Experimental Investigation of hardened Geopolymer aggregates as partial and full replacement of River Sand in Mortar Cube

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ABSTRACT - This paper presents the experimental investigation report on hardened geopolymer paste and an attempt was proposed to use the grounded pieces of hardened geopolymer paste as partial and full replacement of River sand as Fine aggregate in cement mortar. Geopolymer is an emerging type of cementations material purported to provide an environmentally friendly when comparing with cement-based concrete. This paper reports the results of experimental research on compressive strength and deformation (shape factor) of fly ash based geopolymer paste cubes noticed after removing from mould. Also a comparative study was made in between the cement paste cubes and fly ash based geopolymer paste cubes of various mix proportions.

Key words: Hardened Geopolymer paste , Grounded Fine aggregate , user friendly method of curing.

I. INTRODUCTION

Introduction

This trend was found to be consistent between geopolymer paste cubes and cement cubes, implying that the difference between geopolymer and cement paste is due to the type of matrix formation (geopolymerisation or hydration). For geopolymer, pastes made with different mix parameters and the compressive strengths were found. Geopolymers are environment friendly cementitious materials that can be manufactured by using fly ash in combination with sodium silicate and sodium hydroxide solution (Hardjito and Rangan, 2005).After heat curing at 60°C for 24 h, they have been shown to possess optimum mechanical properties (Fernandez-Jimenez et al., 2006; Rangan et al., 2006). Initial studies of reinforced geopolymer concrete structural members showed that the load-carrying capacity of test members is similar to that of ordinary Portland cement (OPC) concrete (Sarker, 2009). Geopolymer concrete is thus believed to be suitable for structural applications. With regard to safety assessment and design of structures, it has been recognisedthat the fracture properties of geopolymerneed to be considered in structural design (Hilsdorf and Brameshuber, 1991). It is, therefore, necessary to evaluate the hardness and compressive strength properties of geopolymer pastes if the safety of structures built with such materials are to be assured. Already, the fracture properties of geopolymer paste cubes have received little attention, although their mechanical properties (Fernandez-Jimenez et al., 2006; Hardjito and Rangan, 2005) and structural behaviour (Sarker, 2009) have been studied to a certain degree.Also, an attempt was proposed to use the mechanically grounded, sieved particles of hardened geopolymer paste as partial and full replacement of fine aggregate in cement based concrete.Earlier lot of studies is in progress to use the following materials as substitutes to River Sand Manufactured Sand(M Sand), Processed Quarry Dust ,Processed Crushed Rock Fines (CRF),– Offshore Sand,Dune Sand,– Washed Soil (Filtered Sand),FlyAsh/BottomAsh/Pond Ash, Slag Sand ,Copper Slag Sand, Construction Demolition Waste,Powdered Glass , Aluminum, saw mill waste, Granite Fines/Slurry and Many More. In this paper it is proposed to use fly ash based hardened geopolymer paste pieces as fine aggregate in mortar by investigating the compressive strength properties with a comparison of same aged cement paste. The effect of the composition of the alkaline liquid decides the compressive strength of geopolymerpaste. A similar test trend was also reported earlier by Hardjito and Rangan (2005). The presence of soluble silicate species leads to fast strength development due to an increase in the extent of dissolution of aluminium and silica in the fly ash and hence enhanced geopolymerisation (Palomo et al., 1999). The effect of soluble silicate content on the compressive strength of geopolymer has been comprehensively investigated and well explained in the literature (Duxson et al., 2007). Also, Struble et al. (1989) investigated

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microstructural aspects of the fracture of hardened cement paste using scanning electron microscopy (SEM). They found that cracks pass around unhydrated cement grains rather than passing through them. This provides experimental evidence to support the claim by Baldie (1985) that unhydrated cement grains behave as strong inclusions in hardened cement paste. When a crack is forced to grow around a particle, high energy is required for crack propagation in the tortuous path created by the particle's angularity. This is generally the case in OPC concrete, where concrete made with crushed river gravel was found to have a higher fracture energy than concrete made with round river gravel (Nallathambi et al., 1984).

II. OBJECTIVE OF THE RESEARCH

To find an alternative material for the Ordinary Portland Cement.

To find an alternative material for the River Sand.

To reduce CO_2 emission and produce eco-friendly concrete. To make a cost efficient product for construction industry and save the Environment.

III. SCOPE OF THE RESEARCH

To study the efficiency of flyash based geopolymer concrete using geopolymer waste as Sand by ambient temperature. To study the effective utilization of these waste materials in the construction industries.

IV. ABOUT GEOPOLYMER CONCRETE

General properties of Geopolymer concrete:

In general the normal consistency and setting times are determined for fly ash, using Vicat‘s apparatus. Normal consistency conducted is similar as we determined for cement normal consistency. Here alkaline solution is used instead of water.

A. Properties of Geopolymer Concrete

GPC, Curing is done in ambient temperature, Nontoxic, bleed free.GPC’s having low drying shrinkage, low creep and good resistance against acid and sulphate attacks.GPC’s durability property of Geo-polymer concrete is higher than the nominal concrete mix. GPC’s geopolymer concrete reduced Co_2 emissions of geopolymer cement make them a good alternative to Ordinary Portland Cement. GPC’s geopolymer concrete has excellent properties within both acid and salt environments.

B. USES OF GEOPOLYMER CONCRETE

GPC reduces permeability and gives high life span.GPC is stronger, more resistant to chemicals and corrosion. GPC it has abundant raw materials resources. GPC Eco-friendly to environment and energy saving. Fire resistance , Insulated panels and walls, Foamed Geo-polymer panels for thermal insulation, Energy low ceramic tiles, Precast concrete products like railways, sleepers, electrical power poles, Protective coating.

V. EXPERIMENTAL INVESTIGATION AND METHODOLOGY OF GPC TEST

The following Methodology is followed in the Research work:

Ingredients of concrete such as fine aggregate, coarse aggregate and water. Collection of raw materials such as fly ash, alkaline liquids. Preparation of specimens for testing. Conduct of tests on prepared specimen. Study and analysis. Results and discussions

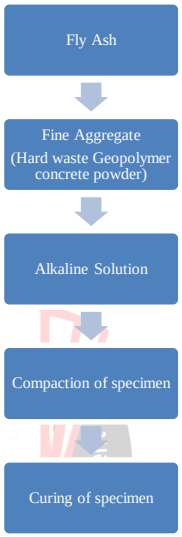

Figure 1: Process of Geopolymer Concrete

VI. EXPERIMENTAL INVESTIGATION

The alkaline liquid used in geopolymer consisted of a mixture of commercially available Sodium Hydroxide flakes and Sodium Silicate Powder. The sodium hydroxide solution was prepared by dissolving the Sodium Hydroxide (NaOH) pellets (98% purity) in water with various molarities. Sodium Silicate solution was prepared with water having 2 molar. While mixing Sodium Hydroxide solution, a considerable amount of heat was noticed. Both alkaline solutions were prepared and mixed together after 4 hours. The paste mixing was done after 6 hours. Specimen preparation and curing regime. Three sets of geopolymer paste cubes were prepared having three cubes in each set. And three numbers of cement paste cubes were casted for this investigation. The mix proportions are posted in Table 1.

Table 1: Mix proportions

Sl. No.	Description	Molarity of Sodium Hydroxide	Molarity of Sodium Silicate	Ratio of activator solution	Ratio of activator with Fly ash	Sample size
1	8M – 1	8	2	1:2	0.6	

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2	8M – 2	8	2	1:2	0.6	70.6x70.6x70.6 mm
3	8M – 3	8	2	1:2	0.6	
4	10 M – 1	10	2	1:2	0.6	
5	10 M – 2	10	2	1:2	0.6	
6	10 M – 3	10	2	1:2	0.6	
7	12 M – 1	12	2	1:2	0.6	
8	12 M – 2	12	2	1:2	0.6	
9	12 M – 3	12	2	1:2	0.6	
10	16 M – 1	16	2	1:2	0.6	
11	16 M – 2	16	2	1:2	0.6	
12	16 M – 3	16	2	1:2	0.6	

For casting geopolymer paste and cement paste similar procedure was used. The mixture was poured into cube moulds of size 70.6 x 70.6 x 70.6 mm. The paste was casted in the mould in three uniform layers and each layer was tamped 25 times with tamping rod. Curing of geopolymer paste cube sand cement paste cubes was done in different ways. The geopolymer paste cube specimens were kept in the moulds and placed in sunlight for heat curing for 7 days. While the cement paste cube specimens were kept in room temperature for 24 hours and removed from moulds and transferred to a tank of clean water for 6 days, ie up to 7th day from casting. Both the specimens were tested on 7thday.

VII. RESULTS AND DISCUSSION

A.Compressive Strength

The compression tests were performed on 7th day using 70.6 × 70.6 x 70.6mm geopolymer paste cubes in accordance with IS10080 – 1982 clause 3.4.The compressive strength values of each mix are summarized in Table 2.

Table 2: Compressive strength in M Pa. at 7 days strength

Sl. No.	Description	Compressive strength in M Pa.
1	8M – 1	20
2	8M – 2	17
3	8M – 3	15
4	10 M – 1	21
5	10 M – 2	19
6	10 M – 3	18
7	12 M – 1	21
8	12 M – 2	18
9	12 M – 3	17
10	16 M – 1	22
11	16 M – 2	19
12	16 M – 3	18

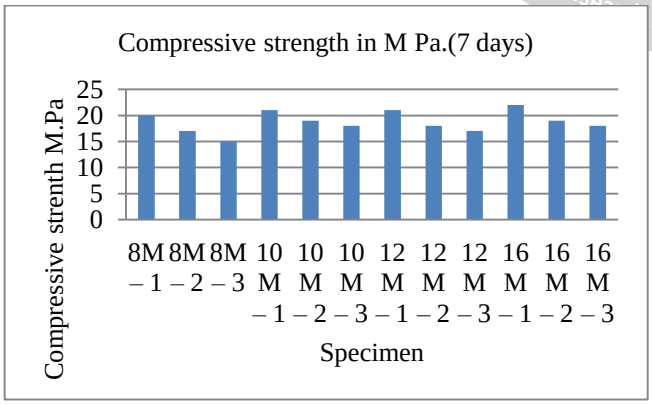

Figure 2 : Compressive strength in M Pa. at 7 days strength

In a geopolymer paste, unreacted ash particles are also found to be embedded in the binder, and show a range of degree of bonding to the gel (Lloyd et al., 2009). The morphology of fly ash is different to that of cement. It is thereby hypothesised that the morphology of the raw material might be the reason for the different GF values of the geopolymer and OPC pastes. In the matrix, a crack will deviate from a path of less energy in order to bypass a tough un-hydrated particle. Crack propagation in a geopolymer is likely to be less tortuous and therefore consumes less energy when compared with that in OPC paste. If all the differences in properties of the geopolymer and cement based are compared together (as was done for the pastes), the difference in brittleness between the two materials is obvious. From a chemical point of view, the intrinsic brittleness of geopolymer-based materials might be due to their highly cross-linked framework (Davidovits, 1991). In general, highly cross-linked materials are brittle in nature. In the current investigation, geopolymer paste cubes were prepared using alkali liquids with different soluble silicate contents. The similar compressive strengths of the geopolymer paste cubes can be developed by adjusting the curing regimes. The test results show that geopolymer paste cube with a similar compressive strength level also exhibit a similar characteristic. This indicates that the brittleness of geopolymer concretes is primarily related to the compressive strength rather than the other parameters investigated in this study.

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Figure 3: Specimen after testing

VIII. CONCLUSION

Based on the experimental work on Geopolymer paste and cement paste reported here, the following are drawn.

(a) After removal of specimen from mould, it undergoes change in shape and dimensions as shown in Figure 1. For conducting compressive strength test, the specimens were shaped to a defined shape and dimension.

(b) The property of self healing was noticed in the specimen the one which was cut in to two pieces and kept in its original position for 6 hrs. There is no trace of joints in cracked section as shown below:

(c) Eventhough the specimen no 11 and 12 is having compressive strength of 19 MPa and 18 MPa , the broken particles have been utilized for making a cement mortar cube to check its compressive strength with full replacement of river sand.

(e) From the experiments its observed that user-friendly Geopolymer concrete can be used for ordinary Portland cement concrete which under condition. The early strength results at 7 days shows that Geopolymer Concrete can be effectively used in the precast concrete construction industries it is possible to made short duration of time. The strength of the GPC cube has higher than the normal mix.

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