DURABILITY STUDY ON GEOPOLYMER CONCRETE BY PARTIAL REPLACEMENT OF FLY ASH WITH CEMENT AND FULL REPLACEMENT OF SAND BY CRUSHER DUST

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ABSTRACT

Due to high infrastructure growth all around the world, the demand for concrete is going high day by day. We all know that this concrete uses the cement as a binding material. It is also known that manufacturing of cement not only utilizes abundant natural resources & energy but also causes environment pollution to a greater extent by releasing substantial quantity of carbon dioxide into the atmosphere. Therefore, it is a high time to reduce the usage of cement and to find an alternative to the cement. At the same time large quantity of fly ash is being generated from large number of thermal plants and it is not being utilized effectively. So, one great idea to utilize the abundantly available fly ash and reduce the consumption of cement is'Geopolymer Concrete'. In Geo polymer Concrete, fly ash, rich with aluminium and silicon is used as a source material. These aluminium & silicon present in fly ash are induced by alkaline liquids such as sodium or potassium hydroxide and sodium silicate to produce a binder paste. This paste binds fine and coarse aggregates within the concrete. Thus produced geo polymer concrete gives the desired strength as needed. However, geo polymer concrete requires high curing temperatures to get the desired strength. So, it is thought that partial replacement of fly ash with cement in geo polymer concrete would be helpful in overcoming the problem of this high curing temperature. Hence, in this investigation fly ash within the geo polymer concrete was partially replaced by cement at replacement levels of 10%, 30% and 50% to check for any improvements in the properties of geo polymer concrete. In this experimental work various properties of geo polymer concrete such as compressive strength, split tensile strength, sulphate attack resistance and acid attack resistance were evaluated. Further details of this investigation are described as given in following chapters.

Keywords: geopolymer concrete, cement, fly ash.

1.0 INTRODUCTION

Concrete is a composite material made up of coarse granular material (aggregates or filler) embedded in a hard matrix of material (cement or binder) that fills the space between the aggregate particles and binds them together. Ordinary Portland cement (OPC) is conventionally used as a primary binder material to produce the concrete. Due to increase in demand for infrastructure all around the world, the need for concrete production is also increasing. Thus production of OPC also increasing day by day. But, the main concern in using the OPC is that its impact on environment. It is estimated that approximately one ton of carbon dioxide is released during the manufacture of one ton of cement due to the calcination of limestone and combustion of fossil fuel. In addition to this the extent of energy required to produce OPC is also high. It is next only to steel and aluminium.

On the other hand, abundant quantity of fly ash, a by-product of burning coal is being generated from thermal power plants all around the world. This creates an opportunity to utilize the fly ash as a substitute for OPC to manufacture concrete. When fly ash is used as a partial replacement for OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel. The development and application of high volume fly ash concrete, which enabled the replacement of OPC up to 60% by mass is a significant development.

OBJECTIVES OF THE RESEARCH

This investigation is mainly intended to manufacture and study the short-term and long term properties of low-calcium (ASTM Class F) fly ash based Geopolymer concrete by partially replacing the fly ash with cement. In this study, it is also aimed to understand the effect of full replacement River Sand with crusher dust as fine aggregate. Till now so much of research has been taken place only using River Sand as a fine aggregate. So, in this study an attempt is made to understand the effect of crusher dust as a fine aggregate. The basic aims of this study are:

- To develop a mixture proportioning process to manufacture low-calcium fly ash-based Geopolymer concrete with and without OPC.
- To study the properties of fresh and hardened low-calcium fly ash-based Geopolymer concrete.
- To study the effect of replacement the fly ash with cement in a geopolymer concrete
- To study the effect of replacement river sand with crusher dust as fine aggregate

SCOPE OF WORK

In this research low-calcium (ASTM Class F) fly ash is used as the base material for making Geopolymer concrete. The fly ash and crusher dust used throughout the investigation were from a single source. The technology and equipment used in the manufacture of Geopolymer concrete were same as those used for manufacturing OPC concrete. The various concrete properties studied include the Compressive strength, Split Tensile strength, Sulphate attack resistance and Acid attack resistance.

2.0 LITERATURE REVIEW:

Berry and Malhotra (1980), their experience with fly ash is as reported below. They developed three basic proportioning approaches to obtain either reduced heat of hydration or more recently, to overcome difficulties in getting acceptable levels of strength in concrete at early ages. Those three techniques are:

Della M. Roy [1], this paper reviews the history of development of alkali activated cements and discusses their present status. Currently, there are major opportunities for such cements based upon (a) substantial knowledge of properties and mechanisms; (b) good track record of field performance in various applications and; (c) future orientation as environmentally friendly materials in accord with making use of substantial amounts of by-product and waste materials, thereby consuming less energy and generating less waste. The equivalent performance to Portland cement materials is one target for these cements, but, in many cases, the properties of alkali-activated cements actually are superior.

Dali Bondar, Cyril J. Lynsdale, and Neil B. Milestone [2], In this paper, it is concluded that the Geopolymers or alkali-activated cementitious materials can be used as new high-performance construction materials with low environmental impact and also with a reasonable cost. This material is a good candidate to partially replace ordinary Portland cement (OPC) in concrete as a major construction material that plays an outstanding role in the construction industry of different structures. Geopolymeric materials can be produced from a wide range of alumina-silica, including natural products such as natural pozzolan and metakaolin or co-products such as fly ash (coal and lignite), oil fuel ash, blast furnace or steel slag and silica fume, and provide a route toward sustainable development

3.0EXPERIMENTAL INVESTIGATION

In this investigation a total of 96 specimens were casted and tested to understand various parameters of geopolymer concrete in which fly ash is partially replaced by cement and river sand is fully replaced by crusher dust as a fine aggregate. The various tests carried out includes the Compressive strength test, Split tensile strength test, Sulphate attack resistance test and Acid attack resistance test. In this investigation, the mix design of geopolymer concrete is carried out as per the "Proceedings of the International Workshop on Geopolymer Cement and Concrete, Allied Publishers Private Limited, Mumbai, India, December 2010, pp 68-106". Here, in the Geopolymer concrete the fly ash was replaced by cement at four different replacement levels i.e. 0%, 10%, 30% and 50% to find out whether there are any improvements in properties of geopolymer concrete by partially replacing fly ash with cement. Also the river sand is replaced by crusher dust as a fine aggregate. Hot air oven curing method was adopted for curing all test specimens.

MATERIALS

In this present investigation work, the different materials used are Fly Ash, Ordinary Portland Cement, 10mm and 20mm Coarse aggregates, Crusher dust as fine aggregate, Alkaline liquids, Water and Super plasticiser.

FLY ASH

(As per IS 1727-1967 reaffirmed in 2004)

In the present experimental work, low calcium (Class F according to American Society for Testing and Materials 2001) dry fly ash procured from the Khaperkheda thermal power plant near Nagpur in Maharashtra state of India was used as the base material. The chemical compositions of the fly ash from all batches, as determined by X-Ray Fluorescence (XRF) analysis, are given in Table 3.1., India has carried out the chemical analysis. The various other tests on fly ash were carried out as per IS 1727-1967 reaffirm 2004 and results were conforming to specifications as per IS 3812-2003.

Properties of Fly Ash (Medium Fine Sixth Hopper)

PHYSICAL TEST	
Specific gravity	2.19
CHEMIACAL ANALYSIS (%)	
Silicon Dioxide (SiO2)	55.5
Aluminium Oxide (Al2O3)	28.3
Ferric Oxide (Fe2O3)	11.2
Calcium Oxide (CaO)	1.18
Mangnesium Oxide (MgO)	0.69
Alkalies equivalent	-
Titanium Oxide (TiO2)	1.8
Sulphur Trioxide (SO3)	0.44
Loss on ignition	1.10

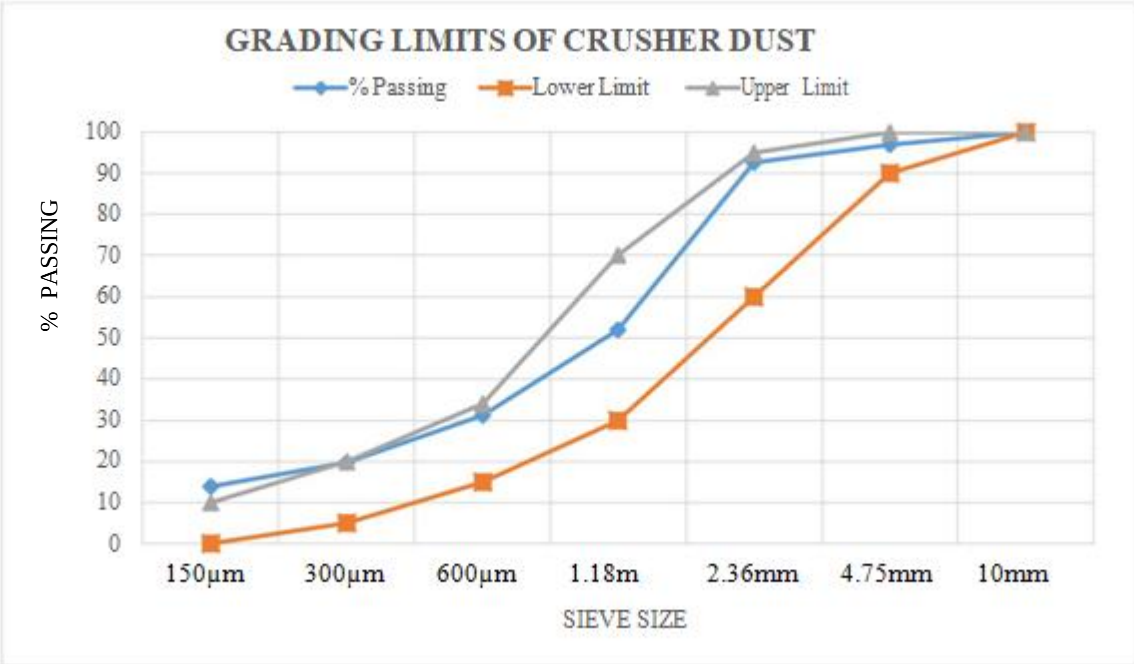
COARSE AGGREGATES

In this experimental investigation, coarse aggregates of size 10mm and 20mm were used. The aggregates were procured from local sources and various tests were carried out on them tested in accordance with the IS 2386-1963 reaffirm 1997 to know their properties and results were conforming to IS 383-1970 reaffirm 2002.

Physical Properties of Coarse Aggregate

(As per IS 383-1970)

Sl.No	Particulars	Size	Specific Gravity	Water absorption
1	Coarse Aggregate	20mm	2.74	0.81%
2	Coarse Aggregate	10mm	2.74	0.81%



PRELIMINARY LABORATORY WORK

In the beginning, numerous trial mixes of Geopolymer concrete were manufactured and test specimens in the form of cubes of 150x150x150mm size were casted. Initially, the mixing was attempted manually. However, it is found that the manual mixing is difficult to use practically in actual applications. Therefore an eighty liter capacity pan mixer with rotating drum available in the concrete laboratory was used to manufacture the Geopolymer concrete.

Data for Design of Low-Calcium Fly Ash-Based Geopolymer Concrete Mixtures (Rangan, 2008, 2009)

Water to Geopolymer Solids	Workability	Design Compressive Strength (Wet mixing time of 4 minutes, steam curing at 60^0C for 24 Hours after casting) (MPa)
0.16	Very Stiff	60
0.18	Stiff	50
0.20	Moderate	40
0.22	High	35

0.24	High	30
0.27	High	25
0.30	High	20

SLUMP TEST

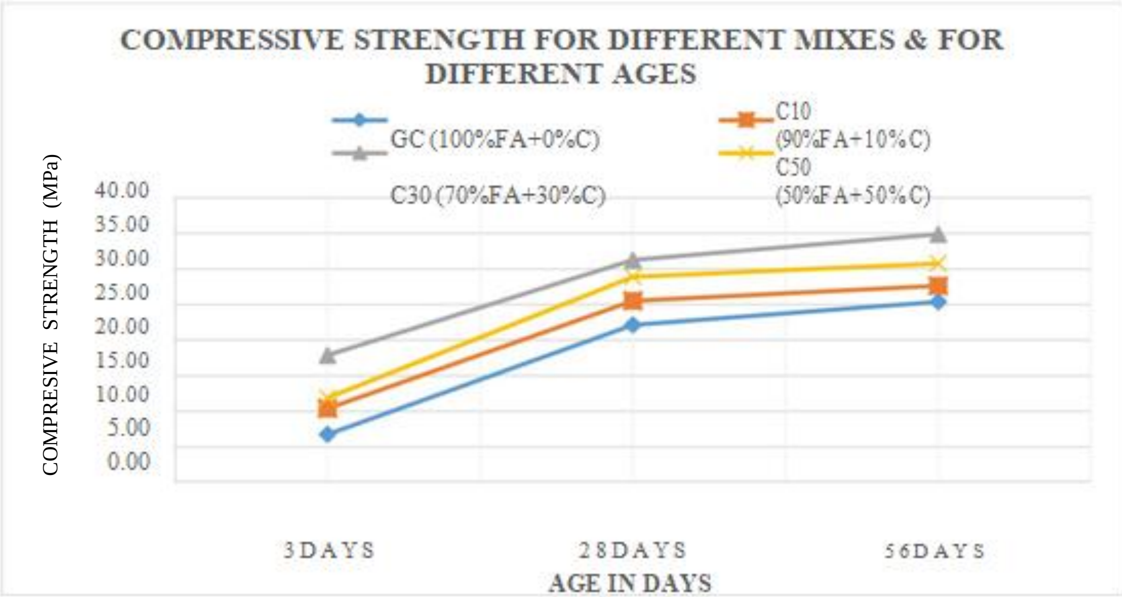
The slump of the fresh Geopolymer concrete mix was checked using a conventional slump cone apparatus and the test was carried out according to IS 1199 – 1959 reaffirmed in 1999

4.0 RESULTS AND OBSERVATIONS

Slump & Compressive strength for different Mixes

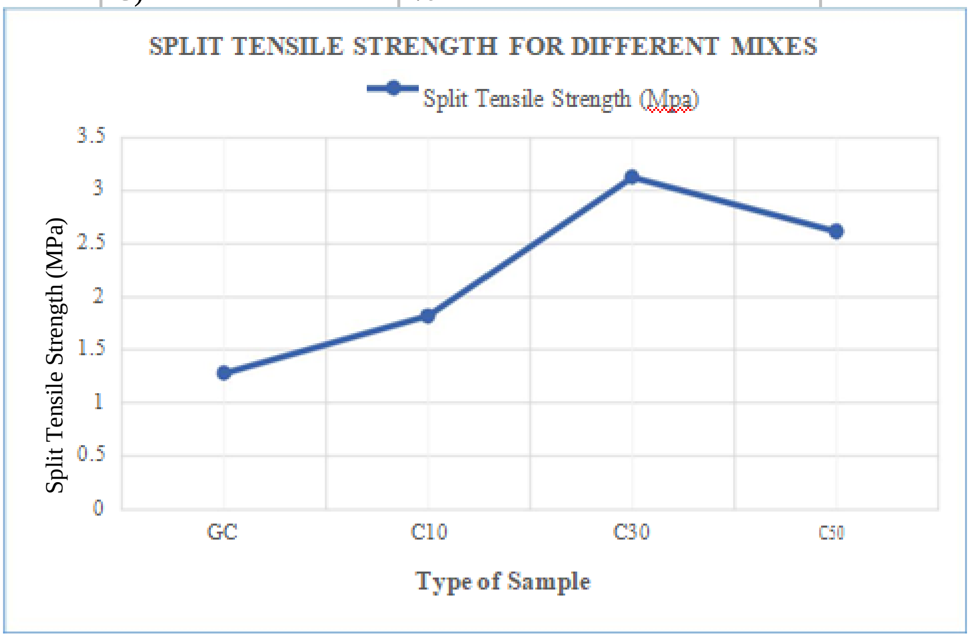
Sl.No	Type of Mix	Slump (mm)	Compressive Strength (MPa)		
			3 Days	28 Days	56 Days
1	GC (100% FA+0% C)	180	6.72	22.13	25.30
2	C10 (90% FA+10% C)	140	10.34	25.50	27.60
3	C30 (70% FA+30% C)	90	17.76	31.20	34.80
4	C50 (50% FA+50% C)	70	11.78	28.90	30.70

The main observation that can be made in this study is that the compressive strength of geopolymer concrete is increasing as the cement content within the GPC is increasing. However it is to note that the compressive strength is increasing upto a replacement level of 30% and after that the compressive strength is decreasing. . It is mainly due to the reason that the optimum water content is available in mix C30 to involve in the hydration process with respect to available cement content.



Split Tensile Strength for different Mixes

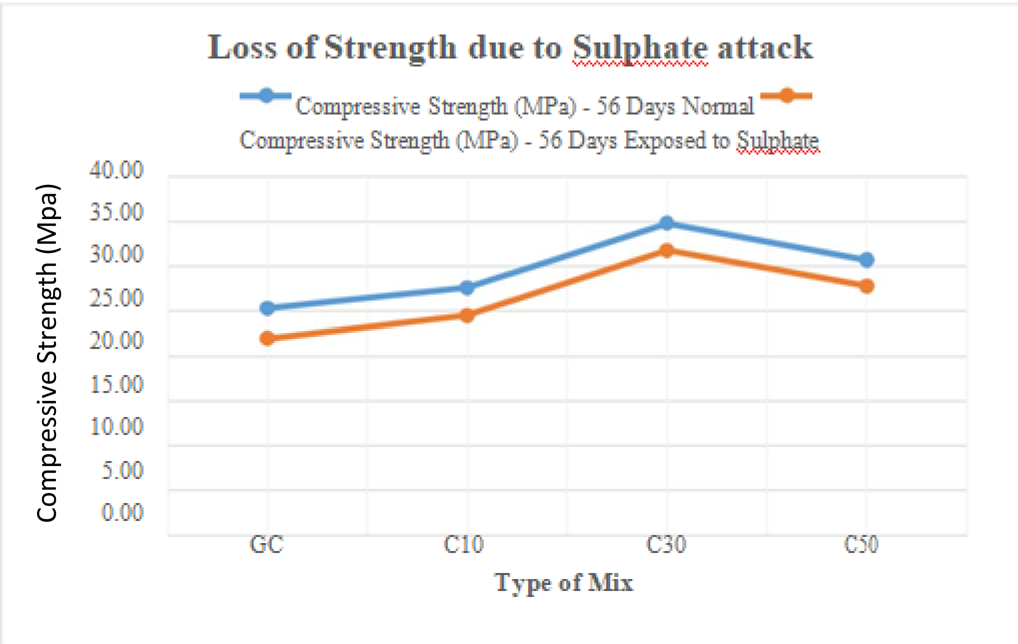
Sl.No	**Type of Mix**	**Split Tensile Strength (MPa)**
1	GC (100% FA+0% C)	1.28
2	C10 (90% FA+10% C)	1.82
3	C30 (70% FA+30% C)	3.13
4	C50 (50% FA+50% C)	2.62



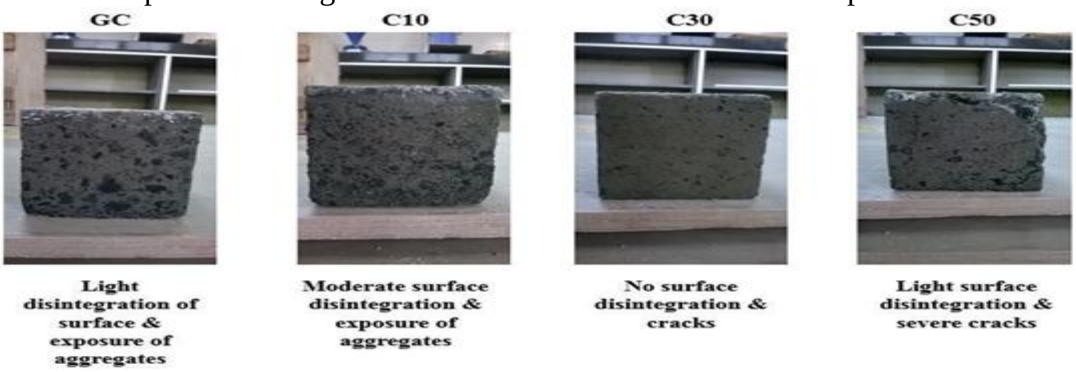
Then, after a period of 8 weeks the specimens were tested for their compressive strength. The loss of compressive strength for different mixes are as shown in the Table 4.4. The loss of compressive strength was highest in mix GC & was least in mix C30. The loss of compressive strength in GPC, exposed to sodium sulphates was mainly due to the reason that, sulphates in Na2SO4 causes the breaking of Si-O-Si- bond of geopolymer concrete and decreases the Si/Al ratio within the GPC [16]. In addition to this, sulphates directly attack the cement hydration products such as alumino silicate gel in GPC and cause expansions. Thus, severe cracks develop within the GPC [18]. A graph of % variation in weight Vs type of mix is plotted as shown in figure 4.4. Figure 4.5 shows the loss of compressive strength for different mixes due to sulphate attack. Figure 4.6 shows the view of surface of specimens exposed to Sodium sulphate solution after 56 days.

Percentage variation in weight of Specimen for different mixes due Sulphate attack

Sl.No	Type of Mix	0th Week	1st Week	2nd Week	3rd Week	4th Week
1	GC (100%FA+0%C)	0.000	4.654	4.787	2.840	1.729
2	C10 (90%FA+10%C)	0.000	5.470	5.063	4.524	4.024
3	C30 (70%FA+30%C)	0.000	4.562	4.428	4.260	3.980
4	C50 (50%FA+50%C)	0.000	3.548	2.380	1.560	0.606



Loss of Compressive strength for different mixes due to Sodium sulphate attack



CONCLUSIONS

Based on the results of the experimental investigation, following conclusions could be drawn.

- For the given geopolymer mix, the desired compressive strength can be achieved for all the mixes at the age of 28 days. However, the highest strength can be obtained by replacing the fly ash with cement at 30% replacement level
- There was not much increase in strength from 28 days to 56 days in all types of mixes
- The Split tensile strength for mixes GC & C10 were lesser than that of the average value of conventional concrete. But, for mix C30 & C50, Split tensile strength values are greater than conventional concrete. So, its insisted to replace the fly ash in GPC at least with 30% cement to achieve desired split tensile strength
- In view of Sodium sulphate attack resistance performance of GPC, the loss of weight was negligible in all types of mixes. So, loss of weight is not a concerning factor with geopolymer concrete. The loss of compressive strength was highest in mix GC (13.20%) and was least in C30 (8.71%). Thus, it is recommended to replace the fly ash in GPC at least with 30% of cement to minimize the loss of compressive strength.
- In view of Sulphuric acid attack resistance performance of GPC, the loss of weight is negligible in all types of mixes. The loss of compressive strength is highest in mix GC (18.81%) and least in mix C30 (11.41%). So, it is suggested to replace the fly ash with cement at least by 30% in GPC to minimize the loss of compressive strength.

SCOPE FOR FUTURE WORK

This chapter depicts about the future research work that can be carried out in line with the present research. In this present research various tests such as compressive strength, split tensile strength, sulphate attack resistance, acid attack resistance of geopolymer concrete with partial replacement of fly ash with cement is investigated. The experimental results were compared with predicted results currently used for OPC concrete as per the provisions of codes. In this research, it is found that the geopolymer concrete is an efficiently competitive material to be used as a structural concrete. It possesses very good mechanical and durability properties. In addition to this, it is also found that the river sand can effectively be replaced by crusher dust.

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