolymer concrete with and without steel fibre.

I. INTRODUCTION

1.1GENERAL

Demand for concrete as construction material is on the increase so as the production of cement. The production of cement is increasing about 3% annually. Although the use of Portland cement is unavoidable in the foreseeable future, many efforts are being made to reduce the use of Portland cement in concrete. Here we are reducing the usage of cement by developing alternate materials.

1.2 HISTORICAL BACKGROUND

Geopolymers are inorganic polymeric binding materials, firstly developed by Joseph Davidovits in 1970, which is applicable since 1972 in France, Europe, and USA. Its chemistry concept was invented in 1979 with the creation of a non-for profit scientific organization. This application shows genuine geopolymer products having brilliantly withstood 25 years of use and that are continuously commercialized.

1.3 GEOPOLYMER CONCRETE

Geopolymer is a binding material, it's a term used to describe inorganic polymers based on alumino-silicates. Geopolymer binders are used together with aggregates to produce geopolymer concrete. It is extremely different from that of ordinary concrete. Setting mechanism depends on polymerization process. Applications of geopolymer concrete are in precast concrete product like railway sleepers, electric power poles, etc. It is also used for marine structures and waste containments.

2. MATERIALS USED

2.1 FLY ASH

FIGURE 1.1 Fly Ash

Flyash , a pulverized fuel ash (known as PFA) is a finely divided residue form combination of powedered coal/lignite in modern plants such as thermal power station. Since fly ash chiefly contains lime, silica. It is a good pozzolona and can readily be used for partial replacement of cement. Fly ash from Mettur power plant was used for the study. The properties of the flyash is given in table.

TABLE 1.Physical Properties

Physical Properties	Values
Fineness modulus	7.86
Specific gravity	2.10

TABLE 2. Chemical Properties

Chemical composition	PERCENTAGE
Silica	59.62
Alumina	26.43
Iron Oxide	6.61
Calcium Oxide	1.20

Magnesium Oxide	0.76
Sulphur-tri- Oxide	0.58
Titanium Oxide	1.56
Loss of ignition	1.76

2.*2 COARSE AGGREGATE*

FIGURE 1.2 Coarse Aggregate

Aggregates are collected from approved quarry and Aggregates having size ranging from 10mm and 20mm are used. The tests are carried out or Coarse Aggregates as per IS 2386-1963 and the results are given in Table 3.

TABLE 3. Properties of Coarse Aggregate

Properties	Value
Specific gravity	2.83

Fineness modules	6.4
Size	Passing through 20mm sieve and retained in 10mm sieve

2.3 FINE AGGREGATES

FIGURE 1.3 Fine Aggregate

The river sand is used which passes through 4.75mm sieve. Physical properties of aggregates are as per IS 2386-1963 and the results are given in Table4.

TABLE 4. Properties of river sand

Properties	Value
Specific gravity	2.6
Fineness modules	2.85
Size	Passing through 4.75mm sieve

2.4 ALKALINE LIQUID

Sodium Silicate (Na2SiO3) and Sodium Hydroxide (NaOH) has been used in GPC and the combination of this solution is called as alkaline liquids. Instead of Sodium Silicate and Sodium Hydroxide, Potassium Silicate and Potassium Hydroxide (KOH) can also be used. For this project, we have got the sufficient sodium silicate from micro fine chemicals. A combination of sodium silicate and sodium hydroxide is to be chosen as the alkaline liquid.

A combination of sodium silicate solution and potassium hydroxide pellets can be used for preparing the alkaline liquid. The KOH solution is prepared by adding 448.8gms. It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use.

The sodium silicate solution is commercially available in different grades. The sodium silicate solution A53 with SiO2-to-Na2O ratio by mass of approximately, i.e., SiO2 = 29.4%, Na2O = 14.7%, and water = 55.9% by mass, is recommended.

FIGURE 1.4 Alkaline Liquid

2.5 STEEL FIBER

FIGURE 1.5 Steel Fiber

Several studies have shown that fiber addition is an efficient method to improve the mechanical performance of brittle matrices as mortars and concretes by cracking arresting, also it is well known the increase in fracture toughness provided by fiber bridging on the main crack plane prior to crack extension.In this study corrugated steel fibre with the aspect ratio50 is chosen. Corrugated steel fibres offer cost efficient concrete reinforcement. The fibres are made from lowcarbon, cold drawn steel wire. They are evenlydistributed in concrete mixtures to improve the impact resistance, fatigue endurance and shear strength of concrete.

2.6 WATER

Casting and curing of specimens were done with the portable well and bore water.

2.6.1 Hardness

Total hardness of sample water = 200ppm

Permanent hardness= 185ppm

Temporary hardness =15ppm

Amount of OH content in 1 lit of

Water sample in terms of $CaCO_3$ = 2325ppm

Amount of Ca present in 1 lit of water= 300ppm

2.6.2 Turbidity

Turbidity of the given sample= 12mg/lit

2.6.3 Dissolved Oxygen

Amount of dissolved oxygen

in tap water = 4.96 mg/lit

2.7 SUPERPLASTICIZERS

Superplasticizers, also known as high range water reducers, are chemicals used as admixtures where welldispersedparticle suspension are required. These polymers are used as dispersants to avoid particleaggregation, and to improve the flow characteristics (rheology) of suspensions such as in concrete applications.

3. MIX DESIGN

Unit weight of concrete = 2400 kg/m3

Mass of combined aggregate = 72%

Mass of concrete = 0.72 X 2400

= 1728 kg/m3

10 mm coarse aggregate = 70%

= 70/100 X 1728

= 1209.6 kg/m3

4.75 mm fine sand =30%

=30/100 X 1728

=518.4 kg/m3

Mass of low calcium fly ash and alkaline liquid

= 2400-1728

= 672 kg/m3

Take liquid-To-Fly ash ratio = 0.35

Mass of fly ash =672/ (1+0.35)

= 497.7 kg/m3

Mass of alkaline liquid = 672-497.7

= 174.2 kg/m3

Take sodium silicate-To-sodium hydroxide ratio = 2.5

Mass of sodium hydroxide solution = 174.2/ (1+2.5)

= 49.7 kg/m3

Mass of sodium silicate solution = 174.2-49.7

= 124.42 kg/m3

TABLE 5. Geopolymer Mix proportions

Materials		Mass (Kg/m3)	
		Mixture-1	Mixture-2
Coarse aggregates:	20 mm	277	277
	14 mm	370	370
	7 mm	647	647
Fine sand		554	554
Fly ash (low calcium ASTM Class F)		408	408
Sodium Silicate solution		103	103
Sodium hydroxide soluton		41 (8Molar)	41 (14 Molar)
Super Plasticizer		6	6
Extra water		None	22.5

4. EXPERIMENTAL DETAILS

TABLE 6.Compressive strength for 8M NaOH in 70% of combined aggregate

Mix no	Fiber	Liquid/ flyash	Materials (Kg / m³)					Extra water (ml)	Slump (mm)	Sample	Weight Kg	Load N	Area mm2	Stress N/mm2
			Fly ash	S.S	S.H	C.A	F.A							
1	0.60	0.45	7.69	2.41	1.05	19.5	6.5	200	1.5	1	8.14	240000	22500	10.59
										2	7.60	200000	22500	8.10
										3	8.30	290000	22500	12.80
										4	7.40	250000	22500	11.15
2	0.60	0.5	7.44	2.59	1.13	19.5	6.5	200	5	1	8.30	370000	22500	16.40
										2	8.20	420000	22500	18.64
										3	8.74	380000	22500	16.89
										4	8.40	280000	22500	12.46
3	0.60	0.55	7.19	2.76	1.2	19.5	6.5	200	12	1	8.11	200000	22500	8.89
										2	8.32	210000	22500	9.31
										3	8.9	300000	22500	13.35
										4	8.44	210000	22500	9.36
4	0.60	0.6	6.98	2.92	1.27	19.5	6.5	200	23	1	8.20	200000	22500	8.89
										2	8.10	190000	22500	8.46
										3	8.33	200000	22500	8.90
										4	8.03	100000	22500	4.47

TABLE 7. Compressive strength for 10M NaOH in 72% of combined aggregate

Mix no	Fiber	Liquid/ flyash	Materials (Kg / m³)					Extra water (ml)	Slump (mm)	Sample	Weight Kg	Load N	Area mm2	Stress N/mm2
			Fly ash	S.S	S.H	C.A	F.A							
1	0.60	0.5	6.94	2.42	1.05	20	6.69	206	3	1	8.24	260000	22500	11.57
										2	8.39	230000	22500	10.29
										3	8.70	290000	22500	12.84
										4	8.24	90000	22500	4.07
2	0.60	0.55	6.72	2.57	1.12	20	6.69	206	4	1	8.14	290000	22500	12.85
										2	8.70	240000	22500	10.69
										3	8.16	280000	22500	12.46
										4	8.34	230000	22500	10.25
3	0.60	0.6	6.51	2.72	1.18	20	6.69	206	20	1	8.68	200000	22500	8.89
										2	8.69	410000	22500	18.23
										3	8.43	180000	22500	8.10
										4	8.29	350000	22500	15.57

5. CONCLUSIONS

Geopolymer concrete is a new invention in the world ofconcrete in which cement is totally replaced by industrial waste which contributes towards the global worming by reducing use of cement and utilisation of by products like fly ash. Since geopolymer concrete is more brittle than conventional concrete, steel fibres are used to make it an elastic one. Water content plays an important role in determining the compressive strength of geopolymer concrete

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