Investigation of Geopolymers prepared using Fly ash and GGBFS

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Abstract

The aim of this work was to investigate the effect of synthesis parameters on compressive strength of Geopolymer synthesized under ambient environmental condition. In the current study, fly ash (FA) and ground granulated blast furnace slag (GGBFS) blended with Geopolymer composite activated with sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) was investigated. The dissolution of alumino-silicates from the waste materials under different alkali condition is studied. The compressive strength of geopolymer blended with fly ash and slag is synthesized under different condition has been investigated. Present work has been investigated to compressive strength of geopolymer composite at different % of mixes (FA+GGBFS) with alkaline activator solution. Compressive strength of geopolymer composite checked on the 7 days, 28 days, and 56 days.

Keywords: *Fly ash; Ground granulated blast furnace slag; Geo-polymer; Geo-polymer paste.*

Introduction

Geopolymers are, inorganic, ceramic, materials that form long-range, covalently bonded, non-crystalline (amorphous) networks, rich in alumina and silica, are made under relatively ambient conditions of temperature and pressure. They are rigid gels, and subsequently can be converted to crystalline or glass-ceramic materials. They are the inorganic polymers having low thickness, small scale/nano-porosity, insignificant shrinkage, high mechanical quality, eminent surface hardness, warm solidness, flame, and concoction resistance, also, are of ease having low vitality utilization and least ozone-harming substance discharge (about 80-90% less contrasted with bond) amid synthesis [1].

Geopolymer cement is a mixture of an alumina-silicate with an activating solution and additional water for increasing workability. The most common activating solution is a mixture of sodium silicate, sodium hydroxide, and water.Geopolymer, ascribed to the formless to semi-crystalline tri-dimensional aluminosilicates that could be shaped at low temperature and brief time by a soluble base response with normally happening aluminosilicates strong materials.

Commercially produced geopolymers have various applications and are being used as fire and heat resistant coatings, adhesives, medicinal applications, high-temperature ceramics, binders for fire-resistant fiber composites, toxic and radioactive waste encapsulation and new cements for concrete. As, geopolymers have attracted many researchers worldwide especially in developing countries, for their potential as an alternative to ordinary Portland cement (OPC), due to its higher strength as well as its superior durability properties in addition to being eco-friendly.

Fly fiery remains, silica seethe, slag, rice husk cinder, and so on are instances of silica-alumina rich materials, which are by-products of various businesses. Utilizing by-products materials from different ventures help to limit the ecological issues, which were due to the dumping issues.Moreover, most of the research has done taken into account with manufacturing processes and synthesizing parameters of geopolymers. Recently, fly-ash, waste from the power sector, is gaining more attraction to be used in producing geopolymers. In the present work has been made to improve the properties of fly ash based geopolymer composite by adding grounded granulated blast furnace slag in different percentages.

'Geopolymerization' prepares Geopolymers, which is a complex multiphase exothermic process involving a series of independent and simultaneous steps consisting of dissolution-reorientation-solidification reactions analogous to zeolite synthesis. Geopolymer composite consists of two main components: material rich in silica and alumina, and alkaline activators. The mechanism of geopolymers are not clear, due to the complexity of various factors affecting geopolymerization during synthesis.The main raw materials for geopolymer synthesis, which have normally been used in research studies, can be classified in three major categories, namely industrial wastes (IW), general wastes and recycles materials (GW), and natural materials (NM).

The properties of geopolymers depend on a number of factors including the chemical composition of base material, composition of activator solution and ambient room temperature conditions.The applications of geopolymer composites have been tested in different field worldwide. Some products have already reached industrial applications, such as a new class of special and blended cements, building products, advanced mineral binders, temperature resistant resins and ceramic composites. Applications of geopolymeric materials are determined by their chemical structure in terms of Si:Al atomic ratio in the polysialate.

Various aluminosilicate materials (such as metakaolin fly ash, GGBFS, silica fume), had been used by researchers as base material to make geopolymer. The main purpose of this work is to analyze the effect of synthesis parameters on compressive strength of geopolymer composites.In present study, only fly ash along with GGBFS and alkaline activators such as sodium silicate and sodium hydroxide were used and investigation on synthesis parameters on compressive strength of geopolymers composite has been dealt, as thorough study on its compressive strength is very much essential.

Material and Methods

Fly ash considered as a waste, generated from Thermal Power Plants, produced by combustion of pulverized coal. Fly ash, of low calcium class-F, collected from National Thermal Power Corporation (NTPC) Tanda UP, India was used as the solid alumina-silicate material for preparation of fly-ash based geopolymer by mixing ground granulated blast furnace slag (GGBFS). GGBFS was obtained from Own Dust India, Kolkata.

The details of Fly-ash and GGBFS physical properties and chemical composition are as shown in Table 1 and 2, respectively. Based on the CaO content, fly ash is classified into two types: class-C (high CaO content) and class F type (low CaO content). The desired quantity of fly-ash was collected from thermal power plant. Then, mixed thoroughly to ensure its homogeneity and packed in air-tight zipper polybags for experimental purpose.GGBFS is obtained by quenching molten iron slag obtained from a blast furnace using water or steam. After quenching, granules of size less than 5mm diameter are obtained. The main constituents of blast furnace slag are CaO, SiO_2, Al_2O_3 and MgO, present in most of the cementitious materials. The granules are further dried and ground in a rotating ball mill to form a fine powder, known as ground granulated blast furnace slag cement.A mixture of sodium hydroxide pellets and sodium silicate solution along with water was prepared as alkaline activating solution to manufacture geopolymer composites.

Table 1 Physical properties of source materials fly ash

Physical properties	Fly ash	GGBFS
Color	Grey	Off White powder
Shape	Spherical	Angular
Avg. particle size (μm)	2.43	3.71
Specific gravity	2.3	2.94
Surface area (m^2/g)	28.07	22.73

Table 2 Chemical composition of source materials fly ash

Components	MgO	Al_2O_3	SiO_2	K_2O	CaO	Fe_2O_3	Na_2O	MnO	LOI
FA (%)	0.54	28.50	57.41	1.26	2.14	5.45	0.60	0.43	1.54
GGBFS (%)	9.70	18.00	31.00	1.04	37.2	0.60	0.09	0.14	1.81

Silica to alumina ratio (SiO_2:Al_2O_3) of the fly ash was ~2.0. As it can be seen from data presented in Table 2, major quantity (91.35%) of fly ash comprises of SiO_2, Al_2O_3 and Fe_2O_3. Calcium oxide (CaO) content was less than 10%, therefore, as per ASTM C618-03, it can be classified as low Ca fly ash (typically class-F). Based on IS:3812 (Part I)-2003, this is classified as siliceous pulverized fuel ash. The fly ash showed a dark grey colour.

For present study, commercially available NaOH flakes with 98% purity were used for the production of alkaline activator solution. In this study the ratio of sodium silicate and sodium hydroxide solution and the ratio of the alkaline activator solution to binder (FA+GGBFS) were conducted different ratio as 6, 7 and 8 % by weight of mix proportion (FA+GGBFS).

Ratio of activator solution respected to Fly ash + GGBFS:

Alkali content (% Na_2O) - 6, 7, and 8 % with respect of SiO_2

Silica content (% SiO_2) - 6 to 8 %.

Water ratio - 0.33

Fly ash to GGBFS ratio - 90:10, 80:20, 70:30, 60:40, 50:50 by weight of mixes.

The mixing and curing procedure following steps describe the manufacturing processes of geopolymer composites.

- Preparation of alkaline activator solution by mixing sodium hydroxide pellets, sodium silicate solution and water in required quantities to obtain desired alkali and silica content along with predetermined water to fly ash and GGBFS ratio, at least one day prior to its use for manufacturing of geopolymer paste.
- Mixing fly ash and GGBFS with activator solution in a Hobart mixer for 5 to 10 minutes to get homogenous slurry.

- Transferring the geopolymer mix (paste) into plastic moulds of 50x50x50 mm cubes and vibrating it for 3-4 minutes on vibrating table to remove any entrapped air.
- Rest period of 24 hours is given before remoulds the geopolymer specimens.
- Storing the geopolymer specimens at a dry place in ambient room temperature until testing.

Figure 3. Geopolymer Specimen prepared using 50*50*50 mm plastic moulds

Relevant Indian standard codes of practice have been followed for the tests. However, some tests were also performed based on the ASTM standard specifications. For the microstructural characterization, scanning electron microscopy (SEM) tests were conducted. X-ray diffraction (XRD) analysis has been used to study the mineralogy of the geopolymer composites.

Results and Discussion

A experimental investigation has been carried out to understand the performance of low calcium fly ash based geopolymer composites when exposed to different percentage of GGBFS are mixes with fly ash and alkaline solution.

Compressive strength of geopolymer composite

The improve profile of compressive strength of geopolymer paste with different percentage of GGBFS at 7 days, 28 days and 56 days are shown in Figure 4.1 to 4.18 respectively. Highest compressive strength of geopolymer paste at 7 days, 28 days and 56 days were observed as 42 MPa, 47.20 MPa and 56 MPa respectively for the mix with alkali solution Na_2O at (6-8) and 50% GGBFS. And other compressive strength has shown in below figure 4.1 to 4.18. Compressive strength with respect of GGBFS and alkaline concentrations (Na_2O:SiO_2)

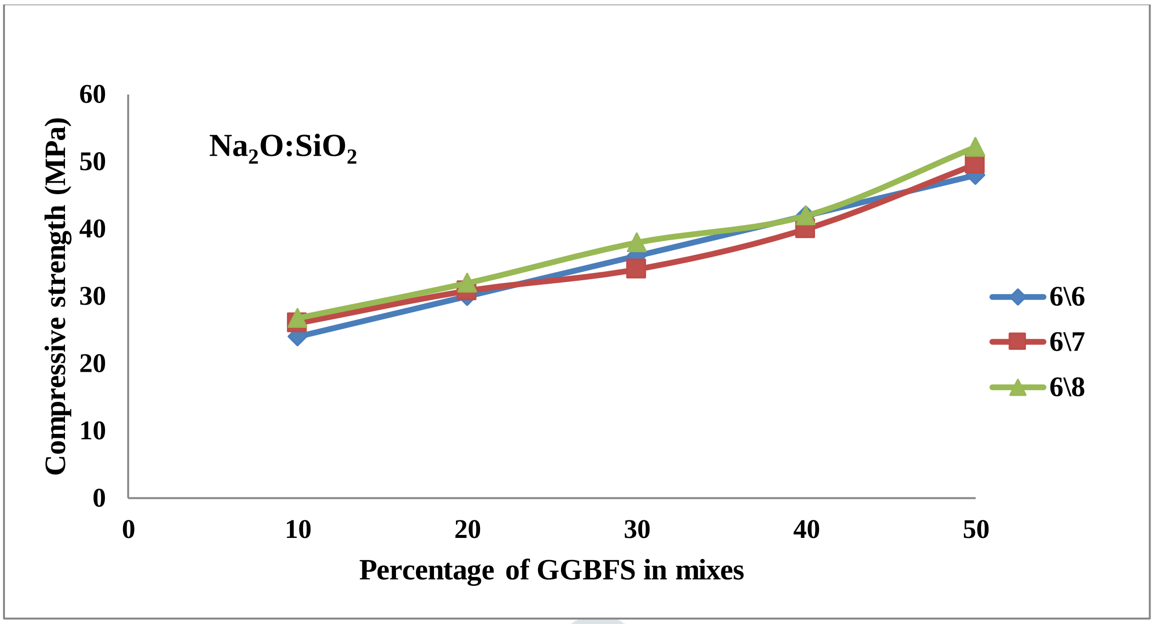

Fig 5 Effect on Compressive strength with variation in Na_2O and SiO_2

From data presented in Figure, it can be seen that with increase in ratio of Na_2O at constant SiO_2 and GGBFS content, the compressive strength has been increased. For 7 days, increase in compressive strength is significant in comparison to change in compressive strength at 28 days and 56 days. With increase in Na_2O from 6% to 8% at constant SiO_2 (6%) and GGBFS, the compressive strength has increased from 35.8 to 39MPa, which is approximate 9% increment in strength after 7 days. With change in Na_2O from 6 to 8% at high SiO_2 (8%), the change in compressive strength is from 38 to 42MPa which is approximate 10.50%.

With increase in SiO_2 from 6 to 8% and low Na_2O (6%), the compressive strength increased from 35.8 to 38MPa, which is approximate 6.15%, whereas at high Na2O (8%), the variation in compressive strength is from 39 to 42MPa, which is approximate 7.7%.

Conclusions

In this paper, experimental investigation to determine the properties of fly ash based geopolymer paste with the incorporation of GGBFS at various percentage levels and produced with different concentration of sodium hydroxide solution are presented and discussed. Higher compressive strength of geopolymer paste was obtained with the increase of the percentage level of incorporation of GGBFS. Highest compressive strength of geopolymer paste was observed as 56 MPa for the paste mix with 16M sodium hydroxide solution and 50% GGBFS. Higher dosage of GGBFS in geopolymer paste mixes helps to form denser structure to gain higher strength. Using fly ash (a by-product of thermal power station) and GGBFS (a by-product iron and steel making industries) to produce geopolymer will help to control the usage of OPC, reduce the dumping problems of these by-product materials, and reduce environmental degradation problems etc.

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