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COMPARATIVE STUDY ON DIFFERENT SOURCE FLY ASH BASED GEOPOLYMER CONCRETE

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ABSTRACT

Currently India has taken major initiative on de-veloping the infrastructure, to meet the requirements of globalisation in the construction of building and other structures. As the most popular and economical construction materials today concrete naturally places the rightful role in these activities as increasingly large quantum of concrete is being utilised. In the absence of available alternative construction materials it is becoming a herculean task to meet the increasing demand of construction industries and promote sustainable construction so that natural resources are exhausting in no time and ecological hazards do grow at uncontrolled rate. Because of environmental and economic reasons, there is a rethinking about the use of cement and instead its partial or total replacement by Industrial waste as an alternative material in the concrete production is receiving priority. This not only reduces the cost of production of concrete but also controls the pollution leading to sustainable development. There are incidental benefits in terms of improving performance. Alternative materials generally used are mainly the industrial wastes which face the problem of safe disposal and cause environmental hazards. Fly ash is such Industrial waste which is generated in huge quantity face the problem of safe disposal. Fly ash is a by-product developed by a Industrial waste during the production of electricity in thermal power plants, India at present productions around 200 million tons of fly ash per annum. Due to its highly pozzolanic and cementitious property, flyash can be used in the much larger amount as a cement replacement material in concrete then practice as of today. Experimental investigation were carried out to explore the effect of fly ash based geopolymer concrete, where fly ash was collected from two sources and 30% of fly ash is replaced by GGBS. The alkaline solution was used NaOH and Na_2SiO_3. From this research, it is found that using different sources of fly ash results in different in strength. The fly ash in which low aluminium and high silica content shows high in strength, also more fine fly ash shows high in strength. Comparison of compressive strength, split tensile strength and flexural strength are carried out.

INDEX TERMS—Geopolymer concrete, fly ash, GGBS, UPCL, RTPP

I. INTRODUCTION

Concrete is most popular building material in the world. However, the production of cement has diminished the limestone reserve in the world and requires were a great consumption of energy. Concrete has been the most preferred construction material for over five decades. It is being in-creasingly used day by day all over the world due to its versatility, mouldability, high compressive strength and many more advantages. Hence the use of concrete as a constructionmaterial has increased. The main advantage of portland cement is its considerably faster rate of setting and hardening, even under water. It replaced all the traditional binding materials and become a unique and universally accepted construction material. The application of Potland cement in concrete industry became extensive in practice with steel reinforcement. India is the word second largest producer of cement. This report has found that, the Indian cement industry sustained its growth rate even in the tough condition of economic slowdown. Cement production is expected to increase above 9% year or year during 2010-11 again the previous financial year

II. GEOPOLYMER CONCRETE

The term Geopolymer was coined by Davidovits in 1978. Geopolymer is an inorganic alumino-silicate polymer, synthe-sized from predominately silicon and aluminium material such as Fly Ash. Alkaline solutions are used to induce the silicon and aluminium atoms: in the source materials, to dissolve to form gel. The polymerization process may be assisted by applied heat followed by drying. The geopolymer gel binds the loose fine and coarse aggregate to form geopolymer concrete. Geopolymer gel replaces the C-S-H gel in cement concrete. Chemical reaction time is substantially fast and the required curing period may be within 24-48 hours. Geopolymer concrete in which activated Fly Ash is used as binding material. Fly Ash is used as binding material by activating it using solutions of sodium silicate and sodium hydroxide.

III. MATERIALS

Materials used in the Geopolymer concrete are: FlyAsh, Alkaline solutions, Aggregate, Ground Granulated Blast furnace Slag (GGBS).

A. FlyAsh

In general, the low calcium (ASTM Class F) dry Fly Ash obtained from power station is used as the base material. Fly Ash is collected from two sources i.e. Rayalaseema Thermal Power Plant, Kadapa (A.P) and Udupi Power Corporation Ltd (UPCL).

B. Alkaline solutions

A combination of sodium silicate solution and sodium hy-droxide solution was used to react with the aluminium and the silica in the Fly Ash. The sodium silicate solution of industrial grade with 80% purity. Sodium hydroxide (commercial grade with 99 % purity) was dissolved in water to make the solution. The alkaline solutions were prepared and mixed together at least one hour prior to use.

C. Aggregate

Aggregates which are used for the preparation of normal concrete may be used for the preparation of the Geopolymer concrete. The aggregates are the main components of the concrete which greatly varies the strength, density and other properties of the concrete. Fine aggregates and coarse aggregates are collected from M.G Traders, Ujire.

D. GGBS

Ground granulated blast furnace slag comprises mainly of calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide. It has the same main chemical constituents as ordinary Portland cement but in different proportions. The addition of GGBS in Geo Polymer Concrete increases the strength of the concrete and also curing of Geo-Polymer concrete at room temperature is possible. GGBS is collected from Jindal South West, Toranagallu, Bellary.

IV. METHODOLOGY

The methodologies followed in this experiment, are as follows; Preparation of Alkaline solution and Modified mixing method.

A. Preparation of Alkaline solution

As per literature review, NaOH solution with concentration ranging from 8-14 molar gives good strength. For this exper-imental study 13M solution is selected. NaOH pellets of 99 percent purity was collected from Nel chem Mangalore. To prepare 1 molar solution 40 grams of NaOH is to dissolved in 1 liter of distilled water. As 13M solution was required for this study, 520 grams of NaOH pellets was dissolved in 1 liter of distilled water. As the reaction is exothermic, the dissolution was done at a very slow rate, keeping the container in water bath to reduce temperature. Ready solution of Na_2SiO_3 OF 80 percent purity was collected from Nel chem.

B. Modified mixing

Generally alkaline solution is prepared at least one day prior to mixing of the concrete. Modified mixing method was followed for the experimental program. In conventional mixing method coarse aggregate, fine aggregate, cementitious material are mixed thoroughly to get uniform colour and then water is added. In modified mixing method fine aggregate and cementitious material (Fly Ash, GGBS) are mixed thoroughly and then alkaline solution is added to make slurry. Now this slurry is added to coarse aggregate and mixed thoroughly until uniform colour is obtained and to get better workability.

TABLE I
PHYSICAL PROPERTY OF FLY ASH

Particulars	Test Results	
	UPCL	RTPP
Fineness	28.44%	23.48 %
Specific gravity	2.15	1.86
Blaines air permeability test	148 seconds	103 seconds

TABLE II
CHEMICAL PROPERTY OF FLY ASH

Particulars	Test Results (%)	
	UPCL	RTPP
SiO_2	47.64	59.9
Al_2O_3	21.08	24.7
Fe_2O_3	11.95	6.7
CaO	5.71	2.0
MgO	-	1.9
SO_3	0.850	1.56
Na_2O	-	0.65
K_2O	-	1.2
LOI	4.36	0.45
MOI	0.23	-
Size (+45 micron)	9.30	-

V. EXPERIMENTAL INVESTIGATION

A. General

This chapter includes the experimental investigation carried out to determine the strength of Fly Ash based Geopolymer concrete of M 30 grade with different sources of Fly Ash (i.e, RTPP and UPCL). This chapter also includes the properties of different materials used during the experimental investigation and also the details about the method of casting the specimens and testing procedures of different tests performed during the investigation.

B. Materials

1) Flyash: Fly Ash was brought from Udupi Power Corpo-ration Ltd, Padubidri and Rayalaseema Thermal Power Plant, Kadapa. Physical and chemical properties of this Fly Ash as given by the suppliers are given in Table-I and Table-II.

2) Fine Aggregate: Locally available clean river sand was sieve analysed and tests for specific gravity were carried out. The results are given in Table-III

3) Coarse Aggregate: Crushed granite of 20 mm maximum size and retained on IS: 480 sieves have been used as coarse aggregate, 60 percent of coarse aggregate passing 20 mm sieve size and 40 percent of coarse aggregate passing 12.5 mm sieve size were combined to obtain coarse aggregate in the investigation. The sieve analysis of combined aggregates confirms to the specifications of IS 383: 1970 for graded aggregates. Test results are given in Table-IV

TABLE III
TEST RESULT OF FINE AGGREGATE

Specific gravity	2.66
Fineness modulus	2.71
Grade	Belong to grading Zone III

TABLE IV
TEST RESULT OF COARSE AGGREGATE

Characteristics	Results	IS Code (IS 2386-1983)
Fineness modulus	5.39	-
Specific gravity	2.75	2.5 to 3

TABLE V
CHEMICAL COMPOSITION OF JSW GGBS

Parameter	JSW GGBS %	As per IS:12089-1987 (Reaffirmed 2008) %
CaO	37.34	- - -
Al_2O_3	14.42	- - -
Fe_2O_3	1.11	- - -
SiO_2	37.73	- - -
Magnesium Oxide (MgO)	8.71	Max. 17.09
Manganese Oxide (MnO)	0.02	Max. 5.5
Sulphide Sulphur	0.39	Max. 2.0
Loss On Ignition	1.41	- - -
Insoluble Residue	1.59	Max. 5
Glass Content	92	Min. 85

4) GGBS: Ground granulated blast furnace slag comprises mainly of calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide. It has the same main chemical constituents as ordinary Portland cement but in different proportions. And the addition of GGBS in Geo-Polymer Concrete increases the strength of the concrete and also curing of Geo-Polymer concrete at room temperature is possible. GGBS is collected from Jindal South West (JSW) Bellary. Test results are given in Table-V

VI. MIX PROPORTION

For the present work concrete of M30 grade is adopted. Same mix proportions were also adopted for fly ash from both the sources. Test on trial mixes for different ratio of alkaline solution are carried out and finally a mix proportion that gives better strength and alkaline fly ash ratio for required workability of 150 to 180 mm is selected. The mix proportion for geopolymer concrete are given in Table-VI.

VII. RESULTS AND DISCUSSIONS

The test results and discussions on compressive strength, splitting tensile strength, flexural strength, where Fly Ash based Geopolymer concrete with 30% replacement of fly ash by ground granulated blast furnace slag (GGBS) for M30 grade concrete using NaOH and $NaSiO_3$ as activators.

TABLE VI
MIX PROPORTION FOR GEOPOLYMER CONCRETE WITH 70% AGGREGATES

Mix proportion of materials	1:0.98:2.27
Fly Ash	360 kg/cum
GGBS	154.9 kg/cum
Fine aggregate	504 kg/cum
Coarse aggregate	1176 kg/cum
NaOH (13M)	116.27 kg/cum
Na2Sio3	89.43 kg/cum
Alkaline Fly Ash ratio	0.40
NaOH: Na2Sio3	1.3:1

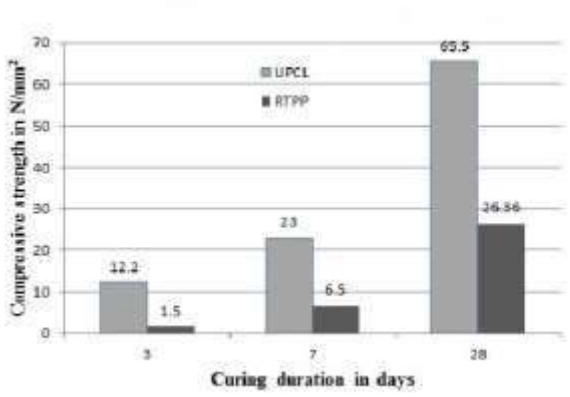

Fig. 1. Comparison of compressive strength

A. Compressive strength

The target mean strength for M30 concrete is 38.25Mpa. The Fig. 1 represents comparison of compressive strength at 3, 7 and 28 days of Fly Ash based geo polymer concrete where Fly Ash is collected from two different sources Rayalaseema Thermal Power Plant, Kadapa (RTPP) and Udupi Power Corporation Ltd, Padubidri (UPCL).

3 Days strength: While comparing the development of strength of 3 days cured specimen, it is seen that GPC produced by Fly Ash collected from UPCL plant is more than that of Fly Ash collected from RTPP plant. The Fly Ash concrete with 30% replacement by GGBS, compressive strength GPC made from Fly Ash of UPCL plant is 87.62% higher compared to RTPP Fly Ash at same age. 7 Days strength: In case of 7 days compressive strength of concrete specimens, it is seen that GPC produced by Fly Ash collected from

UPCL plant is more than that of Fly Ash collected from RTPP plant. The Fly Ash concrete with 30% replacement by GGBS, compressive strength GPC made from Fly Ash of UPCL plant is 71.73% higher compared to RTPP Fly Ash at same age.

28 Days strength: During comparison of the 28 days compressive strength of flyash based Geopolymer concrete, it is seen that there is again increase in strength. The compressive strength of GPC made from flyash of UPCL plant is 59.76% higher compared to RTPP plant at same age.

B. Split tensile strength

Comparison of split tensile strength at 7 and 28 days of Fly Ash based geo polymer concrete where Fly Ash is collected from two different sources Rayalaseema Thermal Power Plant, Kadapa (RTPP) and Udupi Power Corporation Ltd, Padubidri (UPCL) are shown in Fig. 2

7 Days strength: It is seen that there is considerable increase in strength of UPCL based Geopolymer concrete. The compressive strength of GPC made from flyash of UPCL plant is 91.05% higher compared to RTPP plant at same age. 28 Days strength: The compressive strength of GPC made from flyash of UPCL plant is 43.63% higher compared to RTPP plant at same age

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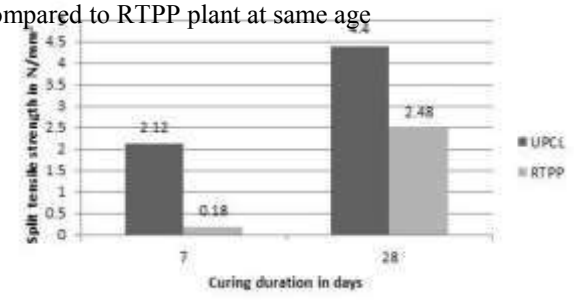

Fig. 2. Comparison of split tensile strength

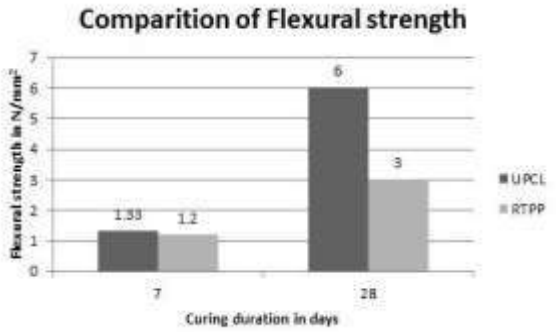

Fig. 3. Comparison of flexural strength

C. Flexural strength

Comparison of flexural tensile strength at 7 and 28 days of Fly Ash based geo polymer concrete where Fly Ash is collected from two different sources Rayalaseema Thermal Power Plant, Kadapa (RTPP) and Udupi Power Corporation Ltd, Padubidri(UPCL) are shown in Fig .3

7 Days strength: The compressive strength of GPC made from flyash of UPCL plant is 9.77% higher compared to RTPP plant at same age.

28 Days strength: The compressive strength of GPC made from flyash of UPCL plant is 50.0% higher compared to RTPP plant at same age.

D. General Discussion

From the test results it is clear that the strength of GPC made of fly ash collected from UPCL ishigher than thatoff lyash collected from RTPP. The variation in strength is due to fineness of Fly Ashof UPCL plant is higher than that of RTPP plant and Fly Ash of UPCL plant contains 3.62% of alumina, which less than that of RTPP plant.

VIII. CONCLUSION

Based on limited study carried out on strength parameters of fly ash based GPC with fly ash collected from two different sources the following conclusions are drawn

1) The variation in the strength gained is due to variation in chemical composition of fly ash from two different sources.
2) In case of GPC the major contribution of strength is by polymerization of Al_2O_3 and Sio_2 by alkaline liquids. As UPCL fly ash contains comparatively more content of $Al_2O_3$the gain in strength has considerably increased.
3) Since, UPCL fly ash is more finer than that of RTPP fly ash, the GPC made from UPCL shows higher in strength.
4) For the mixes which contain more quantity of NaOH than Na_2Sio_3, the strength gained was higher.
5) When Na_2Sio_3 was used in comparatively more quantity than NaOH, setting time was lagged.
6) Since, higher concentration of alkaline liquid was used, leaching was observed on surface of the concrete.

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