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Properties of fly ash based geo-polymer concrete

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***Abstract:* -** The engineering properties of fly ash based geopolymer concrete are given in this paper. The hardened concrete properties such as compressive strength, split tensile strength, and the wet state property of workability are studied. The fly ash content per cubic meter of concrete used in this study are 395 kg, 410 kg and 425 kg Two fine aggregates are used, namely river sand and quarry sand. Three proportions of fine aggregates were considered, viz., 100 percent sand, 50 percent sand – 50 percent crushed stone sand and 100 percent crushed stone sand. The standard specimens are prepared and cured at ambient temperature (25oC to 35oC) for 28 days, 90 days and also in hot air oven for 72 hours. The paste oclass F F fly ash and the alkaline solution mixture of sodium hydroxide and sodium silicate in the ratio 1:2.5 is used as binder. The studies revealed that the fine aggregate composition has very little effect on the hardened properties of geopolymer concrete. Among the different fly ash content, the maximum strength is found to be for the geopolymer concrete mix containing the fly ash content of 410 kg/m3. In heat cured specimens, the variation engineering properties of geopolymer concrete iwith the change in fly ash content s found to be nominal.

***Keywords:* -** *Geopolymer, Fly ash, Inorganic Polymer, Alkaline Binder, Carbon Credit, Green Concrete*

I. INTRODUCTION

Geopolymer is an inorganic polymer. Joseph Davidovits in 1979 proposed that an alkaline liquid could be used to react with silicon (Si) and aluminum (Al) as source material of geological origin or with byproduct materials such as fly ash and rice husk ash to produce binders [1]. Since the chemical reaction that is taking place in this case is a polymerization process and the precursors are of geological origin, these binders were named as ‘Geopolymer’. Geopolymer Concrete is gaining importance world over as the carbon emission and consequent global warming has become the major concern of the entire countries world over. One tone of cement production results in the emission of one tone of carbon dioxide. Many countries are promoting the use of fly ash as building material by granting carbon credit, which will not only reduces the production of cement and emission of carbon dioxide but also promotes the consumption of the waste material fly ash which poses a major problem for disposal world over. In India almost all the states have thermal power plants and abundant availability of fly ash. The ingredients of the alkaline solution viz. sodium hydroxide and sodium silicates are cheap and locally available[2].

Studies on the fly ash based geopolymer concrete dates back to three decades only. Most of the studies are done under heat cured regime since the polymerization process is fast at 60oC to 90oC [3] Most parts of India come under tropical region where the normal temperature during summer is above 30oC [4]. Geopolymer which is naturally cured at ambient outdoor temperature can be considered as a curing free concrete [5]

II. EXPERIMENTAL PROGRAM

Hardened state properties such as compressive strength, split tensile strength and flextural strength of geopolymer concrete after curing under ambient temperature of 25oC to 35oC for 28 and 90 days have been studied and the results were compared with the corresponding values obtained after heat curing in hot air oven. Slump test and compaction factor tests were conducted to study the workability of the concrete.

Materials

Three fly ash content viz., (F1) 395kg, (F2) 410kg and (F3) 425 kg per m3 of concrete were used and three fine aggregate compositions viz., (R1Q0) 100percent sand, (R2Q2) 50percent sand & 50percent crushed stone sand and (R0Q1) 100percent crushed stone sand. Crushed stone of nominal size 20mm and 12mm were used as coarse aggregate in the ratio of 60:40. The combined fineness modulus of aggregate was maintained at 4.5 to 5. The fine and coarse aggregates were conforming to IS:383 (1970). The fly ash used was class F, obtained from Mettur in Tamil Nadu conforming to IS:3812-(1981). Tests were conducted on specimens that were cured at ambient temperature (25oC to 35oC) for 28 days, 90 days and on that cured in hot air oven at 60o C to 90o C for 72 hours. Superplasticisers with SNF base was used at the rate of 1.5percent by weight of fly ash to improve the workability. The water to geopolymer solids ratio was fixed as 0.30 and the activator solution to fly ash ratio was maintained as 0.35. The mix designation is shown in Table.1 and the details of the mix design are shown in Table.2.

Table.1 Specimen designation

Specimen designation	Fly ash (kg/m3)	River sand (percent)	Quarry sand (percent)
F1R1Q0	395	100	0
F1R2Q2	395	50	50
F1R0Q1	395	0	100
F2R1Q0	410	100	0
F2R2Q2	410	50	50
F2R0Q1	410	0	100
F3R1Q0	425	100	0
F3R2Q2	425	50	50
F3R0Q1	425	0	100

III. RESULTS AND DISCUSSION

Tests were conducted as per the corresponding IS standards to study the compressive and tensile strength of geopolymer concrete and the observations are given in graphical form for easy comprehension and comparison. For comparison of workability slump and compaction factor test results were used.

Workability Tests

The workability of the geopolymer concrete was determined by slump test and compaction factor test. All the mixes exhibited moderately stiff consistency. The Q1R0 mixes which used only the quarry sand (crushed stone sand) showed slump as low as 25 mm. However mixes F2R1Q0 and F2R2Q2 has given a slump value of 150 mm and 100mm respectively. Since workability could not be enhanced at the cost of compressive strength, the water to geopolymer ratio could not be increased beyond certain limit. Hence alternate possibilities should be further investigated to enhance the workability when the river sand is fully replaced by the quarry sand (crushed stone sand). Also heavy compaction by vibration is suggested to expel the entrapped air. Cylindrical specimens have showed porosity on the peripheral surfaces of the top layer where complete compaction was lacking. This is mainly due to the higher aspect ratio of cylinder specimen compared to cube. However there was no sign of segregation. The results of the compaction factor test are congruent with that of slump test. Those mixes which showed higher slump above 150 mm also had a higher compaction factor above 0.9. The R0Q1 mixes which used only quarry sand (crushed stone sand) as fine aggregate had only 25mm slump value had their compaction factor ranging from 0.75 to 0.81.

Table.2 Details of geopolymer concrete mix

Parameter	F1R1Q0	F1R2Q2	F1R0Q1	F2R1Q0	F2R2Q2	F2R0Q1	F3R1Q0	F3R2Q2	F3R0Q1
Fly ash content (kg)	395	395	395	410	410	410	425	425	425
20mm crushed stone (kg)	647	647	647	630	630	630	614	614	614
12mm crushed stone (kg)	431	431	431	420	420	420	409	409	409
River sand (kg)	507	253	NIL	494	247	NIL	481	240.	NIL
Crushed stone sand (kg)	NIL	275	550	NIL	268	536	NIL	261	522
Alkaline liquid to fly ash	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Alkaline solution (kg)	138	138. 25	138	144	144	144	148	148.	148
Water to geopolymer solids	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Extra water added (kg)	72	72	72	75	75	75	78	78	78
Super plasticizer (kg)	5.9	5.9	5.9	6.1	6.1	6.1	6.3	6.3	6.3

Compressive strength

Cube compression tests were carried out at 28 days and 90 days cured at ambient indoor room temperature and on heat cured specimens. The test was conducted as per IS:516(1959). The results are shown in Fig.1, Fig.2 and Fig.3 respectively. Maximum cube compressive strength at 28 and 90 days were obtained for F2 fly ash content. This result is in congruence with all the literatures where the fly ash used varied from 400 to 410 kg/m3. The variation in the fine aggregate composition showed only little effect. At 28 days the compressive strength obtained was around 15 MPa and at 90 days it was around 25MPa. But on heat curing the R2Q2 fine aggregate composition showed distinctly high compressive strength at all the three fly ash content. R0Q1 mix showed a uniform compressive strength of 35MPa. The cylinder compressive strength at 90 days varied from 10 to 14 MPa. This is approximately 60percent of the cube compressive strength. The variations are plotted in Fig.4. The heat cured specimen with F2 fly ash content gave consistent cylinder compressive strength around 25 MPa. This was about 70percent of the cube compressive strength. The details are shown in Fig.5.

Split tensile strength

The tensile property of geopolymer concrete was ascertained by testing the split tensile strength and flextural strength. The split tensile strength was found as per IS:5816(1999) and the flextural strength was determined according to IS:516(1959). It was found that the split tensile strength was about 8 to 12 percent of the corresponding cube compressive strength. The failure pattern of heat cured specimens were found to be brittle in nature. The graphical plot of the split tensile strength is shown in Fig.6, Fig.7 and Fig.8.

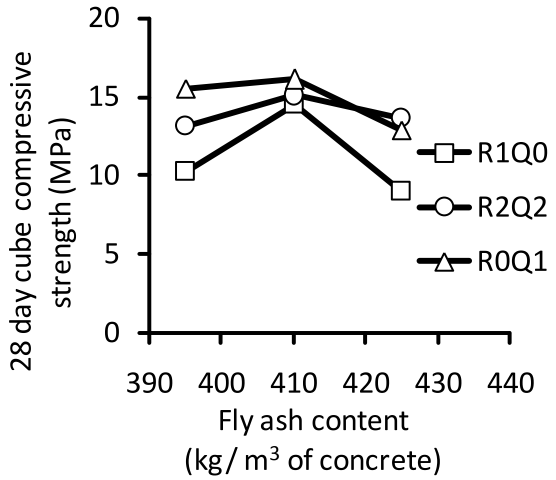

Fig.1 cube compressive strength at 28 days

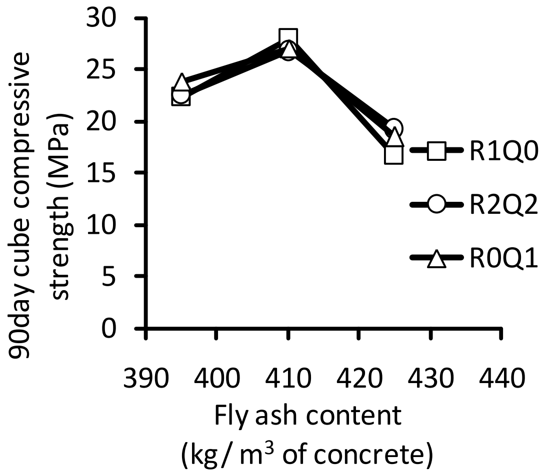

Fig.2 cube compressive strength at 90 days

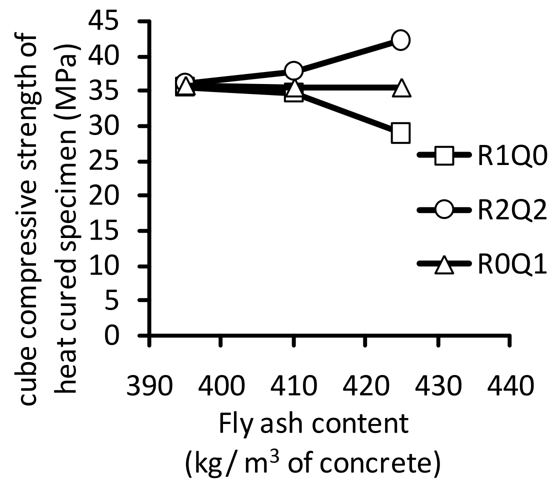

Fig.3 cube compressive strength of heat cured specimen.

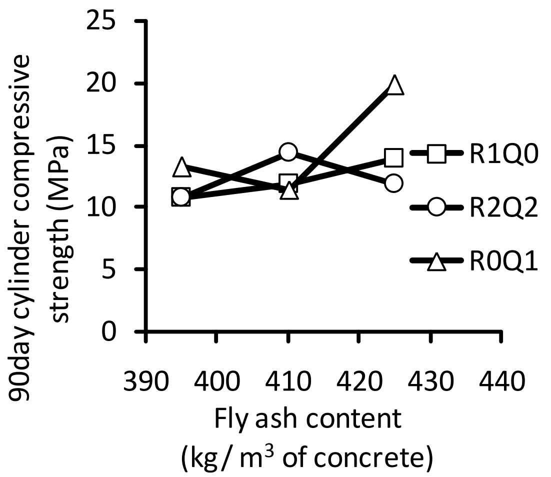

Fig.4cylinder compressive strength at 90 days

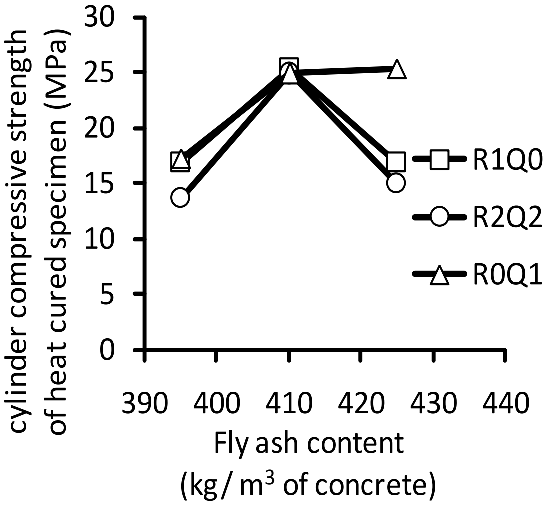

Fig.5 cylinder compressive strength on heat curing

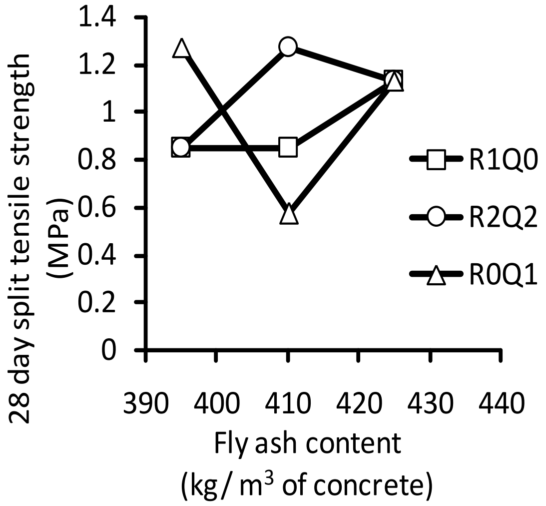

Fig.6 cylinder split tensile strength at 28 days

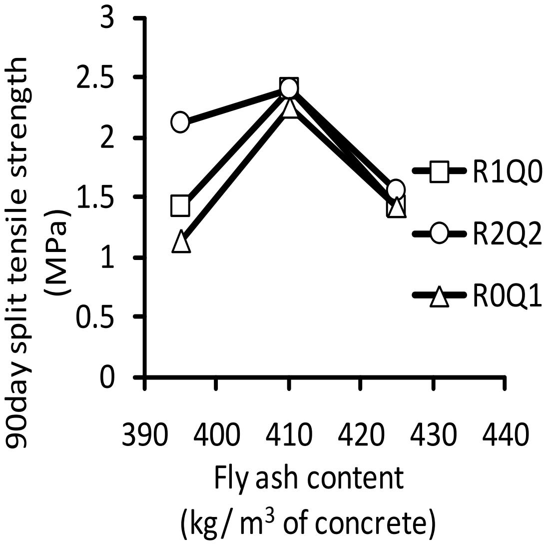

Fig.7 Cylinder Split Tensile Strength at 90 days

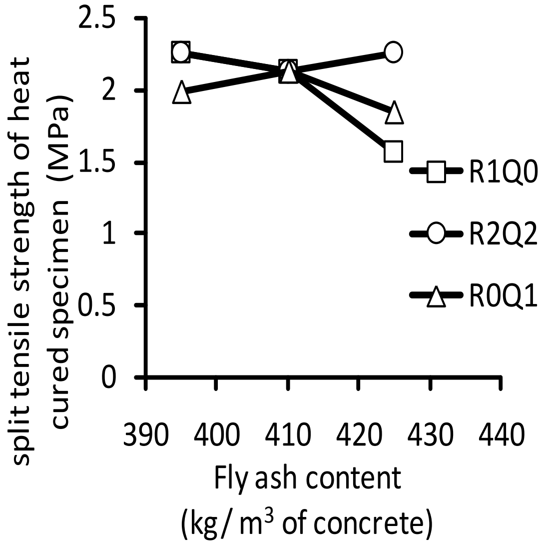

Fig.8 Cylinder Split Tensile Strength on Heat Curin g

IV. CONCLUSION

The important findings of the experimental study are as follows.

- For geo-polymer concrete, the curing period is an important factor when curing is done under ambient room temperature. The strength gain is found to be more than 60percent at 90 days when compared to that of 28 days strength.
- The strength gain in geo-polymer concrete is significant when heat cured for 72 hours .
- The strength of heat cured specimen is found to be almost equal to the corresponding strength of 90 day ambient cured specimen or almost two times as that of the 28 day strength.
- The fly ash content is much significant when the geo-polymer concrete is cured in ambient temperature. However, The change in strength of hear cured specimen is nominal with the the variation of fly ash content from 395 to 425 kg per cubic meter of concrete

The present study promotes the use of fly ash, which is otherwise considered as waste material. Hence the fly ash geo-polymer concrete is a sustainable material for future construction works. However, design methodologies are to be developed for geo-polymer concrete prior to actual use in worksite

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