Effect of Aluminium Oxide as additive in Heat Resistant Geopolymer Concrete

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Abstract:

In OPC concrete there is permanent damages and spalling while the temperature is high. In most of the research work it is determined that concrete loses the compressive strength 50 to 75% of the original strength. Heat resistant geopolymer concrete is consider because the high grade of concrete leads to uneconomic and emits the CO_2 emission. Geopolymer is an emerging class of silica-alumina binders which possesses a potential for high-temperature resistance. In this paper to develop the heat resistance performance and strength factors by adding aluminium oxide as admixture dosage varied 1% and 2% by weight of fly ash. Heat resistant GPC were prepared as industrial by-product waste like fly ash, fine aggregate and coarse aggregate, sodium hydroxide and silicate were used as alkali activators. The molarity of NaOH solution 12 and 14. The specimens were cast and oven cured at 60°C for 24 hours. The specimens were tested to determine mechanical properties of heat resistant geopolymer concrete.

Keywords — **Geopolymer, aluminium oxide, silica-alumina, alkali activators.**

I. INTRODUCTION

Utilization of geopolymer materials can reduce 80% of greenhouse gas emissions associated with material production, and overcome issues related to cement production and unregulated disposal of industrial materials by recycling these materials in geopolymermanufacture.

Geopolymers invented by Joseph Davidovits in 1970‟s were initially developed toserve as a fire resistant material, but it has now gained momentum as an effective alternate to cementitious binders to limit greenhouse gas emissions. He coined the term Geopolymers for a class of materials rich in silica and alumina activated by alkaline solutions. The chemical composition of Geopolymers resembles natural zeolitic materials but its microstructure isamorphous.

Geopolymers utilize the polycondensation of silica and alumina precursors and a high alkali content to attain structural strength .In Geopolymers, Alumina and Silica are interlinked tetrahedrally by sharing all the oxygen atoms. A polymeric structure of Al–O– Si formed constitutes the main building blocks of geopolymeric structure.

Till date, the exact mechanism of strength attainment of geopolymers has not been understood. But the chemical reaction shows that water is expelled during the geopolymerization reaction. Hence, water plays no active role in the geopolymerization reaction and only contributes to workability of the geopolymer matrix. This is in contrast to the hydration process of ordinary portland cement concrete.

The geopolymers differ from ordinary portland cement concrete in the manner in which they attain structural integrity. Attainment of strength and matrix formation in pozzolonic concrete depends on the presence of C-S-H gel. The choice of these source materials depends on several factors such as type of application, demands of the end users, cost andavailability.

II. MIX DESIGN

Since there are no standard codal provisions available for the mix design of geopolymer concrete, the density of geopolymer concrete was assumed as 2400 kg/m3 and other calculations were made based on the density of concrete as per the mix design given by Lloyd & Rangan (2010).The mix design

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was referred in book of Geopolymer chemistry & applications by joseph davidovits.

Mix proportion

Sodium hydroxide concentration :12M &14M
Sodium hydroxide to sodium silicate :1:1
Alkaline activator to binder ratio : 0.4
Curing type : Oven curing
Curing period (oven) : 24 hours @ 60°c
Combination of mix : without and with 1% & 2% of Al_2O_3

Fig 2.1 Casted Specimen   Fig 2.2 Oven Curing

Fig 2.3 Cured Specimen

III. TEST PROCEDURE

Compressive strength

The compressive strength of concrete mixes was studied using cubes of size 100 mm x100 mm x 100 mm in accordance with IS 516. All the cubes were cured under oven curingconditionat60C.Foreachtrialmix,theaverageofthreespecimensweretaken to determine the compressive strength at 24 hours of curing loaded under 2.3 kN/sec for 100mm specimen compression testing machine (CTM).. The load was applied continuously till its direction gets reversed. The reversal of load direction demonstrates that the sample has failed.

Fig 3.1 Compression Testing machine

Split tensile strength test

The tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. In this method is used to evaluate the indirect tensile strength of concrete. The dimension of cylindrical specimens is 100mm diameter and 200mm length. The specimens were casted and cured at 60C for 24 hours of curing; or any desired age. Central lines were drawn on the two ends of the cylinders to ensure that they were in the same axial plane. The load was applied progressively until the cylinders split, and the subsequent load was recorded. Finally, note down the breaking load (P). The formula is used to estimate the split tensile strength (f_{ct}) of the concrete specimens.

$$f_{ct} = 2P/\pi dl \text{(N/mm}^2\text{)}$$

Fig 3.2 Split Tensile Testing machine

Flexural Strength

Flexural strength of the concrete mixes was evaluated using prismatic specimens of size 100 mm x 100 mm x 500 mm as per IS 516 after 24 hours of oven curing, with the aid of 3000 kN capacity flexure Testing Machine by subjecting the concrete specimens under four-point loading. The mode of failure is givenin

$$f_r = FL/bd^2$$

(When **a** > 200mm for 150mm specimen or > 130mm for 100mm specimen)

or

$$f_r = 3Fa/bd^2$$

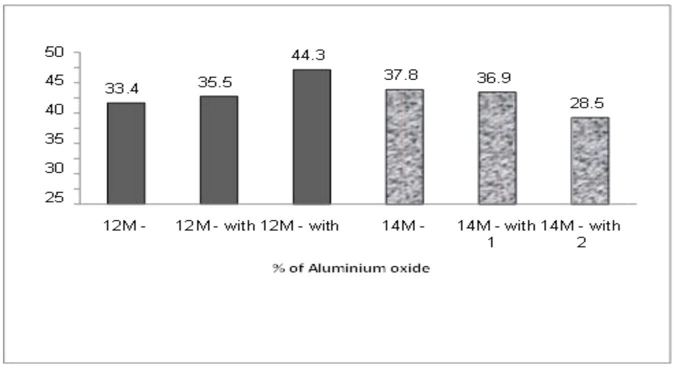
Fig 3.3 Flexural Testing Machine

IV. RESULT

Over one hundred fifty specimens were casted and tested to examine the strength of HRGPC made with addition of Al_2O_3. Tests were conducted on HRGPC with two different molarity of NaOH and three types of mixes like without adding Al_2O_3, admixture of 1% of Al_2O_3 and admixture of 2% of Al_2O_3. The results show the variation in compressive strength of HRGPC with respect to the influence of % of admixture and NaOH concentration. Further the flexural strength, splitting tensile strength and elastic modulus of the GPC specimens were also tested. Charts have been drawn to depict the variations in the aforesaid parameters of HRGPC specimen. The test results are discussedbelow.

Compressive strength

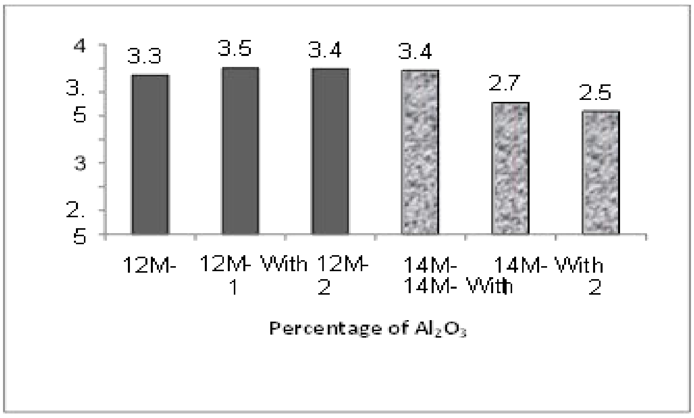
Compressive strength (As per ASTM C39-2014/ IS 516-1959)	Trial -1 (N/mm²)	Trial -2 (N/mm²)	Average (N/mm²)
12M - without Al_2O_3	35.39	31.44	33.42
12M - with 1% of Al_2O_3	36.73	34.40	35.57
12M - with 2% of Al_2O_3	44.07	44.61	44.34
14M - without Al_2O_3	38.60	37.06	37.83
14M - with 1% of Al_2O_3	36.92	37.01	36.97
14M - with 2% of Al_2O_3	29.23	27.86	28.55



From the results, it can be seen that the compressive strength of HRGPC increased with increase in NaOH concentration. At 24 hrs of oven curing, the strength increase of without Al_2O_3 specimen (GP) ranged from 5 to 10% for the corresponding rise in molaritystartingfrom12Mand14M.TheincreaseinNaOHconcentrationcouldhaveincreased the rate of dissolution of silica and alumina ions in the alkaline solution resulting in the compressive strength gain.

Split tensile strength test

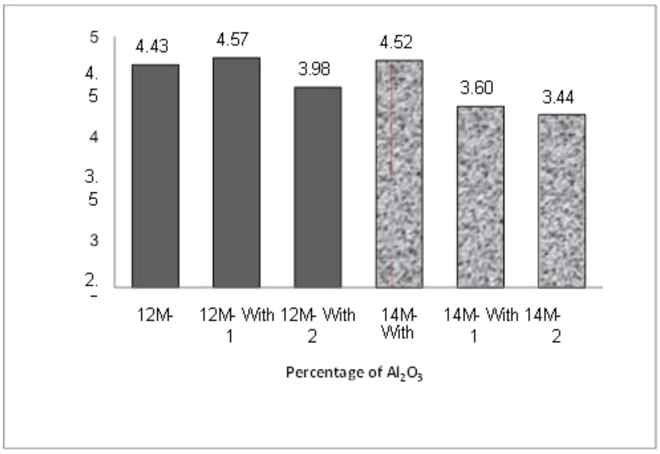
Tensile strength (As per ASTM C496-1996/ IS 5816-1999)	Average load (kN)	Stress (N/mm²)
12M - without Al_2O_3	105.40	3.355
12M - with 1% of Al_2O_3	110.15	3.506
12M - with 2% of Al_2O_3	109.80	3.495
14M - without Al_2O_3	108.60	3.457
14M - with 1% of Al_2O_3	86.95	2.778
14M - with 2% of Al_2O_3	81.25	2.595



Without adding of Al_2O_3 gives promising results compared to research papers. When comparing the 12M - 1% of Al_2O_3 mix with 12M - 2% of Al_2O_3 there was a slight improvement in split tensile strength. But with further increase in molar concentration with % of Al_2O_3, the split tensile strength seemed to getdecreased.

Flexural Strength

Flexural strength (ASTM C78-2018/ IS 516-1959)	Avg. Stress (N/mm²)
12M - without Al_2O_3	4.438
12M - with 1% of Al_2O_3	4.579
12M - with 2% of Al_2O_3	3.988
12M - without Al_2O_3	4.526
12M - with 1% of Al_2O_3	3.609
12M - with 2% of Al_2O_3	3.447



The variation in the flexural strength of the HRGPC mixes with respect to NaOH concentration. While increasing NaOH concentration increases the flexural strength of the GPC mixes. The improved performance with the increase in the NaOH concentration isprimarilybecauseoftheincreasingamountofleachingofSiandAlathigher concentration of NaOH. In 12M - 1% of Al_2O_3 gives slightly high strength compared to 12M- 2% of Al_2O_3. The rate of decreasing the strength is low in14M mixes compared to 12M mixes.

V. CONCLUSION

- The experimental results show that it is possible to produce geopolymer concrete possessing substantial strength and durability using flyash and aluminium oxide.
- Increase in NaOH concentration increased the compressivestrength.
- The strength increase ranged between 5 to 10% for the corresponding in 12 molarity and percentage of adding aluminiumoxide.
- The mechanical properties of flyash based HRGPC in 12 molarity with adding aluminium oxide gave promising results compared to 14 molarity mixes.
- Its conclude that, the experimental investigation leads 12M-1% and 12M- 2% of Al_2O_3 found to be the best among sixmixes.

VI. REFERENCE

1. *Hafez E. Elyamany, Abd Elmoaty M. Abd Elmoaty, Ahmed M. Elshaboury, "Setting time and 7-day strength of geopolymer mortar with various binders", Construction and Building Materials, 187 (2018)974–983.*
2. *M. Albitar, M.S. Mohamed Ali, P. Visintin, M. Drechsler, "Durability evaluation of geopolymer and conventional concretes", Construction and Building Materials, 136 (2017)374–385*
3. *Hafez E. Elyamany, Abd Elmoaty M. Abd Elmoaty, Ahmed M. Elshaboury, "Magnesium sulfate resistance of geopolymer mortar", Construction and Building Materials, 184 (2018)111–127*
4. *F F Zainal, S F M Amli, K Hussin, A Rahmat and M M A B Abdullah, "Corrosion Studies of Fly Ash and Fly Ash-Slag Based Geopolymer", Materials Science and Engineering, 209 (2017)012026*
5. *B. Sri Umniati, Puput Risdanareni, Fahmi Tarmizi Zulfikar Zein, "Workability Enhancement of Geopolymer Concrete through the use of retarder", AIP Conference Proceedings, 1887, 020033(2017)*
6. *Thangaraj Sathanandam, Paul O. Awoyera, Venkudusamy Vijayan, Karupannan Sathishkumar, "Low carbon building: Experimental insight on the use of fly ash and glass fibre for making geopolymer concrete", Sustainable Environment Research, 27 (2017)146e153*
7. *Dr. Kookutla Ramesh, "An experimental study on effect of aluminum oxide on strength and corrosion resistance of concrete", International Journal of Engineering Research & Technology, ISSN: 2278-0181,Vol. 3 Issue 11, November-2014*
8. *Adhitya Leonard Wijaya, Januarti Jaya Ekaputri, and Triwulan, "Factors influencing strength and setting time of fly ash based-geopolymer paste", MATEC Web of Conferences 138, 01010(2017)*
9. *Bo Wun, WeiXiong, BoWen, "Thermal fields of cracked concrete members in fire", Fire SafetyJournal, (2014)66,15–24*
10. *Ali A. Aliabdo, Abd Elmoaty, M. Abd Elmoaty, Mohahamed F. Mohamed, "Permeability indices and corrosion resistance of geopolymer and Portland cement concretes", Magazine of concrete research, (2018), Volume 70 Issue 12,pp.595-609*
11. *Amer Hassan, "Experimental study of fly Ash based geopolymer concrete", International Journal of Advanced Earth Science and Engineering ,(2018), Volume 7, Issue 1, pp.635-648*
12. *Geopolymer chemistry and application by JosephDavidovits*