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An Experimental Study on Flyash Based Geopolymer Concrete with A Partial Replacement Of Fine Aggregate by Waste Glass Powder

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Abstract: Geopolymer concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules. Fly ash combining with alkaline solution is new binder used in manufacturing fly ash based geopolymer concrete, an eco-friendly alternative for traditional concrete using Portland cement binder. In this research, the issues of environmental and economic concern are addressed by the use of waste glass powder as partial replacement of fine aggregates in Geopolymer concrete. The glass waste was ground finer and was sieved through 600 micron IS sieve. Fine aggregates were replaced by waste glass powder as 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% by weight for M-35 mix. All the specimens were tested for its strength properties at the age of 7, 14 and 28 days. Then the values are compared with those of normal fly ash based Geopolymer concrete. The test results indicated that the maximum compressive strength was obtained with 20% replacement of glass powder to fine aggregate.

Keywords: Geopolymer concrete, fly ash, waste glass powder, alkaline solution, durability, replacement, alkali-silica reaction.

I. INTRODUCTION

Concrete is one of the most widely used construction material; it is usually associated with Portland cement as the main component for making concrete. The demand for concrete as a construction material is on the increase. It is estimated that the production of cement will increase from about from 1.5 billion tons in 1995 to 2.2 billion tons in 2010. On the other hand, the climate change due to global warming, one of the greatest environmental issues has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases, such as CO_2, to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming (McCaffrey, 2002). The cement industry is responsible for about 6% of all CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere.

In this respect, the geopolymer technology proposed by Davidovits (1988a; 1988b) shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of reducing the global warming, the geopolymer technology could reduce the CO_2 emission to the atmosphere caused by cement and aggregates industries by about 80% (Davidovits, 1994c).Fly ash, which is rice in silica and alumina, has full potential to use as one of the source material for geopolymer binder.

Recent works on the geopolymerisation of fly ash, reported production of geopolymeric materials with high mechanical strength, low density, less water absorption, negligible shrinkage and significant fire and chemical resistance. Due to these properties, Geopolymeric materials are viewed as an alternative to Portland cement for certain industrial applications in the areas of construction, transportation, road building, aerospace, mining and metallurgy.

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II. Literature Review

B. VijayaRangan et al.,[1] concludesthat theFly ash-based geopolymer concrete has excellent compressive strength and is suitable for structural applications. The paper has identified several economic benefits of using fly ash based geopolymer concrete.

DjwantoroHardjito et al.,[2] presents the higher concentration (in terms of molar)of sodium hydroxide results in a higher compressive strength of Geopolymer concrete. Higher the ratio of sodium hydroxide liquid ratio by mass, higher is the compressive strength of the Geopolymer concrete. As the curing temperature in the range of 30to90°c increase,the compressive strength of the geopolymer concrete also increases.The resistance of Geopolymer concrete against sulphate is excellent.

Nguyen Van Chanh et al.,[3] examined Geopolymer is a type of amorphous alumino-silicate cementitious material. Geopolymer can be synthesized by polycondensation reaction of geopolymeric precursor, and alkali polysilicates. This paper presents the results of studying materials ,mixture composite, microstructure of Geopolymer, and parameters affecting properties of geopolymer concrete.

S.Ng&S.J.Foster,Futures[4] concludes, the equations developed for elastic modulus of conventional concrete cannot be applied that of GPC,the density and poisson's ratio of geopolymer concrete are similar to those of OPC concrete. For a given compressive strength, geopolymer concrete has a significantly lower elastic modulus based on a two-phase material approach is presented and shown to provide a good correlation.

J.Temuujin et al.,[5]concludes, Compressive strength of fly ash based geopolymer mortar wasfound to depend on the strength of the geopolymer binder and excellent bonding between the geopolymer binder and aggregate. Increasing the proportion of aggregate in the mortar reduced theamount of geopolymerisation but did not significantly impact oncompressive strength. It is proposed that compressive strength of geopolymer mortars with high levels of aggregate can be increasedby optimizing the amount of alkali.

NimishaSasindran C and Vidya Jose[6] studied the use of GLP in concrete would prevent expansive ASR in the presence of susceptible aggregate. This paper concludes that increase in glass powder content has a significant effect on the workability of geopolymer concrete. The workability increases with the increase in the amount of glass powder. The compressive strength of geopolymer concrete in-creases with the increase in the amount of glass powder up to 15% replacement of fly ash.

M. Adaway& Y. Wang[7] proposed that theGlass, being non biodegradable, is not suitable for addition to landfill, and as such recycling opportunities need to be investigated. Three concrete samples were tested at 7 and 28 days, for glass replacement proportions of 15, 20, 25, 30 and 40%.. The optimum percentage replacement of sand with fine glass aggregate was determined to be 30%.Compressive strength was found to increase with the addition of waste glass to the mix up until the optimum level of replacement. This can be attributed to the angular nature of the glass particles facilitating increased bondingwith the cement paste.

Ahmad Shayan and AiminXu[8] used the large proportion of the postconsumer glass is recycled into the packaging stream again, and some smaller proportions are used for a variety of purposes, including concrete aggregate. However, a significant proportion, which does not meet the strict criteria for packaging glass, is sent to landfill, taking the space that could be allocated to more urgent uses. Glass is unstable in the alkaline environment of concrete and could cause deleterious alkali-silica reaction (ASR) problems. Microstructural examination has also shown that GLP would produce a dense matrix and improve the durability properties of concrete incorporating it.

KunalKupwade-patil and Erezallouche [9] examinedAlkali silica reaction occurs due to chemical reaction between hydroxyl ions in the pore water within the concrete matrix and certain forms of silica.. The ASR reaction is initiated only when the material is still in a gel like a form.The paper concludes that the bar specimen tested as per ASTM C 1260, On average OPC specimens six times greater expansion than GPC after 34 days of exposure to NaOH.

II. Research Significance

The objective of the work was to replace the fine aggregate with waste glass powder and tests on structural performance of concrete was carried out at various percentages from 0 % to 40% and the results were compared with a basic mix. A waste glass powder best suits the replacement due to its low cost, and availability as well as the low weight when compared to river sand.

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IV. MATERIALS

4.1FLY ASH

In the present work class F fly ash was used for the Investigation and their properties are tabulated as quoted in table 4.1.1&4.1.2.

Table 4.1.1 Chemical Properties Of Fly Ash (Class F)

S.No	Components	(%)
1.	Silicon dioxide(SiO_2)	60.54
2.	Alumina(Al_2O_3)	23.87
3.	Iron oxide(Fe_2O_3)	9.64
4.	Magnesium oxide(Mgo)	1.52
5.	Calcium oxide(CaO)	1.07

TABLE 4.1.2 PHYSICAL PROPERTIES OF FLY ASH (CLASS F)

S.NO	Types of Test	Fly Ash – Class F
1.	Specific gravity	1.90
2.	Fineness	7%
3.	Normal Consistency	33%
4.	Initial setting time	45 min
5.	Bulk density	1.077 g/cm^2
6.	Specific surface area	4205.72 cm^2/gm

4.2 WASTE GLASS POWDER

Waste glass powder is obtained from the locally available recycling plant in salem where the glass wastes are crushed and sent to the main plant has to be recycled to new glass. A large proportion of the postconsumer glass is recycled into the packaging stream again, and some smaller proportions are used for a variety of purposes, including concrete aggregate. However, a significant proportion, which does not meet the strict criteria for packaging glass, is sent to landfill, taking the space that could be allocated to more urgent uses. We are using the glass powder which are passing through IS sieve1.18mm.

Figure 4.2 waste glass powder

4.2.1 Sieve Analysis Of Waste Glass Powder

I.S. Sieve Size	Wt retained (Kg)	% of weight retained	Cumulative of % retained	% of passing
4.75 mm	-	-	-	100
2.36 mm	-	-	-	100
1.18 mm	-	-	-	100
0.60 mm	0.216	21.6	21.6	78.40
0.30 mm	0.391	39.1	60.7	39.30
0.15 mm	0.241	24.1	84.8	15.20
0.075 mm	0.104	10.4	95.2	4.80
Pan	0.048	4.8	100	0

4.2.2 Chemical Properties Of Waste Glass Powder

S.No	Components	(%)
1.	Silicon dioxide(SiO_2)	71.50
2.	Calcium oxide(CaO)	9.67
3.	Sodium oxide(Na_2O_3)	7.85
4.	Magnesium oxide(Mgo)	1.80
5.	Alumina(Al_2O_3)	2.45

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4.2.3 Physical Properties Of Waste Glass Powder

S No.	*Characteristics*	*Values obtained*
1.	*Specific gravity*	*2.81*
2.	*Dry density*	*979.12* Kg/m^3
3.	*Fineness modulus*	*1.67*

4.3 COARSE AGGREGATE

In this present investigation, locally available crushed granite aggregate was used, as per IS 383-1970, coarse aggregate in sieve size 20mm passing and 4.75mm retaining in saturated surface dry (SSD) condition were used.

Figure 4.3 Coarse Aggregate

4.4 FINE AGGREGATE

The locally available river sand was used as fine aggregate in the present investigation. The sand was screened at site to remove deleterious material and tested as per procedure given in IS: 383-1970.

Figure 4.4 Fine Aggregate

4.5 ALKALINE LIQUID

Alkaline Activated Solution (AAS) used here was a mixture of sodium silicate (Na2SiO3) and sodium hydroxide (NaOH). Sodium hydroxide was available in flakes form, dissolved in distilled water to get solution with 12 Molarity.

Figure 4.5 Alkaline liquid

The ratio of sodium silicate to sodium hydroxide solution is 2.50. The mass of NaOH solids in a solution varies depending on the concentration of the solution expressed in terms of molar, M. More amount of heat was generated during the mixing of water with NaOH flakes. For this reason, It is recommended that the NaOH solution should be made 24 hours before casting and should be used with 36 hours of mixing the pellets with water as after that it is converted to semi-solid state. Sodium silicate solution is then mixed with the NaOH solution prior to batching. Sodium-based solutions were chosen because they were cheaper than Potassium-based solutions.

V. EXPERIMENTAL INVESTIGATION

5.1 Casting of specimens

Before casting of specimens the moulds were tightened by using bolts and nuts and then oiled.

5.1.1 Batching

In batching concrete, the quantity of fly ash, fine aggregate and coarse aggregate shall be determined by mass and sodium silicate and sodium hydroxide solution measured in volume or mass.

5.1.2 Mixing

Mixing can be done by following two process in geopolymer concrete using pan mixer.

Dry Mixing

The fly ash, coarse aggregate and fine aggregate were mix together. The mixing time shall be at least 3 minutes.

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Wet Mixing

Then the sodium silicate and sodium hydroxide solution was mixed with dry solid for 3minutes water would be added if any necessity (3% of water).

5.1.3 Moulding, Compaction and Surface finishing

- After the wet mixing the moulding process was done by following two methods
- Geopolymer concrete was compacted in mould of three layers with 25 manual strokes. For each layer mould was placed on mechanical vibrator table for compaction.The Compacted mould surface was finished by trowel.

5.1.4 Curing of specimens

- After 24 hours, the specimens were demoulded and the specimen was kept at respective curing condition.
- Curing is the process of preventing the loss of moisture from the concrete while maintaining a satisfactory temperature regime.
- The Casted moulds are being in the hot air oven at the temperature of about 70ºC for curing.

VI. Results.

A strength test were conducted for geopolymer concrete such as

(i) Compressive strength test for 7,14 and 28 days
(ii) Split tensile test for 28 days
(iii) Flexural strength test for 28 days
(iv) Bond strength test for 28 days

(i) Compressive Strength

It was found that the compressive strength for control mix is 43.76MPa at 28 days. The maximum compressive strength of 50.89MPa was obtained from the 20% replacement of glass waste to fine aggregate at 28 days.

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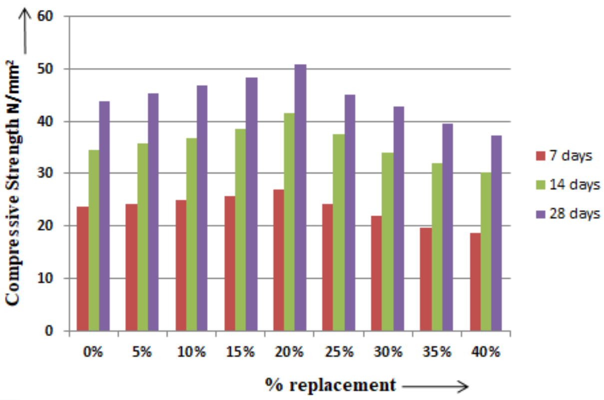

(ii) Split tensile test

Split tensile test was carried out for control mix and optimum percentage for the age of 28 days.

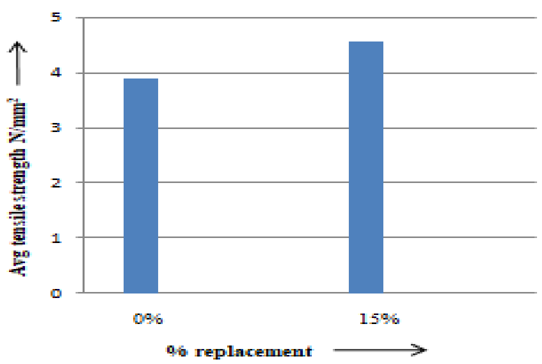

Fig 6.2 Average Split tensile test at 28 days

(iii) Flexural strength test

A Flexural strengthtest was carried out for control mix and optimum percentage for the age of 28 days.

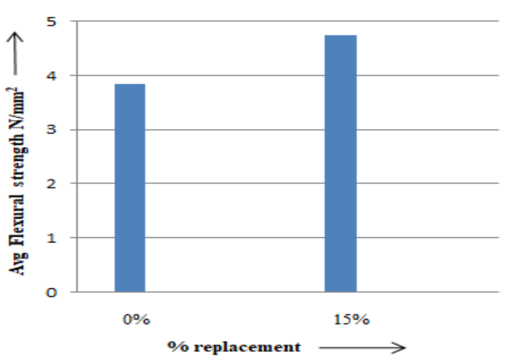

Fig 6.3 Average Flexural strength test at 28 days

(iv) Bond strength test

A Bond strength test was carried out for control mix and optimum percentage for the age of 28 days.

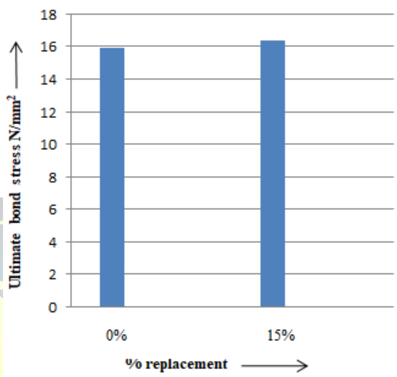

Fig 6.4 Average Bond stresstest at 28 days

(v) Light weight test results

The dry weight of various percentage of replacements are noted down and compared with 0% so that loss in weight is calculated due to the addition of waste glass powder for cube of size 100mm x100mm x 100mm.

S. no	Waste glass %	Avg dry weight of cube (gm)	Percentage decrease in weight
1.	0 %	2472	0%
2.	5 %	2428	1.78 %
3.	10%	2378	3.81 %
4.	15%	2323	6.03 %
5.	20%	2294	7.20 %

Conclusions and Recommendations

- 20 % replacement of fine aggregate by waste glass powder showed 16.30%increase in compressive strength at 28 days.
- Similarly tensile strength result show that optimum replacement increases the strength by 16%.
- Flexure strength test and bond strength test results are also compared with the optimum replacement.
- With increase in waste glass content, average weight decreases by 7.20% for mixture with 20% replacement thus making the waste glass concrete light weight.

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- Use of waste glass in concrete can prove to be economical as it is available in very low cost as compared to river sand.
- Use of waste glass in concrete will eradicate its disposal problem.
- Use of waste glass in concrete will preserve natural resources particularly river sand and thus make concrete construction industry sustainable.

REFERENCES

[1] Davidovits J. Chemistry of Geopolymeric Systems, Terminology. In: Joseph Davidovits, Davidovits R, James C, editors. Geopolymer '99 International Conference; 1999 June 30 to July 2, 1999; France; 1999. p. 9-40.

[2] Hardjito D, Wallah SE, Sumajouw DMJ, RanganBV"Introducing Fly Ash-based Geopolymer Concrete: Manufacture and Engineering Properties". In Proceedings of the International Conference Our World in Concrete, Singapore, August 2005.

[3] Ngugen Van Chanh, Trung BD, Tuan DV (2002). Recent research geopolymer concrete. The 3rd ACF International Conference – ACF/VCA.

[4] T.S. Ng and S.J.Foster, "Making Concrete 'Greener' with Fly Ash," Concrete International,V. 21, No. 5, May 2009, pp. 61-66.

[5] J.Temuujin, Palomo, A.; Grutzeck, M. W.; and Blanco, M. T., "Alkali-Activated Fly Ashes, A Cement for the Future," Cement and Concrete Research, V. 29, No. 8, 2010, pp.
1323- 1329.

[6] NimishaSasindran C and Vidya Jose "Effect of Glass Powder on Geopolymer Concrete" Concrete International, V. 21, No. 5, May 1999, pp. 61-66.

[7] M. Adaway& Y. WangDeakin University, Waurn Ponds, Australia Recycled glass as a replacement for fine aggregate in structural concrete – Effects on partial Compressive strength-Electronic Journal of Structural Engineering 14(1) 2015.

[8] Ahamadshyaan, AiminXu Value added utilization of waste glass in concrete and its Applications- cement and concrete research 34 (2004) 81-89.

[9] Kunalkupwade- patil and eresallouche : Effect of alkali silica reaction in geopolymer Concrete-World of coal ash (WOCA) conference-may 2011.

[10] IS:456: 2000, Plain and Reinforced Code of practice.

[11] IS: 10262-2009 (Reaffirmed 2004): Recommended guidelines for concrete mix design, Bureau of Indian Standard, New Delhi-2004.

[12] IS: 383-1970: Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, Bureau of Indian Standard, And New Delhi- 19.

[13] ASTM C1260 - 0 : Standard test method for potential alkali reactivity of aggregates.(mortar bar method).