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Durability Properties of Fly Ash Slag Based Geopolymer Concrete with Partial Replacement of Recycled Coarse Aggregate

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ABSTRACT

Recycled coarse Aggregate (RCA) is sourced from local construction and demolition waste. The RCA is used as a partial replacement of natural coarse aggregate (NCA) in fly ash slag based geo polymer concrete at 0%, 10% , 20% , 30% , 40% and 50% by wt. While the fly ash slag based geopolymer concrete containing 100% NCA is control and is considered as the first series. Fly ash & GGBS is used as the source material for the geo polymer and 10 M sodium hydroxide and sodium silicate alkali activators are used to synthesise the fly ash slag based geopolymer in this study. In all replacements a constant alkali activator to fly ash ratio is used. Durability properties such as sorptivity, water absorption and volume of permeable voids of fly ash slag based geopolymer concrete were also affected by addition of recycled coarse aggregates and these properties increase with percentage replacement increase in RCA contents. The effects of RCA on the measured mechanical and durability properties of fly ash slag based geopolymer concrete follow similar trend in cement concrete. Relations of compressive strength with volume of permeable voids and water absorption of fly ash slag based geopolymer concrete containing RCA are also observed. The feasibility using fly ash slag based GPC and to find out their durability characteristics .GPC was developed using fly ash and GGBS in different percentages by replacing coarse aggregates and the strength & durability characteristics of their new concrete were investigated in order to explain its utilization. In the present research work, flyash slag based geopolymer was used as the binder as a substitute of Portland cement paste to produce concrete. The flyash slag based geopolymer concrete paste binds the loose CA, FA and other loose materials together to form the geopolymer concrete by addition of super plasticizer or not.

Keywords: Geopolymer; Fly ash & ground granulated blast furnace slag; Recycled coarse aggregate; Construction and demolition waste; Mechanical properties and durability properties

I. INTRODUCTION

Recycled coarse aggregates are obtained from the construction demolished waste which requires huge land to dispose off. Instead disposing we try to replace natural aggregates in different proportions. These may does not give the total strength if we use entire aggregates as replacement.

Cement is only a constituent of concrete and global emissions estimates have not been made for the concrete industry but the author would estimate this to be in the range of 10 to 14 percent. The growth of the concrete industry is being fuelled by key world economics resulting in an increased demand for construction materials, in particular concrete. An average concrete mix requires approximately 350kgs of cement per cubic meter, the heavy usage of cement in concrete resulted in the increase of carbondioxde in the world. It is widely accepted that concrete is the most extensively used construction material. Currently, the world production of concrete is about one tone per year for every living person. Concrete is the second most consumed material apart from water. Despite current global financial crisis resulting in reduced demand for construction materials, a long term projection is that by 2030 the concrete industry is expected to have grown roughly five times larger than in 1990, with close to five billion tones sold annually worldwide. Concern about human induced climate change and its impacts are increasing. It is a manmade product, essentially consisting of a mixture of cement, aggregates ,water and admixtures . Sand, crushed stone or gravel form the major part of the aggregate. These materials are blended in required proportions according to the strength parameter and grade of concrete.

GEOPOLYMER CONCRETE

In the context of increased awareness regarding the ill-effects of the over exploitation of natural resources, eco-friendly technologies are to be developed for effective management of these resources. Construction industry is one of the major users of the natural resources like cement, sand, rocks, clays and other soils. The ever increasing unit cost of the usual ingredients of concrete have forced the construction engineer to think of ways and means of reducing the unit const of its production. At the same time, increased industrial activity in the core sectors like energy, steel and transportation has been responsible for the production of large amounts like fly ash, blast furnace slag, silica fume and quarry dust with consequent disposal problem.

Advantages of Geopolymer Concrete

Geopolymer concretes offer a number of benefits over conventional OPC concrete including:

- Significantly lower CO_2 emissions than OPC concretes – up to˜90%
- Better thermal insulation properties
- Higher temperature/fire resistance
- Provides a viable use for 'waste' materials which are often disposed in landfill
- Better compressive strength.

OBJECTIVE OF THE STUDY

The objective of this study is to assess the utility and efficacy of silica fume and alkaline liquids as a geopolymer concrete as an alternative to ordinary Portland cement concrete. The properties of materials have to be known before it can be used as an alternative of ordinary concrete.

This study focuses on replacement of normal cement with GGBS , FLY ASH as termed to be geopolymer concrete. If geopolymer concrete emerges successfully and attain the properties as normal concrete, it would be a milestone achievement for the local construction industries. Therefore, the main objective of this research is to determine the feasibility of pozzolanic materials as in geopolymer concrete. The objectives of the study are briefly summarized below.

- To make a concrete without using cement (i.e. Geopolymer concrete).
- To evaluate the optimum mix proportion of Geo-polymer concrete with silica fume replaced of cement and also the mix proportion of OPC.
- To study the different Strength, Durability properties of Ordinary and Geo-polymer concrete.
- To make the study of the concrete this has been casted in different moulds and cured in both normal and elevated temperatures.

II. LITERATURE REVIEW

Song X J, Marosszeky M, Brungs M and Munn R , carried out a study on the sulphuric acid attack on fly ash-based geopolymer concrete. They find that the sulphuric acid ingress in geopolymer concrete is controlled by a diffusion process. Excellent gelaggregate interface was observed from SEM micrographs, where the geopolymer matrix at the corroded region remains identical to the unaffected one and still serves the binding function to the surrounding aggregates.

Sobolev K G , studied the effect of adding up to 50% by mass of granulated blast furnace slag in the cementitious material that resulted in the increase of chemical and thermal resistance. The very low permeability of the concrete obtained, provided high resistance to chemical attack and to freezing and thawing cycles. There was no visible destruction of blast furnace slag concrete samples after 140 cycles of freezing and thawing at -50ºC, and they also demonstrated high resistance to elevated temperatures.

Potha Raju M, Shoba M and Rambabu K studied the concrete elements exposed to fire undergo temperature gradients and as a result, the surface layers spall, exposing steel reinforcement. Relatively few studies have been undertaken on heat induced changes in fly ash concrete. The structural property of concrete that has been studied most widely as a function of heat exposure is compressive strength. Less attention has been given to flexural strength as influenced by heat exposure. Therefore, to investigate the effect of temperature on the flexural strength of fly ash concrete, the present study was carried out with M28, M33 and M35 grades of concrete. Concrete specimens 100 × 100 × 500 mm with partial replacement of cement by fly ash (10%, 20% and 30% replacement levels) were heated to 100°C, 200°C and 250°C for 1 h, 2 h and 3 h duration in an electric oven. The specimens were tested for flexural strength in the hot condition immediately after removing from the oven. The fly ash concrete showed consistently the same pattern of behaviour as that of concrete without fly ash under elevated temperatures during flexure. The fly ash concrete with fly ash content up to 20% showed improved performance compared with the specimens without fly ash by retaining a greater amount of its strength.

III. METHODOLOGY

GGBS:

Ground granulated blast furnace slag (GGBS) is produced by rapid cooling of the material molten iron slag (a by - product of iron and steel making) from a blast furnace in water or steam , to produce a glassy, granular product that is then dried and ground into the fine powder. Main components of blast furnace slag are calcium oxide, silica dioxide , alumina oxide ,magnesium oxide.

FLY ASH :

Fly ash is a by-product of the combustion of pulverized coal in thermal power plants. The dust-collection system. Fly ash is a by-product of the combustion of pulverized coal in thermal power plants. The dust-collection system removes the fly ash, as a fine particulate residue, from the combustion gases before they are discharged into the atmosphere. Fly ash particles are typically spherical, ranging in diameter from\1 lm up to 150 lm. The type of dust collection equipment used largely determines the range of particle sizes in any given fly ash. The fly ash from boilers at some older plants using mechanical collectors alone is coarser than from plants using electrostatic precipitators

Figure 1

NaOH

The sodium hydroxide (NaOH) with 97-98% purity, is generally available in flake or pellet form. These pellets are dissolved in water to make a solution with the required concentration. Concentration of NaOH solution can vary however, 8 Molar solutions are adequate for most applications. The mass of NaOH solids in a solution varies depending on the concentration of the solution.

Na_2SiO_3

Sodium silicate is also called as water glass or liquid glass , these materials are available in aqueous solution and in solid form. The present composition are colourless or white , but commercial samples are green or blue in colour due to presence of impurities.

These solution is commercially available in different grades in market. The sodium silicate solution A53 with silicon dioxide to sodium oxide ratio by mass of approximately 2, i.e., SiO_2 = 29.4%, Na_2O = 14.7%, and water = 55.9% by mass, is generally used.

SUPER PLASTICIZER AND ADDITIVES

Super plasticizers are capable of reducing water contents by about 30 percent. However it is to be noted that full efficiency of super plasticizer can be got only when it is added to a mix that has as initial slump of 20 to 30 mm. stiff concrete mix reduces its water reducing efficiency by adding super plasticizer. Depending on the solid content of the mix, a dosage of 1 to 3 percent by weight is recommended.

For the present investigation, a super plasticizer namely CONPLAST SP 430 has been used for obtaining workable concrete at low a/m ratio. CONPLAST SP 430 complies with IS 9103: 1999 [130] and BS: 5075 part 3 and ASTM C 494, TYPE 'B' as a HR WRA. CONPLAST SP 430 related to Sulphonated naphthalene formaldehyde (NSF) which condense with addition of chloride.

IV. RESULTS AND ANALYSIS

Sorptivity:

The sorptivity test is a simple and rapid test to determine the tendency of concrete to absorb water by capillary suction. The test was developed by Hall and is based on Darcy's law of unsaturated flow. One of the methods to examine the related permeability of concrete is sorptivity, which is measuring the rate of absorption of water into concrete.

	i	√t	s=i/√t
OPC	0.63	2.57	0.246
RCA GPC	0.60	2.57	0.235

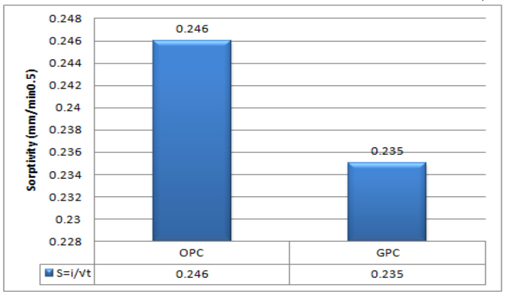
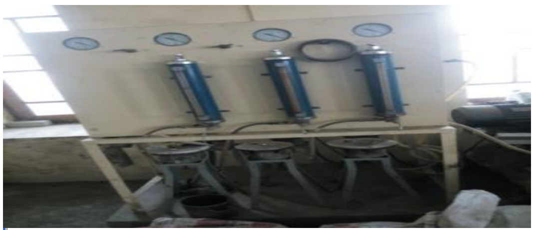


Figure 2

Permeability

The test consists in subjecting the mortar or concrete specimen of known dimensions, contained in a specially designed cell, to a known hydrostatic pressure from one side, measuring the quantity of water percolating through it during a given interval of time and computing the coefficient of permeability.



	Volume of water collected (ml)	Time (Hrs)	Height of Sample (m)	Area of Sample (cm2)	Pressure Head (m)	Coefficient of permeability (cm/sec)
OPC	9	96	0.1	78.53	100	$3.31x10^{-10}$
GPC	6	96	0.1	78.53	100	$2.2x10^{-10}$

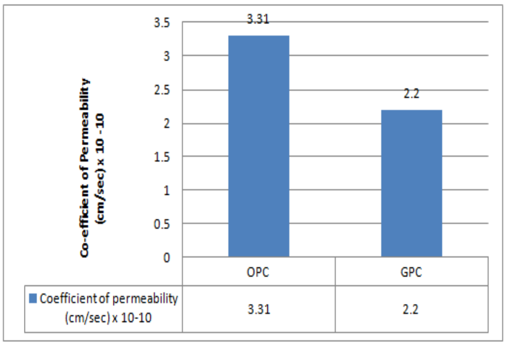


Figure 3

UPV Test

This test was conducted as per the procedure given in IS: 13311:1992. Ultrasonic pulse velocity (UPV) is a non destructive technique that involves measuring the speed of sound through materials in order to predict material strength, to detect the presence of internal flaws such as cracking, voids, honeycomb, decay and other damage

	PULSE VELOCITY (V) (Km/Sec)	
	OPC	RCA GPC
28 Days	4.2	4.9
90 Days	4.4	5.3

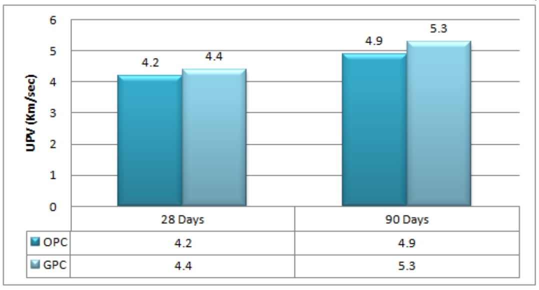


Figure 4

RCPT Test

The test set up is called Rapid Chloride Penetration Test (RCPT) assembly. This is two-compartment cell assembly. Disk specimen is assembled between the two compartments cell assembly and checked for air and watertight. The cathode compartment is filled with 3% NaCl solution and anode compartment is filled with 0.3 normality NaOH solutions. Then, the concrete specimens were subjected to RCPT by impressing a 60V from a DC power source between anode and cathode

	RCPT Value (Columbs)
OPC	1850
RCA GPC	1645

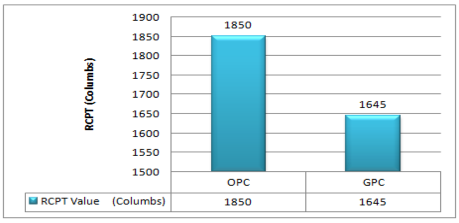


Figure 5

Sulphate Resistance Test

The test was performed to study the effect of sulphate on concrete. Sulphate may be present in soil or ground water which comes in to the contact of concrete and affect it.

$MgSO_4$ solution

	OPC			GPC		
	28 Days	**56 Days**	**90 Days**	**28 Days**	**56 Days**	**90 Days**
Wt. Before Exposure (Kg)	2.42	2.44	2.46	2.47	2.48	2.52
Wt. After Exposure (Kg)	2.44	2.49	2.53	2.49	2.51	2.56
% Gain in weight	**1.1**	**2.4**	**3.2**	**1.2**	**1.5**	**1.9**
Compressive strength before Exposure (N/mm^2)	54.2	56.4	57.8	56.1	58.6	59.1
Compressive strength After Exposure (N/mm^2)	53.5	55.21	56.24	55.65	57.95	58.09
% Loss in Strength	**1.3**	**2.1**	**2.7**	**0.8**	**1.1**	**1.7**

Figure 6

Na_2SO_4 solution

	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.38	2.41	2.43	2.45	2.47	2.5
Wt. After Exposure (Kg)	2.40	2.46	2.49	2.46	2.48	2.52
% Gain in weight	**1.2**	**2.1**	**2.5**	**0.3**	**0.7**	**0.9**
Compressive strength before Exposure (N/mm²)	54.2	56.4	57.8	56.1	58.6	59.1
Compressive strength After Exposure (N/mm²)	53.52	54.99	56.06	55.54	57.9	57.91
% Loss in Strength	**1.25**	**2.5**	**3**	**1**	**1.2**	**2**

Figure 7

H_2SO_4 solution

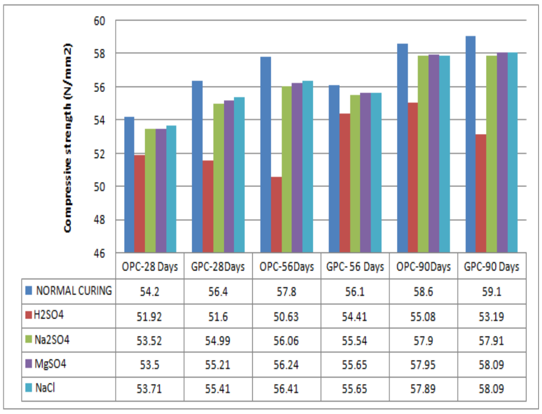
	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.41	2.48	2.52	2.45	2.48	2.52
Wt. After Exposure (Kg)	2.23	2.19	2.01	2.41	2.37	2.46
% Gain in weight	**7.3**	**11.5**	**20.2**	**1.5**	**4.1**	**9.2**
Compressive strength before Exposure (N/mm²)	54.2	56.4	57.8	56.1	58.6	59.1
Compressive strength After Exposure (N/mm²)	51.92	51.60	50.63	54.41	55.08	53.19
% Loss in Strength	**4.2**	**8.5**	**12.4**	**3**	**6**	**10**

Figure 8

Nacl

	OPC			GPC		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
Wt. Before Exposure (Kg)	2.42	2.44	2.46	2.43	2.45	2.48
Wt. After Exposure (Kg)	2.37	2.35	2.35	2.42	2.41	2.40
% Gain in weight	**2**	**3.5**	**4.2**	**0.5**	**1.5**	**3.0**
Compressive strength before Exposure (N/mm²)	54.2	56.4	57.8	56.1	58.6	59.1
Compressive strength After Exposure (N/mm²)	53.71	55.41	56.41	55.65	57.89	58.09
% Loss in Strength	**0.9**	**1.75**	**2.4**	**0.8**	**1.2**	**1.7**

Figure 9



Ghrap 1

V. CONCLUSIONS

1. FA Slag GPC containing RCA is having less porosity when compared to OPC.
2. The capillarity rate of FA Slag GPC containing RCA is less than OPC.
3. The resistance towards the chemical attack on concrete has significantly proven essential for both the concrete, where FA Slag GPC containing RCA has resisted well in circumstances like sulphate, chloride and acid attacks compared to OPC
4. The chloride penetration in FA Slag GPC containing RCA is less comparatively than OPC, so it can be used in chloride zone area.
5. The mix of both the concrete are taken special attraction in this, where it is proven in UPV test and took huge amount of time to travel the rays. Hence we can conclude the materials are conjoined in the specimens.

From the cumulative results we can come to an conclusion than replacement of OPC with FA Slag GPC containing RCA can be done, which can bring the dual benefit such as preserving the natural resources and reduce the emission of green house gases into the atmosphere.

Recommendations for Future Research:

Further investigations have to be carried out regarding the Geopolymer concrete. One major topic, which has to be studied, is related to the influence of cement type and aggregate shape and surface properties on the bonding between cement paste and coarse aggregate. Also, a thorough investigation has to be carried out in order to obtain an appropriate relationship between the water-cement ratio, the aggregate-cement physical interface and also the heat of hydration.

1. Though FA Slag GPC containing RCA enhances all concrete properties by minimizing voids etc, the long-term behavior of concrete like Creep and shrinkage has to be studied.
2. The durability properties of FA Slag GPC containing RCA can be evaluated by varying mix proportions, like aggregate content, cement content, super plasticizer content, maximum aggregate size and the use of different types and quantity of filler.
3. Comparative study related to normal conventional vibrated concrete can be studied using the mix design adopted in this research.
4. Long-term study on durability of FA Slag GPC containing RCA considering rebar corrosion monitoring in addition to other durable properties of concrete.
5. The same work can be performed with different combinations of mineral and chemical admixtures.

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