Experimental Investigation on Course Aggregate Blended Its Effects on Mechanical Properties of Geopolymer Concrete

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ABSTRACT- Concrete is one of the most widely used construction material and it is usually associated with Portland cement as the main component for making concrete. Geopolymer can be considered as the key factor which does not utilize Portland cement, nor releases greenhouse gases. In this respect, Davidovits (1988) proposed an alternative binder for the concrete technology and it shows a good results. These binders are produced by an alkaline liquid reacts with the silica (Si) and aluminium (Al) present in the source materials. The technology proposed by the Davidovits is commonly called as Geo-polymers or Geo-polymer technology. This paper presents the study on Mechanical properties of GPC These properties have been tested for 7, 28 &90 days curing at room temperature.

Keywords- GGBS Fly ash, geopolymer concrete, Alkaline liquid, MRCA, compressive strength, split tensile strength, flexural strength.

1. INTRODUCTION

In now a day's usage of concrete occupies second place around the world other than the water. Ordinary portland concrete primarily consists of cement, aggregates (coarse & fine) and water. In this, cement is used as a primary binder to produce the ordinary Portland concrete. Due to increasing of developments in infrastructure, the usage of conventional concrete will be more and as well as the demand of cement would be increases in the future. Approximately it is estimated that the consumption of cement is more than 2.2 billion tons per year (Malhotra, 1999).

On the other hand, the usage of Portland cement may create the some environmental issues such as global warming, green house effect etc. Because these problems may generate due to increasing of carbon dioxide (Co_2) present in the environment, from the past results nearly one tone of portland cement releases equal quantity of carbon dioxide (Co_2). In order to avoid these environmental issues associated with Portland cement , there is need to use some alternatives such as fly ash, ground granulated blast furnace slag (GGBS), rise husk ash etc are as the binders to make the eco friendly concrete. The aggregates (coarse and fine) are the most important ingredient of concrete occupying almost 70-80% of its total volume and directly affect the properties of concrete. So, there is need to use some alternatives such as coal ash, furnace slag, fiberglass waste materials, rubber waste, waste plastics, work sludge pellets etc.

In this respect, Davidovits [1988] proposed an alternative binder for the concrete technology and it shows a good results. These binders are produced by an alkaline liquid reacts with the silica (Si) and aluminium (Al) present in the source materials. The technology proposed by the Davidovits is commonly called as Geo-polymers or Geo-polymer technology.

The present study dealt with the development and the mechanical properties of geopolymer concrete incorporating MRCA as coarse aggregate with different replacement levels from 0% to 50% at ambient room temperature curing.

2. EXPERIMENTAL PROGRAM

2.1 Materials

Fly ash

According to ASTM C 618 (2003) the fly ash can be divided into two types based on amount of calcium present in the Fly ash. The classified Fly ashes are Class F (low-calcium) and Class C (high-calcium). In the Present investigation Class flyash produced from Rayalaseema Thermal Power Plant (RTPP), Muddanur, A.P was used and

GGBS collected from the Astraa chemicals, Chennai and it was used in the manufacturing of GPC. The chemical and physical properties are presented in the Table 1

Table 1: Chemical and Physical Properties of Class F Fly Ash and GGB

Particulars	Class	ASTM C 618	
Chemical composition			
% Silica(SiO_2)	63.4		31.41
% Alumina(Al_2O_3)	30.5		17.24
% Iron Oxide(Fe_2O_3)	3.0	SiO_2+ Al_2O_3+ Fe_2O_3>70	0.62
% Lime(CaO)	1.0		34.48
% Magnesia(MgO)	1.0		6.79
% Titanium Oxide (TiO_2)	0.62		-
% Sulphur Trioxide (SO_3)	0.1	Max. 5.0	1.85
Loss on Ignition	0.24	Max. 6.0	2.3
Physical properties			
Specific gravity	2.24		2.68
Fineness (m^2/Kg)	360	Min.225 m^2/kg	400

Coarse aggregate

Hard Broken Granite (HBG)

Crushed granite stones of size 20 mm and 10 mm of coarse aggregate are used. The bulk specific gravity in oven dry condition and water absorption of the HBG 20 mm and 10mm as per IS code were 2.58 and 0.3% respectively.

Mill Rejected Coal Aggregates (MRCA)

The coal from mines consists of several impurities such as magnesium sulfate, fire clay, slate and pyrites in the form of sulphurin. These impurities have higher specific gravity than pure coal and hence, it needs coal washing technique to clean coal before exploitation. Specific gravity of pure coal is 1.2 to 1.7 and for impure coal is 1.7 to 4.9. Therefore, coal should be screened to size and it degree an increasing stress on environmental property. So coal washing is adopted for separating the impurities from the pure coal. Disposal of coal washeries cause serious environmental problem in order to maintain environmental sustainability and to solve the problem while disposing MRC are used as partial replacement of coarse aggregate of size. MRCA of size 20 mm and 10 mm of coarse aggregate are used. The bulk specific gravity in oven dry condition and water absorption of the MRCA 20 mm and 10mm as per IS code were 2.46 and 0.3% respectively.

Fine aggregate

Natural sand

The sand used throughout the experimental work was obtained from the river Swarnamukhi, near chandragiri in chittoor district. The bulk specific gravity in oven dry condition and water absorption of the sand as per IS code were 2.64 and 1% respectively.

Alkaline Liquid

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution. The sodium silicate solution (Na_2O= 13.7%, SiO_2=29.4%, and water=55.9% by mass) was purchased from a local supplier. The sodium hydroxide (NaOH) in flakes or pellets from with 97%-98% purity was also purchased from a local supplier. The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in required quantity of water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molarity, M. For instance, NaOH solution with a concentration of 8M consisted of 8x40 = 320 grams of NaOH solids (in flake or pellet form) per litre of the solution, where, 40 is the molecular weight of sodium hydroxide (NaOH) pellets or flakes.

2.2. Mix Proportions

Based on the limited past research on GPC (Hardjito & Rangan, 2005), the following proportions were selected for the constituents of the mixtures. The table 2 give the mix proportion.

Table 2: GPC Mix Proportions

Materials		Mass (kg/m^3)				
		100% CA	10% MRCA + 90% HBG	20% MRCA + 80% HBG	30% MRCA + 70% HBG	40% MRCA + 60% HBG
Coarse Aggregate	20 mm	774	77.4 + 696.6	154.8 + 619.2	232.2 + 541.8	309.6 + 464.4
	10 mm	516	51.6 + 464.4	103.2 + 412.8	154.8 + 361.2	206.4 + 309.6
Fine aggregate		549	549	549	549	549
Fly ash (Class F)		204.5	204.5	204.5	204.5	204.5
GGBS		204.5	204.5	204.5	204.5	204.5
Sodium silicate solution		102	102	102	102	102
Sodium hydroxide solution		41 (8M)	41 (8M)	41 (8M)	41 (8M)	41 (8M)
Extra water		55	55	55	55	55
Alkaline solution/ (FA+GGBS) (by weight)		0.35	0.35	0.35	0.35	0.35
Water/ geopolymer solids (by weight)		0.29	0.29	0.29	0.29	0.29

2.3. Experimental Setup

Compression test is one of the most common test conducted on hardened concrete, partly because it is most important and it is easy to perform further most of the desirable characteristic properties of concrete are qualitatively related to its strength. The compression test was carried out using 2000 KN compression testing machine.The compressive strength of the GPC was conducted on the cubical specimens for all the mixes after 7, 28 and 90 days of curing as per code

$f'_c = P/A$

Splitting Tensile Strength (STS) test was conducted on the specimens for all the mixes after 28 days of curing as per code. Three cylindrical specimens of size 150 mm x 300 mm were cast and tested for each age and each mix. The load was applied gradually till the failure of the specimen occurs. The maximum load applied was then noted. Length and cross-section of the specimen was measured. The splitting tensile strength (f_{ct}) was calculated as follows:

$f_{ct} = 2P / (\Pi\, l\, d)$

Flexural strength test was conducted on the specimens for all the mixes at different curing periods as per code. Three concrete beam specimens of size 100 mm x 100 mm x 500 mm were cast and tested for each age and each mix. The load was applied gradually till the failure of the specimen occurs. The maximum load applied was then noted. The distance between the line of fracture and the near support 'a' was measured. The flexural strength (f_{cr}) was calculated as follows: When 'a' is greater than 13.3 cm for 10 cm specimen, f_{cr} is

$f_{cr} = (P \times l) / (b \times d^2)$

When 'a' is less than 13.3 cm but greater than 11.0 cm for 10 cm specimen, f_{cr} is

$f_{cr} = (3 \times P \times a) / (b \times d^2)$

3. RESULTS AND DISCUSSION

The mechanical properties viz., compressive strength, split tensile strength and flexural strength of GPC incorporating mill rejected coal as coarse aggregate with replacement levels from 0% to 40% respectively. The compressive strength split tensile strength and flexural strength test values of concrete mixes were measured once 7, 28 and 90 days of curing.

3.1 Compressive Strength

The Table.3 shows the compressive strength of GPC mixes (100_CA:0_MRCA, 90_CA:10_MRCA, 80_CA:20_MRCA, 70_CA:30_MRCA and 60_CA:40_MRCA) at different curing periods.

Table 3: Compressive Strength of GPC

Mechanical property	Age (days)	Mix type				
		100:0	**90:10**	**80:20**	**70:30**	**60:40**
Compressive strength, f'_c (MPa)	7	28.04	30.23	33.12	35.65	26.51
	28	38.25	40.53	43.66	46.21	36.24
	90	45.89	46.98	50.03	52.36	44.38

Compressive strength was tested for the mixes with the various MRCA replacement levels of 0%, 10%, 20%, 30% and 40%. The samples were tested after curing periods of 7, 28 and 90 days. It was observed that there was a significant increase in compressive strength with the increase in percentage of MRCA from 0% to 30% in all curing periods. After 7 days of curing, 30% MRCA sample exhibited a compressive strength of 35.65 MPa, whereas after 28 days of curing it was 46.21 MPa and after 90 days of curing it was 52.36 MPa. It is to be noted that the significant improvement in compressive strength is mainly due to the blended of aggregates. From the results it is concluded that MRCA acts as filling material which fills the voids of the concrete and hence makes the concrete dense. From the aggregate properties, it is known that MRCA have lower values of crushing and impact strength when compared to those of HBG. The lower value of crushing and impact strength of MRCA is mainly attributed to the decrease in compressive strength of MRCA based concrete mixes. However, when the percentage MRCA was increased to 40% a drastic fall in compressive strength was evidenced irrespective of the time of curing. The compressive strength values of the mixes with 40% replacement of MRCA were found to be 26.51 MPa, 36.24 MPa and 44.38 MPa respectively after 7, 28 and 90 days of curing. The fall in the compressive strength at 40% MRCA can be explained presumably due to the lower value of crushing and impact strength of MRCA is mainly attributed to the decrease in compressive strength of GPC.

3.2 Split tensile strength

The Table 3 shows the split tensile strength of GPC mixes (100_CA:0_MRCA, 90_CA:10_MRCA, 80_CA:20_MRCA, 70_CA:30_MRCA and 60_CA:40_MRCA) at different curing periods.

Table 4: Split Tensile Strength of GPC

Mechanical property	Age (days)	Mix type				
		100:0	**90:10**	**80:20**	**70:30**	**60:40**
Split tensile strength, f_{ct} (MPa)	7	2.48	2.66	2.88	3.12	2.35
	28	3.26	3.42	3.64	3.91	3.12
	90	3.79	3.86	4.06	4.38	3.69

Split tensile strength was also performed by replacing coarse aggregate with from 0% to 40%. The split tensile strength was found to increase with increasing percentage of MRCA up to 30%, independent of the age of curing. A drastic fall of split tensile strength was observed when the MRCA percentage was increased further to up to 40%. The split tensile strength at 30% MRCA was found to be 3.12 MPa after a curing period of 7 days, whereas at 28 and 90 days with 30% MRCA the split tensile strength were 3.91 MPa and 4.38 MPa. It is to be said that MRCA acts as filling material which improves the interfacial transition zone (ITZ) and leads to the improvement of split tensile strength. At 40% replacement of MRCA, the split tensile strength was very low, yielding a value of 2.35 MPa after 7 days of curing. Similarly, at 40% MRCA replacement and after 28 days and 90 days of curing the STS values were observed to be very low yielding values of 3.12 MPa and 3.69 MPa. Hence, it can be recommended to use MRCA at 30% partial replacement of coarse aggregate in order to attain the best results as compare to conventional concrete.

3.3 Flexural strength

Table 4 shows the flexural strength of GPC mixes (100_CA:0_MRCA, 90_CA:10_MRCA, 80_CA:20_MRCA, 70_CA:30_MRCA and 60_CA:40_MRCA) at different curing periods.

Table 5: Flexural Strength of GPC

Mechanical property	Age (days)	Mix type				
		100:0	**90:10**	**80:20**	**70:30**	**60:40**
Flexural strength, f_{cr} (MPa)	7	3.28	3.41	3.57	3.71	3.19
	28	3.83	3.95	4.10	4.31	3.73
	90	4.20	4.25	4.39	4.52	4.13

SFlexural strength was also performed by replacing coarse aggregate with from 0% to 40%. The flexural strength was found to increase with increasing percentage of MRCA up to 30%, independent of the age of curing. A drastic fall of flexural strength was observed when the MRCA percentage was increased further to up to 40%. The flexural strength at 30% MRCA was found to be 3.71 MPa after a curing period of 7 days, whereas at 28 days with 30% MRCA the flexural strength was 4.31 MPa. A significant improvement in flexural strength up to 4.52 MPa was observed after 90 days of curing. It is to be pointed out that MRCA acts as filling material which improves the interfacial transition zone (ITZ) and leads to the improvement of flexural strength. At 40% replacement of MRCA, the flexural strength was very low, yielding a value of

3.19 MPa after 7 days of curing. Similarly, at 40% MRCA replacement and after 28 days and 90 days of curing the flexural strength values were observed to be very low yielding values of 3.73 MPa and 4.13 MPa.

4. CONCLUSIONS

Based on the investigation, the following conclusions have been drawn.

[1] There was a significant increase in compressive strength, split tensile strength, flexural strength with the increase in percentage of MRCA from 0% to 30% in all curing periods. The optimum percentage of MRCA obtained is 30% of its volume of concrete.

[2]The maximum compressive strength of geopolymer concrete for 7days, 28days and 90 days curing period is 35.65 MPa, 46.21 MPa and 52.36 MPa respectively by partial replacement of coarse aggregate by 30% replacement of mill rejected coal aggregate.

[3] The maximum Split Tensile Strength of geopolymer concrete for 7days, 28days, 90 days curing period is 3.12 MPa, 3.91 MPa and 4.38 MPa respectively by partial replacement of coarse aggregate by 30% replacement of mill rejected coal aggregate.

[4] The maximum flexural strength of geopolymer concrete for 7days, 28days and 90 days curing period is 3.71MPa, 4.31 MPa and 4.52 MPa by partial replacement of coarse aggregate by 30% replacement of mill rejected coal aggregate.

[5] When the percentage of mill rejected coal aggregate was increased to 40% a drastic fall in compressive strength, split tensile strength and flexural strength have been evidenced.

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