FACTORS INFLUENCING COMPRESSIVE STRENGTH OF GEOPOLYMER CONCRETE

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Abstract

To study effects of several factors on the properties of fly ash based geopolymer concrete on the compressive strength and also the cost comparison with the normal concrete. The test variables were molarities of sodium hydroxide(NaOH) 8M,14M and 16M, ratio of NaOH to sodium silicate (Na_2SiO_3) 1, 1.5, 2 and 2.5, alkaline liquid to fly ash ratio 0.35 and 0.40 and replacement of water in Na_2SiO_3 solution by 10%, 20% and 30% were used in the present study. The test results indicated that the highest compressive strength 54 MPa was observed for 16M of NaOH, ratio of NaOH to Na_2SiO_3 2.5 and alkaline liquid to fly ash ratio of 0.35. Lowest compressive strength of 27 MPa was observed for 8M of NaOH, ratio of NaOH to Na_2SiO_3 is 1 and alkaline liquid to fly ash ratio of 0.40. Alkaline liquid to fly ash ratio of 0.35, water replacement of 10% and 30% for 8 and 16 molarity of NaOH and has resulted in compressive strength of 36 MPa and 20 MPa respectively. Superplasticiser dosage of 2 % by weight of fly ash has given higher strength in all cases.

***Keywords**: compressive strength, alkaline liquid, fly ash*

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1. INTRODUCTION

Construction activity in India during the last decade has more than doubled. The significant breakthrough in software, IT and BPO industries has given a new ray of hope to large number of middle class Indian families especially in urban areas where there can be lot of improvement in infrastructure with the liberalization and globalization of Indian economy. Concrete has been the most preferred construction material for over five decades. It is being increasingly used day by day all over the world due to its versatility, mould ability, high compressive strength and many more advantages. Hence the use of concrete as a construction material has increased.

The fact that production of cement adds to the pollution of environment is a well-known fact to civil engineers and environmentalists. The large-scale production of cement is posing environmental problems on one hand and unrestricted depletion of natural resources on the other hand. Each tone of Portland cement production results in loading about one tone of CO_2 into the environment [1]. Environmental problem will constitute some of the foremost and most formidable challenges to civil engineering profession in the coming decade. Environmental and economic reasons require the revision of present concrete making materials. Fortunately within this scenario a new player has emerged that can help in mitigating the problem and the player is Geopolymer Concrete.

In 1988, Davidovits [2] proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials of geological origin or by-product materials such as fly ash and rice husk ash, he termed these binders as Geopolymer. Palomo et al [3] suggested that pozzolans such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. In this scheme, the main contents to be activated are silicon and calcium in the blast furnace slag and the main binder produced is a C-S-H gel, as the result of the hydration process.

Very less information is available for variation of compressive strength with change in the ratio of sodium hydroxide to sodium silicate. Because this ratio influences the cost of concrete because the cost of geopolymer concrete is mainly depend on alkaline liquids. So an attempt is also made to decrease the cost of sodium silicate by replacing water by 10%, 20% and 30%.

1.1 Geopolymers

Davidovits .J. [4] proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminum (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term ‘Geopolymer’ to represent these binders.

Geopolymers are members of the family of inorganic polymers. The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, which result in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds [4].

1.2 Constituents of Geopolymer Concrete

There are two main constituents of geopolymers, namely the source materials and the alkaline liquids. The source materials for geopolymers based on alumina-silicate should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, etc. Alternatively, by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc could be used as source materials. The choice of the source materials for making geopolymers depends on factors such as availability, cost, type of application, and specific demand of the end users. In present investigation fly ash being used [5].The alkaline liquids are from soluble alkali metals that are usually Sodium or Potassium based. The most common alkaline liquid used in geopolymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

2 EXPERIMENTAL WORK

2.1 Materials

Fly ash was collected and brought from Raichur Thermal Power Station. Physical and chemical properties of this Fly ash are supplied by the suppliers are presented in Table 1 and 2 as per IS: 3812:2003 [6].Locally available clean river sand was used and its physical properties are given in Table 3. Crushed basalt have been used as coarse aggregate. Two different sizes of coarse aggregates i.e 60 % of 20 mm down size and 40 % of 12.5 mm down size were used in the present study. Average specific gravity and combined fineness modulus is given in Table 4.

Table – 1: Physical Properties of Fly Ash

Sl. No.	Particulars	Test results
1	Fineness	380 m2/kg
2	Lime reactivity	8.52 n/mm2
3	Specific gravity	1.8
4	Fineness	519 m2/kg

Table – 2: Chemical Properties of Fly Ash

Sl. No.	Chemical Composition	% content
1	Sio2	58.95
2	Al2o3	29.24
3	Fe2o3	0.98
4	Mgo	1.05
5	So3	1.01
6	Na2o	0.24

Table –3: Physical Properties Fine Aggregate

Sl NO	Physical Property	Result
1	Specific Gravity	2.57
2	Fineness Modulus	2.71
3	Zone	II

Table –4: Physical Properties Coarse Aggregate

Sl NO	Physical Property	Result
1	Specific Gravity	2.70
2	Fineness Modulus	6.81

The alkaline liquid used in geopolymerization is a combination of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3). It is known to activate the fly ash by dissolving the outer surface and initiating polymerization/chemical process. The sodium hydroxide is available in the form of solid pellets, with 97% purity. The sodium hydroxide solution was prepared by dissolving the pellets in water. The mass of sodium hydroxide solid in a solution depends on the concentration of solution and is expressed in terms of molarities. Commercially available sodium silicate solution was used. Super plasticizer CONPLAST SP-430 a product from FOSROC Chemicals conforming to IS: 9103 [7] was used.

2.2 Mix Design of Geopolymer Concrete

Some simple guidelines for the design of heat-cured low calcium fly ash-based geopolymer concrete are proposed (Rangan, 2008) [8]. The role and the influence of aggregates are considered to be the same as in the case of Portland cement concrete. The mass of combined aggregates may be taken to be between 75% and 80% of the mass of geopolymer concrete. In order to meet these performance criteria, the alkaline liquid-to-fly ash ratio by mass, water-to- geopolymer solids ratio by mass, the wet-mixing time, the heat-curing temperature, and the heat - curing time are selected as parameters. After number of trials alkaline liquid to fly ash ratio by mass in the range of 0.35 and 0.40 resulted in good compressive strength and the same thing is reported in literature [5]. Note that wet-mixing time of 4 minutes, and steam-curing at 60o C for 24 hours after casting are proposed.

In other words, the coarse and fine aggregates in a geopolymer concrete mixture must neither be too dry to absorb water from the mixture nor too wet to add water to the mixture. In practical applications, aggregates may contain water over and above the SSD condition.

2.3 Casting and Curing of Test Specimens

Geopolymer concrete is manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. In the laboratory, the fly ash and the aggregates were first mixed together in dry state. The alkaline liquid was mixed with the super plasticizer and the extra water, if any. The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another 10 - 15 minutes. The fresh concrete could be handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength. The fresh concrete was cast and compacted in the moulds of cubes 150 mm x 150mm, by the usual methods used in the case of Portland cement concrete. Fresh fly ash-based geopolymer concrete was usually cohesive. The workability of the fresh concrete was measured by means of the conventional slump test.

Heat-curing of geopolymer concrete is generally recommended. It substantially assists the chemical reaction that occurs in the geopolymer paste. Both curing time and curing temperature influence the compressive strength of geopolymer concrete. Longer curing time improves the polymerization process resulting in higher compressive strength. The rate of increase in strength was rapid up to 24 hours of curing time; beyond 24 hours, the gain in strength is only moderate as per literature. In our investigation curing temperature selected is 60oC for 24 hours.

3 RESULTS AND DISCUSSIONS

3.1 Effect of Fly ash to Alkaline Liquid and Concentration of NaOH

From Fig – 1 indicates compressive strength v/s ratio of sodium hydroxide to sodium silicate for alkaline to fly ash ratio of 0.35. It is observed that compressive strength of geopolymer concrete is increasing, as the ratio of sodium hydroxide to sodium silicate increases for all concentration of sodium hydroxide solution. Proportionate increase in compressive strength is observed for 8M and 14M for the ratio of 1.5,2 and 2.5 and the difference in compressive strength is quite increased for a ratio of 1.5, 2 and 2.5 except 1. For 16M concentration the increase in compressive strength is more from 1.5 to 2. Appreciable increase in compressive strength is observed for 16M compared to 8M and 14M for all ratios of sodium hydroxide to sodium silicate solution.

Fig – 2 indicates compressive strength v/s ratio of sodium hydroxide to sodium silicate for alkaline to fly ash ratio of 0.40. Similar behavior is observed in Fig – 2. The variation in compressive strength between 8M and 14M is higher for ratio of sodium hydroxide to sodium silicate solution i.e.1.5, 2 and 2.5.As the alkaline liquid to fly ash ratio increases compressive strength decreases. Decrease in compressive strength of geopolymer concrete is because of increases in water in the preparation of alkaline liquid. This behavior is similar to normal concrete as water to cement ratio increases compressive strength decreases.

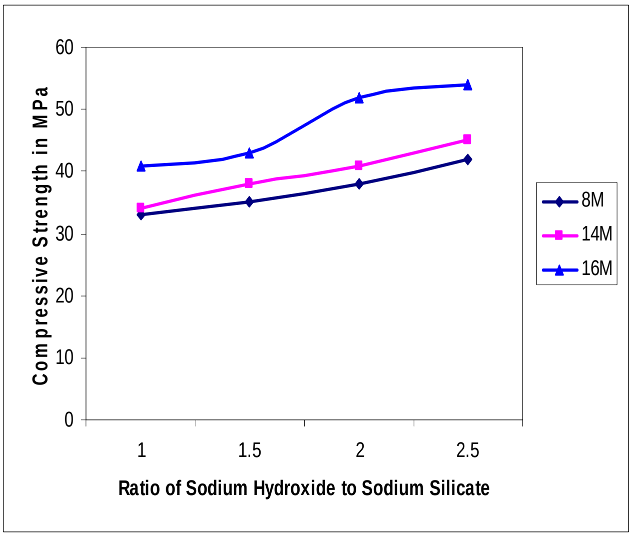

Fig - 1: Variation of Compressive Strength for Different ratio of NaOH to Na2SiO3 & for different concentration of NaOH for Alkaline to Fly ash ratio of 0.35 and Superplasticizer content of 2%.

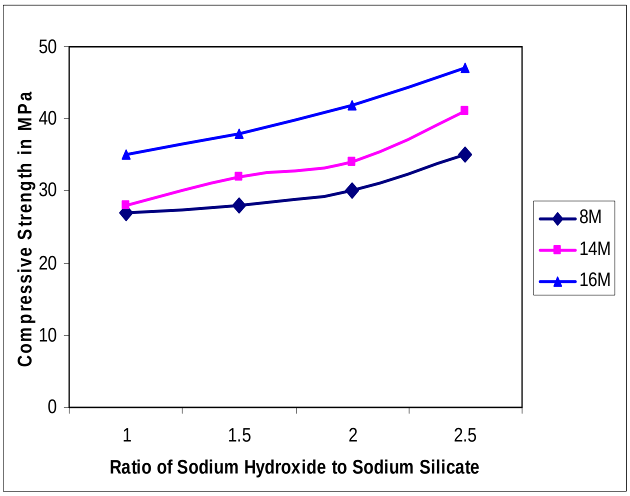

Fig - 2: Variation of Compressive Strength for Different ratio of NaOH to Na2SiO3 & for different concentration of NaOH for Alkaline to Fly ash ratio of 0.40 and Superplasticizer content of 2%.

3.2 Effect of water replacement in Sodium Silicate

Fig-3 is a plot between compressive strength v/s concentrations of sodium hydroxide. It exhibits that compressive strength of geopolymer concrete is decreasing rapidly as percentage of water is increasing for all concentration of NaOH. During casting of specimens, increase in workability of concrete is observed for 10% and 20% water replacement but for 30% water replacement, concrete exhibits segregation. From these results it is found that addition of water decreases the strength of geopolymer concrete. This behavior is similar to normal concrete.

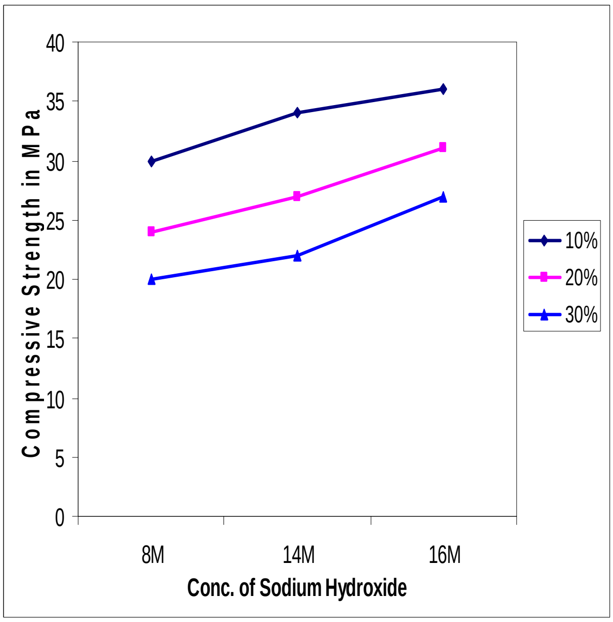

Fig. – 3: Variation of Compressive Strength for Different percent replacement of water & for different concentration of NaOH for Alkaline to Fly ash ratio of 0.35.

CONCLUSIONS

Several series of tests on geopolymer concrete were performed. Based on the experimental results reported in the paper, the following conclusions are drawn:

- The compressive strength of geopolymer concrete increases with increase in concentration of NaOH solution.
- The compressive strength of geopolymer concrete decreases with increase in Alkaline liquid to Fly ash ratio.
- Use of commercially available Naphthalene-based superplasticizer improved the workability of the fresh geopolymer concrete. Dosage of this admixture is limited to 2% by mass of fly ash. Beyond this dosage degradation in the compressive strength is observed.
- Water replacement for sodium silicate shows decrease in the compressive strength of geopolymer concrete as increase in water replacements well as the workability of the fresh concrete increases.

REFERENCES

[1] Robert Mccaffrey., (2002). “Climate Change And The Cement Industry”, *Conference On Market And Economic Trends Influencing The Global Cement Industry*.

[2] Davidovits, J., (1988). “Soft Mineralogy and Geopolymers”, *Proceedings of the of Geopolymer 88 International Conference, the Université de Technologie, Compiègne, France.*

[3] Palomo A, Grutzek MW, Blanco MT., (1999) “Alkali-activated fly ashes. A cement for the future”, *Cem Concrete Research; 29:1323–9.*

[4] Davidovits, J. (1994) “High-Alkali Cements for 21st Century Concretes. In Concrete Technology, Past, Present and Future”, *Proceedings of V. Mohan Malhotra Symposium, Editor: P. Kumar Mehta, ACI SP- 144, 383-397.*

[5] B. Vijaya Rangan., (2008). “Studies On Fly Ash-Based Geopolymer Concrete”, *Malaysian Construction Research Journal, Vol. 03 [No. 2].*

[6] IS: 3812:2003 (Part-1 and 2) (Reaffirmed 1999).., “Specification for fly ash for use as pozzolans and admixture”, *Bureau of Indian Standards.*

[7] IS 9103: 1999 “Concrete Admixtures - Specification”, *First Revision, Bureau Of Indian Standards.*

[8] B. Vijaya Rangan., (2008). “Mix design and production of fly ash based geopolymer concrete”, *The Indian concrete journal.*

[9] IS 456 : 2000., (2000). “Plain And Reinforced Concrete - Code Of Practice” *Fourth Revision, Bureau Of Indian Standards.*

[10] Davidovits, J., (1994). “Properties of geopolymer cements”, *1st International Conference on Alkaline Cements and Concretes (Krivenko, ed.). Kiev, Ukraine, 1: 131-149.*

[11] Davidovits, J., (1994). “Global Warming Impact on the Cement and Aggregates Industries”, *World Resource Review, 6(2), 263-278.*

[12] Davidovits .J. (1999) “Chemistry of Geopolymeric systems, Terminology” *Geopolymers International Conference France.*