DURABILITY STUDY OF GEOPOLYMER CONCRETE CURED AT AMBIENT TEMPERATURE

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ABSTRACT. Durability of concrete strongly influences the life and serviceability of structural member. This paper evaluates the performance of geopolymer concrete (GPC) casted by blending of Ground granulated blast furnace slag (GGBFS), Flyash (FA) and Silica Fume (SF). Normal GGBFS based GPC prepared as a reference for evaluating the durability characteristics of geopolymer concretes. All specimens were cured at ambient temperature and tested for acid attack and Sorptivity rate. All specimens were continuously immersed up to 28 days in acidic solution. Acid attack test resulted that Blending of two or more binders (i.e. GGBFS, FA and SF) reduced, acid resisting capacity of hardened mass. Compressive strength loss due to acid attack was observed up to 25.26% when specimen prepared with three different binders (i.e. GGBFS, FA and SF). However, specimen prepared with GGBFS as only binder resulted in 9.21% decrement in compressive strength. As far as sorptivity rate is concerned it is observed that specimen prepared with two or more binder resulted in less rate of water absorption, hence less sorptivity rate. This study shows that it could be viable to use GGBFS as a primary binding material to achieve enough durability.

Keywords: Geopolymer concrete, Ambient curing, Durability, Acid attack, Sorptivity.

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INTRODUCTION

In 1988 Davidovits [1-2] suggested that an alkaline liquid might be used to react with the base material of geological origin which should be rich in silicon (Si) and aluminum (Al) or in by product materials such as fly ash and rice husk ash to produce binders. Due to the chemical action that takes place in this case is a polymerization process, he gave the name of term "Geopolymer" to represent these binders. GPC is concrete which does not exploit any Portland cement in its production. GPC is being widely studied broadly and shows good promise as a substitute PCC. Research shifted from the chemistry aspect to engineering implementation and commercial production of GPC. There are two main constituents of geopolymer, viz. source materials and the alkaline liquids. The source materials for geopolymer based on alumina-silicate must be rich in silicon (Si) and aluminum (AI). These could be natural minerals such as red mud, kaolinite, clays, etc. Alternatively, waste materials such as silica fume, fly ash, rice-husk ash slag, could be used as base materials. The alkaline liquids are from soluble alkali metals that are mostly either sodium based or potassium based. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na_2SiO_3) or potassium silicate [3-4]. Since alkaline solution are being used to start geopolymerisation process it could also have called Alkali Activated Concrete (AAC). After the meticulous analysis of past research work it is observed that AAC need to cure at higher temperature (>65˚C) [5-9]. Past study supports that, this drawback shall be overcome by using GGBFS as a base material instead of Fly ash. However, utilization of GGBFS resulted in quick setting of concrete which may lead to development of cracks in it. This drawback shall be overcome by using Silica fume which may help to arrest the cracks at micro level [10-24]. Past study suggests that very few author have carried out durability test on hardened mass of Geopolymer concrete [25-26]. This study focuses on evaluating acid resisting capacity of Geopolymer concrete cured at ambient temperature as well as sorptivity rate of hardened mass.

MATERIAL USED

In this experimental work, blending of three binders (viz. Class F Flyash(FA), Groung granulated blast slag(GGBFS) and silica Fume(SF)) was used. The fly ash obtained from the vanakbori thermal power station, Gujarat, India. The chemical composition of class F fly ash is mentioned in table1. In the present experimental work, GGBFS was used as the base material since it is much preferred in Geopolymer application due to high content of calcium oxide which is also responsible for early strength gain. Chemical composition of GGBFS is mentioned in Table 1. In this experimental work, Silica fume was used as a partial replacement of GGBFS by mass. Silica fume helps to fill micro voids due to its finer particle which will increase packing density of the mass as well. The chemical composition of silica fume mentioned in following Table 1. Combination of sodium silicate (Na_2SiO_3) solution and sodium hydroxide (NaOH) solution was used as the alkaline binder. It is proposed that the alkaline binder need to be rendered by combining both of the solutions together at least one-day advance to use. The sodium silicate (Na_2SiO_3) solution A53 grade (Na_2O = 14.7%, SiO_2 = 29.4% and water = 55.9% by mass) and sodium hydroxide (NaOH) in the form of pellets was purchased from Sadguru Chemicals, Veraval, Rajkot. Locally available 10mm and 20mm course aggregates were used for this experimental study. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable depending on the local rock source and conditions, but the most common constituent of sand is silica (silicon dioxide SiO_2), usually in the form of quartz. ISO 14688 grades sands as fine, medium and coarse with ranges 0.063mm to 0.2mm to 2 mm. The naturally available river sand used as fine aggregate. The mix design for the material mentioned above is given in Table2

Table 1 Chemical Composition of Pozzolonic Binders

PARAMETERS	GGBS	FA	SF
SiO_2	34.01	63.53	88
Al_2O_3	16.62	27.4	0.6
Fe_2O_3	1.71	3.67	0.3
CaO	34.85	1.26	0.95
MgO	9.11	0.35	0.95
Na_2O	0.48	0.19	0.7
K_2O	0.46	0.85	0.7
TiO_2	0.69	-	-

Table 2 Mix Design kg per cubic meter

Mix Design	GGBS	FA	SF	Fine Aggregate	Course Aggregate	NaOH Solution	Na_2SiO_3 Solution	Molarity (M)
T0	368	-	-	554.4	1293.6	46	138	14M
T1	349.6	-	18.4	554.4	1293.6	46	138	14M
T2	331.2	-	36.8	554.4	1293.6	46	138	14M
T3	312.8	-	46.9	554.4	1293.6	46	138	14M
T4	220.8	110.4	36.8	554.4	1293.6	46	138	14M
T5	184	147.2	36.8	554.4	1293.6	46	138	14M

EXPERIMENTAL WORK

The alkaline liquid was prepared by combining sodium hydroxide and sodium silicate with a mass ratio 3.0, 24 hours preceding to use. The molarity of sodium hydroxide in term of molar was taken 14M. In the day of casting all the ingredients are mixed thoroughly by hand mixing. After mixing of ingredients fresh concrete paste then placed in a mould of size 15cm x 15cm x 15cm for compressive strength test and 100mm (diameter) x 50mm (height) cylinder specimen for sorptivity test. After placing the sample in mould, mould was vibrated in table vibrator in order to remove air bubbles and to prepare homogeneous mix. The test specimen was demoulded after 24 hours of casting and cured at ambient temperature (30˚ ± 2˚ C). Compressive strength test was performed at 7 days and 28 days. Each specimen was weighed and immersed in acidic solutions for 28 days. The acid solution was prepared by mixing 2.5% concentrated Sulphuric Acid (H_2SO_4) and 2.5% Hydrochloric Acid (Hcl) of weight of the water. The acid solution was replaced at every 7 days and pH was maintained as 3.0. The specimens then removed from acidic environment and brushed carefully in order to remove dust, debris and loosed mass. Mass was measured after 2 hours of drying period. Sorptivity test was conducted with specimen of size 100mm x 50mm as mentioned in ASTM

C1585-13. The side was coated to allow free water movement only through submerged side of the specimen

RESULT AND DISCUSSION

Compressive Strength Test:

The compressive strength of GGBS base geopolymer concrete is shown in figure 1. Each value of compressive strength represents average of compressive strength of 3 specimens.

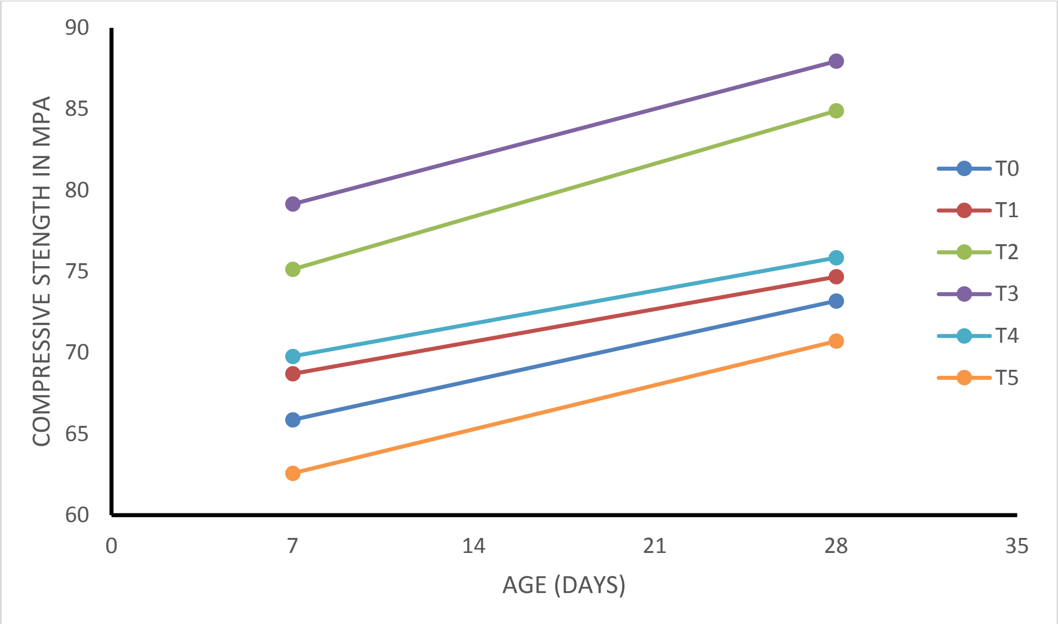

Figure 1 Compressive Strength Development of Geopolymer concrete

It can be seen from figure that, addition on Silica fume gives higher amount of compressive strength. However, blending of three different binder shows decrement in the compressive strength, however Mix design 4 (T4) shows compatible values of compressive strength which is a combination of GGBS, FA and SF. Past study supports that strength development after 28 days is very negligible [26], therefore test for 56 days and 90 days was not conducted for compressive strength.

Acid Attack Test (Resistance to attack by Sulphuric acid and Hydrochloric acid)

Compressive strength was measured after 90 days of acid curing and compressive strength at the age of 28 days of standard specimen was considered as a reference. The compressive strength of the acid cured sample is mentioned in the figure 2. It is noteworthy that addition on Silica fume increased acid resisting capacity of hardened mass. It can be seen from figure 2 that, incorporation of SF in geopolymer concrete provide greater resistance of acidic environment. However, blending of three different binders reduces the acid resistance capacity of hardened mass. Maximum 25% reduction in compressive strength was observed in case of blending of three different binders. Result suggest that incorporation of silica fume in GGBS based GPC made improvement in strength loss as compared to mix that of without silica fume, however incorporation flyash in GGBS based GPC significantly increased strength loss. Therefore, it is not viable to use blending of three different binders in an acidic environment. However Further study requires to set optimum amount of FA and SF in GGBS based Geopolymer concrete.

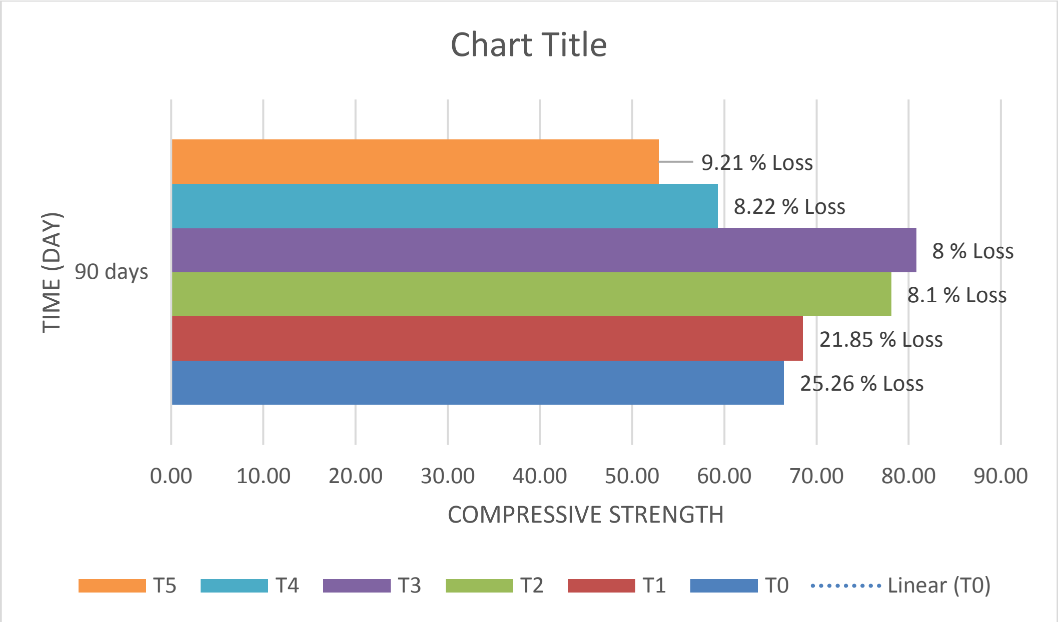

Figure 2 Change in compressive strength of Geopolymer concrete exposed to acidic environment

Sorptivity Test

Sorptivity test were conducted on Geopolymer concrete for the mix design mentioned in table 2. It can be seen from figure that sorptivity coefficient for GPC containing GGBS as only binder is 3.81 x 10^{-3} mm/$s^{0.5}$ and that of the mixes with SF was in range of 1.5 x 10^{-3} mm/$s^{0.5}$ to 1.29 x 10^{-3} mm/$s^{0.5}$. Thus it can be seen from result that incorporation Silica Fume in GGBS based GPC significantly reduced sorptivity rate. The reduction in sorptivity rate shows dense matrix which have less pore space. Moreover, as revealed by results incorporation of Flyash (FA) in GGBS based GPC further reduced sorptiviy rate, which indicates denser mass hence lesser pore space. There are two possible explanations for increment in strength first is, incorporation SF and FA in GGBS based GPC increases packing density which helps to reduce the pore structure. Second incorporation FA and SF reacts with alkaline solution resulted in more aluminosilicate gel.

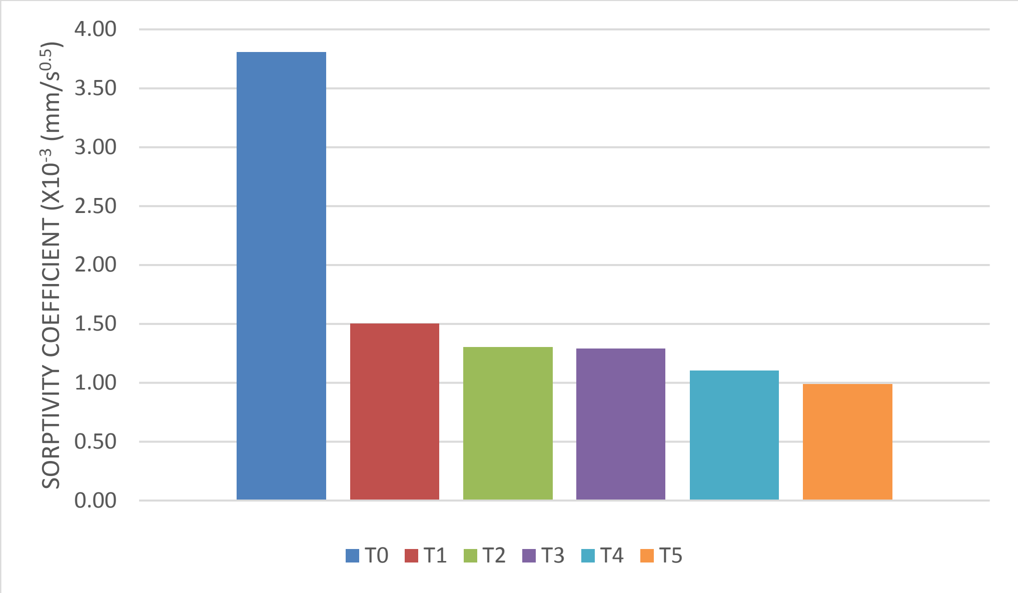

Figure 3 Sorptivity rate of Geopolymer concrete

CONCLUSION

Acid attack test and sorptivity rate test of Geopolymer concrete developed by blending of three binders viz. GGBS, FA and SF was conducted in this study. Based on the result following conclusion can be drawn.

- Incorporation of SF in GGBS based concrete resulted in better compressive strength. The compressive strength was increased from 65.87 MPa to 79.15 MPa of GGBS based GPC, when 15% of GGBS replaced by SF at age of 7 days cured under ambient temperature. Compressive strength reduced from 65.87MPa to 62.58MPa of GGBS based GPC, when 50% of GGBS replaced by 40% FA and 10% SF.
- Compressive strength increased from 65.87 Mpa to 69.78MPa of GGBS based GPC, when 40% of GGBS replaced by 30% FA and 10% SF.
- Result of Acid attack reveals that incorporation of FA in GGBS based concrete resulted in lesser resistance towards acidic environment. The strength loss was observed up to 25.26% in mix design 5 (T5), However incorporation of only SF in GGBS based GPC reveal improved acid resistance capacity.
- Sorptivity rate was reduced of the specimen which was casted by blending of two more binders than that of control specimen.

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