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STRENGTH AND DURABILITY OF FLYASH BASED GEOPOLYMER CONCRETE IN THE PRESENCE OF SILICA FUME

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Abstract - - *Concrete is till now the most popular material in construction and one of the most environmentally harmful materials. During the manufacturing of Ordinary Portland Cement (OPC), a large amount of CO_2 is released into the atmosphere causing global warming. Geo-polymer is an alternative material which can act as a binder by replacing cement. It mainly makes use of waste by-product substances like fly-ash, which is cheaper and will reduce environmental pollution to a large extent. Fly-ash is one of the major waste materials available from thermal power plants. River sand is mined from the river beds and sand mining has disastrous environmental consequences. To overcome this tribulation. M-Sand is used as a replacement of river sand. Alkaline solution (Sodium Hydroxide, Sodium Silicate) is used for the preparation of geo-polymer concrete. It will act as water in geo-polymer concrete. In this report literature review on concrete, mix design of geo-polymer concrete and material properties based on test conducted in the structural Engineering laboratory are discussed and presented. In this experimental work have analyses the Strength and Durability properties of fly-ash & M-Sand based geo-polymer concrete. From the investigation it has found Geo-polymer concrete shall be used as an alternative to Ordinary cement concrete due to the Compressive strength, Split tensile strength, impact test on concrete and Durability test. The tested results are also compared with conventional concrete and found that. GPC possess better strength than conventional concrete of comparable mix and shall be used for construction purpose to overcome environmental concerns. The durability test was conducted on Acid attack test, Water absorption test. The tested results are also compared to conventional concrete and found that GPC better than conventional concrete.*

***Key Words*: Geo-polymer, Fly-ash, Silica Fume, Sodium hydroxide, Sodium silicate, Durability, Sulphuric acid.**

1. INTRODUCTION

Concrete is a material that is used for many purposes in construction and does not need maintenance during the life-time of the structures. Concrete structures made from Portland cement, when exposed to aggressive environments: tend to deteriorate much faster than their expected service life. Durability of OPC concrete is connected to the properties of its constituent ingredients such as $Ca(OH)_2$ and calcium silicate hydrates. Deterioration may take place due to number of chemical reactions occurring between the aggressive environment and calcium containing components of the concrete. The reactions between the acidic effluent and cement hydrates produce calcium salts which may be highly soluble or feebly soluble. In both the cases it will not product the matrix. With growing environmental consciousness at all levels of society, the pollution and health hazards, especially associated with the concrete, cement and clay-bricks industries are coming under intense scrutiny from environmentalists and the governments. Durability and sustainability of Portland cement concrete are other important issues. For making green, durable and sustainable concretes, alternative binders such as geo-polymers are being investigated. There are two major environmental benefits of using geo-polymer binder over OPC: potential reduced greenhouse gases emissions and utilization of industrial by-products. In principle, geo-polymer is a product of alkali activation of any alumino-silicates materials such as fly-ash. High early strength and resistance to chemical attack are some of the properties of geo-polymer concrete which gave an edge over ordinary Portland cement concrete. Fly-ash based geo-polymer can be used as cement to mix with aggregates to form concrete. In this context, considering the low cost, low CO_2 emission and low energy usage in the production of fly-ash based geo-polymer, cement and concrete are regarded as possible alternative green materials to OPC. These materials are still at the beginning stages of development and hence need further research work in order to become technically and economically viable construction materials.

There is a general consensus about the strength advantages of geo-polymer concretes over OPC and there is a widespread debate regarding their durability. Some groups believe that the availability of wide scientific background, together with the already known OPC durability problems, is sufficient for their commercialization but others consider the durability of geo-polymer concretes to be an unproven issue reported an increase in compressive strength of geo-polymer concrete with increase of silica fume. It is also reported that geo-polymer concrete in the presence of silica fume is highly resistant to acidic environment but the role of silica fume is not well understood. From basic concept, durability is defined as the capability of concrete to resist weathering action, chemical attack and abrasion. The preparation and formation the fly-ash based geo-polymer products depend heavily upon the purity and concentration of alkali solutions and raw materials, chemical and physical characteristics of fly-ash, alkali activators and curing

conditions. The gels influence the final structure of geo-polymer and control the ionic transport. The porosity influences the migration of alkali from fly-ash based geo-polymer into the ion solutions, the moisture and then has an effect on the mechanical strength and durability. Fly-ash based geo-polymer with compact and denser structure shows high mechanical strength and good efflorescence. Incorporation of silica fume into fly-ash expected to improve the mechanical properties of resulting geo-polymers by decreasing porosity. In this paper attempts have been made to investigate the role of silica fume on the durability properties of fly-ash based geo-polymer concretes in aggressive environment particularly sulphuric acid.

2. EXPERIMENTAL PROGRAMES

The present work aims to study the effect of filler type on fresh and hardened concrete properties such as slump flow, Compressive strength test, Tensile test, Durability test were considered in this study.

2.1 MATERIALS

2.1.1 CEMENT

Ordinary Portland Cement of 53 grade confirming to IS: 12269-1987 was used in the present study. The The properties of cement are shown in Table 2.1.1.

TABLE 2.1.1 PROPERTIES OF CEMENT

S. NO	PROPERTY	RESULT
1	Normal Consistency	36%
2	Specific Gravity	3.15
3	Fineness of Cement	10%
4	Initial Setting Time	30 min
5	Final Setting Time	10 hrs

2.1.2. FINE AGGREGATE

In the present investigation locally existing river sand is used as fine aggregate. The fine aggregate obtained from silt and clay and organic substances. In some standard tests were conducted for its various properties of sand like specific gravity, fineness of modulus as per IS: 383-1970

TALE 2.1.2 PROPERTIES OF FINE AGGREGATE

S. NO	PROPERTY	RESULT
1	Specific Gravity	2.73
2	Fineness Modulus	2.80
3	Grading Zone	II

2.1.3. COARSE AGGREGATE

If locally available angular size, machine crushed granite metal of normal size 10mm aggregate used as coarse aggregate. If is permitted some impurities such as powered dust, clay minerals and organic substances etc. In coarse aggregate also conducted some standard tests for its various properties. The physical properties of coarse aggregate shown in Table 2.1.3

TABLE 2.1.3 PROPERTIES OF COARSE AGGREGATE

S. NO	PROPERTY	RESULT
1	Bulk Density	1572kg/m^2
2	Specific Gravity	2.70
3	Impact Test	10.09%

2.1.4 SILICA FUME

Silica fume is the one of the pozzolonic material used in experiment. Silica fume is a by product produced from the manufacture of of silicon or Ferro silicon industry from the reduction of large amount quartz with coal in electric arc. The physical properties of silica fume shown in Table 2.1.4

TABLE 2.1.4 PROPERTIES OF SILICA FUME

PROPERTIES	RESULT
Color of Silica Fume	Light to Dark Grey
Specific Gravity	2.2
Surface Area	20000 m^2/kg
Bulk Density	450 kg/m^3

2.1.5 FLYASH

Fly-ash is another pozzolonic material used in experiment. Fly-ash is ensuring from the explosion of powered coal and transported by fuel gases and composed by electrostatic precipitation. The physical properties of Fly-ash shown in Table 2.1.5

TABLE 2.1.5 PROPERTIES OF FLYASH

S. NO	PROPERTY	RESULT
1	Fineness property	3.5%
2	Specific Properties	2.32
3	Consistency Property	45%

21.6 SUPER PLASTICIZER

In this investigation super plasticizer Conplast SP430 in the form of Sulphonated Naphthalene polymers complies with IS: 9103-1999 and ASTM 494 type F was used to improve the workability of concrete. The properties of super plasticizer are shown in Table 2.1.6

TABLE 2.1.6 PROPERTIES OF CONPLAST SP 430

S. NO	PROPERTY	RESULT
1	Specific Gravity	1.22
2	Chloride Content	NIL
3	Air Entrainment	1%

3. MIX PROPORTION

The used alkaline solution solution ratio for geo-polymer concrete was kept constant as 0.35 whille the dosage of super plasticizer was constant as 1%. For all the used concrete mixtes, the coarse aggregate as 1168.48 kg/m^3 and fine aggregate as 575.52 kg/m^3. For fly-ash content of 560 kg/m^3, the replacement of material as 5%, 10%, 15%. By using different percentage of material 12 cubes and cylinders were cast and table shows the mixture proportions of these mixes.

The hardened properties included cube compressive strength, tensile and flexural tests carried out. Concrete compressive strength was determined according to BS 1881: Part 3, 150mm cubes were used. Tensile strength was determined in cylinder where diameter 150mm and height as 300mm. Each results represented in this section is the average of three tested specimens.

In addition, Durability were performed to investigate morphological features in concrete.

TABLE 2.2.1 MIX RATIO

S. NO	DESIGNATION	PERCENTAGES
1	CC	Cement + 0% Silica fume
2	CC 1	Cement + 5% Silica fume
3	CC 2	Cement + 10% Silica fume
4	GPC	Fly-ash + 0% Silica fume
5	GPC 1	Fly-ash + 5% Silica fume
6	GPC 2	Fly-ash + 10% Silica fume

TABLE 2.2.2 MIX PROPORTIONS

CEMENT CONCRETE

Cement	Fine Aggregate	Coarse Aggregate	W/C Ratio	Super Plasticizers
1	2.55	3.29	0.4	0.02

GEOPOLYMER CONCRETE

Fly-ash kg/m3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Alkaline activator kg/m^3		Super plasticizer kg/m^3
			NaOH	Na2SiO3	
1	1.03	2.09	0.35		0.01
Na2SiO3 / NaOH			1.5		
Concentration of NaOH solution			16Molarity		
Curing			Heat curing @ 100ºC for 24 hours		

3.1 HARDENED CONCRETE

3.1.1. OMPRESSIVE STRENGTH

Testing of hardened concrete plays an important role in controlling and confirming the quality of concrete works. Its most common test conducted on hardened concrete and an easy test to perform. Most desirable characteristics properties of concrete are qualitative related to it compressive strength. The test were carried out on 150x150x150mm size cube as per IS 516-1959. The test conducted in 7th and 28 days and the results shown in the table 3.1.1

TABLE 3.1.1 COMPRESSIVE STRENGTH RESULTS

S. NO	SPECIEMENS	COMPTTESSIVE STRENGTH (MPa)	
		7 DAY	28 DAY
1	CC	29.04	43
2	CC 1	32.76	46
3	CC 2	36.72	52
4	GPC	39.33	57.33
5	GPC 1	42.22	58.67
6	GPC 2	43.1	60.66

TABLE 3.1.2 SPLIT TENSILE STRENGTH RESULTS

S. NO	SPECIMENS	SPLIT TENSILE STRENGTH (MPa)	
		RIVER SAND	M-SAND
1	CC	4.12	4.20
2	CC 1	4.31	4.26
3	CC 2	4.16	4.32
4	GPC	4.44	4.46
5	GPC 1	4.49	4.51
6	GPC 2	4.38	4.41

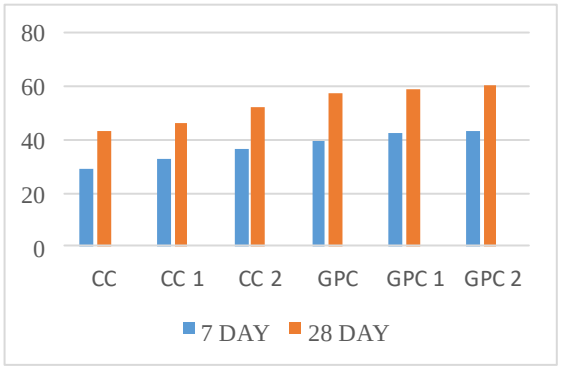

Fig. 3.1 Compressive strength

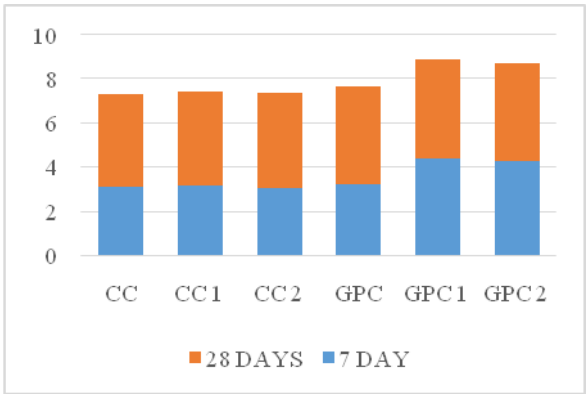

Fig. 3.2 Split Tensile Strength

3.1.2 SPLIT TENSILE STRENGTH

One of the important properties of concrete is "tensile strength" as structural lads make concrete vulnearable to tensile cracking. Tensile strength of concrete is much lower than its compressive strength. The split tensile test of geo-polymer concrete with various percentages of silica fume. To perform investigation in the above context the research proceeds with casting of 28 cubes of size 150x150x150mm, cylinders of size 150mm diameter and 300mm height. These specimens are undergone under various tests such as compressive strength, split tensile strength.

4. DURABILITY

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, abrasion while maintaining its desired engineering properties.

4.1.1 ACID RESISTANCE

Acid resistance was tested on 150mm size concrete cube specimens at the age of 24 hours at 70^0C of heat curing. The cube specimens were weighted and immersed in water diluted with five percent by weight of Hydrochloride acid for 7, 14, 28 days. These the specimens were taken out from the acid water and the surfaces of the cubes were cleaned. Then the weight and the compressive strength of the specimens were found out and the average percentage of loss of weight and compressive strength were calculated.

TABLE 4.1.1 ACD RESISTANCE TEST

SPECIMENS	COMPRESSIVE STRENGTH (MPa)		
	BEFORE CURING	AFTER CURING	REDUCTION OF WEIGHT
CC	41.201	38.625	6.25
CC 1	43.023	41.840	4.44
CC 2	48.000	45.870	2.68
GPC	52.443	49.190	6.20
GPC 1	57.346	54.982	4.11
GPC 2	58.450	56.457	3.42

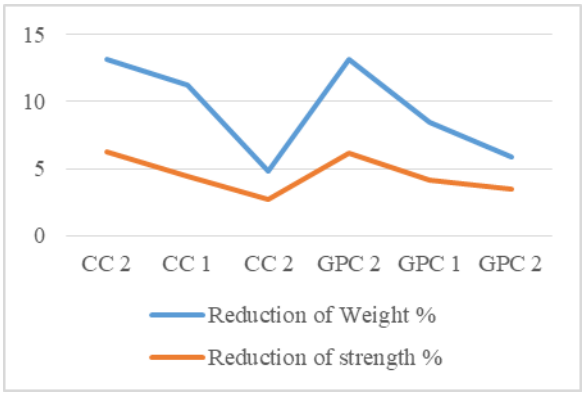

Fig. 4.1 Acid Resistance

4.1.2 WATER ABSORPTION TEST

Water absorption characteristic of concrete plays an important role for the durability. The test was perform to evaluate the water absorption characteristics of geo-polymer and control concrete. Test specimens for compressive strength and change in mass test were 150x150x150mm cubes of control concrete and geo-polymer concrete each.

TABLE 4.1.2 WATER ABSORPTION TEST RESULT

S. NO	SPECIMENS	INITIAL WEIGHT (kg)	OVENDRY WEIGHT (kg)	WEIGHT AFTER IMMERSION (kg)	GAIN (%)
1	CC	8.35	8.27	8.51	2.90
2	CC 1	8.25	8.17	8.39	2.69
3	CC 2	8.60	8.47	8.68	2.48
4	GPC	8.47	8.23	8.52	3.52
5	GPC 1	8.59	8.46	8.69	2.72
6	GPC 2	8.30	8.22	8.44	2.68

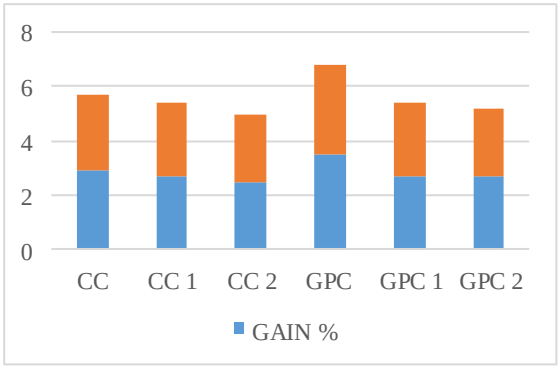

Fig. 4.2 Water Absorption Test

5. CONSULSIONS

In this investigation geo-polymer concrete was produced fly-ash as binder to replace completely OPC in concrete. Also M-sand was used in place of River sand in geo-polymer concrete. Besides concrete mix with OPC was also studied for compressions and presented in this report. Based on the tests conducted on specimens made of Conventional concrete and GPC.

The report presented information on M-Sand and Fly-ash based geo-polymer concrete. Fly-ash and M-Sand are used as the source material instead of the Portland cement and river sand to make concrete.

- The M-Sand based geo-polymer concrete shows good workability compared to concrete made with river sand and cement concrete of same mix proportions.
- The compressive strength of M-Sand based geo-polymer concrete is 30% higher than the concrete made with river sand and cement concrete of same mix proportions.
- The split tensile strength of M-Sand based geo-polymer concrete is 40.38% higher than the River sand based cement concrete of same mix proportions
- M-Sand based geo-polymer concrete is 40.38% higher than the river sand abased cement concrete of same ix proportions.

- The M-Sand and Fly-ash based geo-polymer concrete shows excellent resistance to acid attack compared to River sand used cement concrete

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