Performance of Geopolymer Concrete Mixes At Elevated Temperatures

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Abstract

Reducing the greenhouse gas emissions is the need of the hour. Five to eight percent of the world's man-made greenhouse gas emissions are from the Cement industry itself. It is an established fact that the green house gas emissions are reduced by 80% in Geopolymer concrete vis-a-vis the conventional Portland cement manufacturing, as it does not involve carbonate burns etc. Thus Geopolymer based Concrete is highly environment friendly and the same time it can be made a high-performance concrete. In the present study, fly ash, blast furnace slag and catalytic liquids have been used to prepare Geopolymer concrete mixes. This study is continued to investigate the behaviour of such Geopolymer concrete under high temperatures ranging from 100^0C to 500^0C. Cubes of size 100mm x 100mm x 100 mm are tested for their residual compressive strengths after subjecting them to these high temperatures.

Keywords - Fly ash, Blast Furnace Slag, Catalytic Liquid

INTRODUCTION

Portland cement has been a very satisfactory hydraulic binder for structural applications for a long time now; however, there are many new issues stemming from its ever increasing use. Cement production consumes huge quantities of virgin materials, is energy-intensive, and leads to high emission of the greenhouse gas ie., CO_2 (**Satish Chandra, 2002**). Again, Sulphur dioxide emission also can be very high, depending upon the type of fuel used. Installation of new cement plants is becoming increasingly capital-intensive. Finally, of late, many cement concrete structures have exhibited early distress and problems, which has an adverse effect on the resource productivity of the industry.

'Geopolymer Concrete' (GPC) is a type of inorganic polymer composite, which has recently emerged as a prospective binding material based on novel utilization of engineering materials. It has the potential to form a substantial element of an environmentally sustainable construction industry by replacing/supplementing the conventional concretes (**Duxson et al., 2007**). GPC can be designed as high strength concrete with good resistance to chloride penetration, acid attack. Sulphate attack,etc. The geo-polymeric concretes are commonly formed by alkali activation of industrial alumino silicate waste materials such as fly ash (FA) and ground granulated blast furnace slag (GGBS), and have very small footprints of greenhouse gases when compared to traditional concretes. Because of possible realization of even superior chemical and mechanical properties compared to Ordinary Portland cement (OPC) based concrete mixes, and higher cost effectiveness, GPC mixes based on FA and GGBS are being discussed for their potential application in concrete industry including structural concreting, precast panels and ready-mixes. In the present investigation, the strength-properties of GPC after exposure to elevated temperatures are studied and are compared with the published results pertaining to OPC mixes.

Conventional Concrete Exposed To Elevated Temperatures

Xu et al. (2003) have noted an increase upto 10% in the residual compressive strength when the test temperature was raised to 200°C. Within the temperature range is 400°C–600°C the decrease in residual compressive strength is more dramatic with values ranging from 97%-71% at 400°C then dropping upto 30% of the initial at temperatures of the order of 600°C. Within the temperature range 600°C–1000°C the residual compressive strength continues to drop to about 9-10%.

Yaragal et al., (2009) have established that when the concrete is exposed to elevated temperatures, loss in weight of specimen increases for temperatures above 200^0C. With increase in grade of concrete, there is an increase in the loss of weight of specimens due to exposure to elevated temperatures. In general there are substantial losses of upto 75% in strength, on heating the specimens from 100^0C to 800^0C, for grades M20, M25 and M30. For M35, M40 and M45, there are higher strength losses up to 80%.

Experimental Methodology

Materials:

In the present investigation, Class-F fly ash and blast furnace slag are used in equal proportion (50% each) as cementacious materials for the preparation of GPC mixes. A mixture of analytical grade Sodium hydroxide (97% purity) and Sodium silicate solution (Na_2O– 13.72%, SiO_2-34.16% and H_2O-47.2%) is used in the present investigation as the catalytic liquid. The use of a commercially available super-plasticizer has helped to improve the workability of concrete. OPC is not at all used in these mixes.

Mix Design:
Currently no standardized methods of mix design for geo-polymer concrete mixes are available. So mixes are essentially designed by trials as of now. Four trial mixes, whose performance had been found satisfactory in the form of both workability and strength points of view, were considered as candidate mixes herein. The details of such mixes are given in Table 1.The focus of the present study is to investigate the residual strength characteristics of GPC mixes, by observing deterioration in strength characteristics of GPC mixes when exposed to elevated temperatures. 100 mm cube specimens were cast using these geo-polymer concrete mixes, were de-moulded after 24-hours and then left for air-curing (the ambient temperatures are between 27^0-30^0C) till 28-days of age.

Table1. Details of Mix Proportions of GPC Mixes

Mix. ID.	GGBS (kg)	FA (kg)	Coarse Agg. >10mm (kg)	Fine Agg. (kg)	NaOH Flakes (kg)	Sodium silicate solution (kg)	Water (kg)	SP (kg)
GPC1	300	300	858	682	19.25	75	**186**	**6.60**
GPC2	233	233	786	786	15.0	58.3	**153.8**	**5.12**
GPC3	275	275	786	519	19.25	75	170	6.05
GPC4	250	250	786	786	16.0	62.5	**144.5**	**5.50**

***Exposure to GPC Mixes to Elevated Temperatures*:**
One set of three cube specimens is subjected to different elevated temperatures in the range of 100-500^0 C, in increments of 50^0 C, in a thermostat-controlled electric furnace. In each case, a retention period of 2-hours is maintained at the specified maximum temperature. After the 2-hours soaking period, the furnace is switched-off and the specimens are allowed to cool to room temperature without any thermal shock. The cubes are weighed (for noting down the percentage loss in their weights), before testing them for their residual compressive strengths. (The effect of exposure to any particular elevated temperatures in terms of reduction in the compressive strength of the mix, compared to strength of the same mix at room temperature is quantified in terms of a Residual Compressive Strength Coefficient)

DISCUSSIONS

Rheological properties of the fresh GPC are dependent on the type and the contents of the materials used in the mixture. As compared with the conventional Portland cement concrete mixes, GPC mixtures exhibit a different rheological behavior. Both static and dynamic viscosities of GPC are found to be, generally, substantially higher. Due to this high viscosity and cohesiveness, though the mixes were comfortable to work with, very low slumps were recorded which in turn demanded longer vibration. . Again the initial setting time and final setting times of all GPC mixes used in the study are found to be more than 30 minutes and within 600 minutes, respectively.

Weight Loss Observations:
No significant distortions were observed in any of the specimens of the four representative mixes, in size and shape, due to exposures to elevated temperatures upto 500^0C. Average percentage losses in weight of geo-polymer concrete cubes, after exposure to various elevated temperatures are shown in the figure1. From the figure1, it can be observed that, the weight losses in GPC specimens are gradually increasing for all mixes, with increase in temperatures upto 500^0C and the considerably more weight losing start from 250^0C onwards.

Residual Compressive Strength:
The geopolymer concrete gains about 60-70% of the total compressive strength within 7 days. The behaviour of residual compressive strength of geo-polymer concrete cubes after exposure to various elevated temperatures is depicted in figure 2 and figure 3 From these figures, it can be observed that, the residual coefficient of compressive strength of 7 days and 28 days cubes exposed to 200^0C is slightly higher than that of cubes tested at normal room temperature and while further increment of temperature there is loss in compressive strength gradually

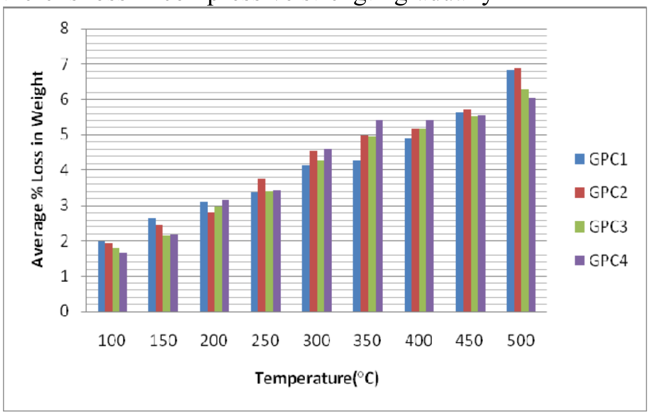

Fig.1. Variation of percentage weight loss for various elevated temperatures

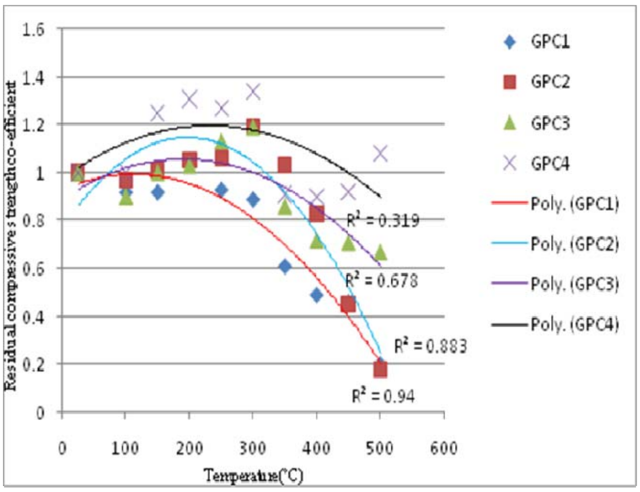

Fig.2. Varation of residual coefficient for compressive strength v/s temperatures (7 Days)

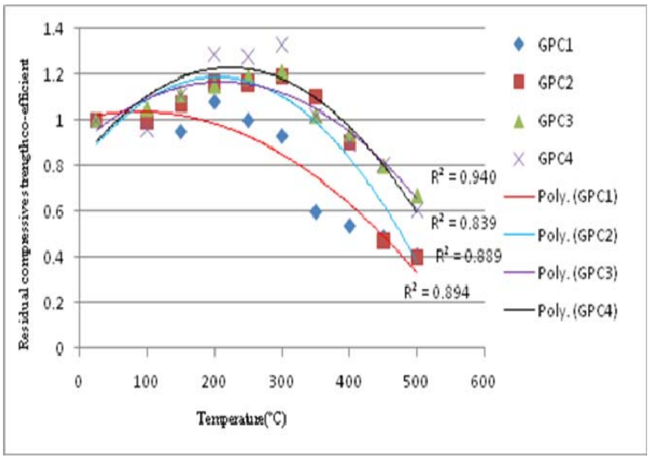

Fig.3. Variation of residual coefficient for compressive strength v/s temperatures (28 Days)

CONCLUSIONS

A mixture of fly ash and ground granulated blast furnace slag in equal proportions, is used as binding/cementacious material in complete replacement of conventional Portland cement to prepare geopolymer concrete mixes. The parameter studied includes compressive strength and weight loss after expose to elevated temperature. Further, it is also established that high temperature curing is not required in all cases of GPC, as sunlight curing (avarge temperature of± 30^0C), can used at least in tropical countries for Geopolymer concrete mixes.

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