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Compressive strength of rice husk ash based geopolymer: The effect of alkaline activator

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ABSTRACT

In this paper, the effect of alkali activator to binder (AAB) ratio and molarity of alkaline activator on the rice husk ash based geopolymer were investigated. Compressive strength has been determined on 70.6 × 70.6 × 70.6 mm specimens by varying AAB ratio from 0.5 to 0.7 and molarity of alkali activator solution from 12 M to 16 M. The microstructure was also examined using scanning electron microscope (SEM). Experimental results revealed that the maximum compressive strength is obtained up to 39.95 N/mm^2 after 28 days. It has been observed that compressive strength is directly proportional to both AAB ratio and molarity of alkali activator solution. With increasing the molarity, microstructure become quite dense, this may be attributed to high degree of geopolymerisation.

1. Introduction

Manufacturing of every tonne of cement requires tremendous amount of energy for roasting 2.8 tonne raw materials that send nearly a tonne of carbon-dioxide skywards. Consequently, one of the challenging issue is hazardous impact on environment due to manufacture of cement. In order to address this problem, geopolymer has been identified as alternative material to earn carbon credit and save energy. The term geopolymer introduced by Davidovits in 1978, has potential to compete with cement. Geopolymer is an inorganic polymer synthesized by activating aluminosilicates with alkaline activator. The alkaline solution such as NaOH and KOH and several wastes or by-products such as metallurgical slags, coal combustion ashes and various waste which are rich in Al and Si can be utilized for synthesization of geopolymer [1]. The geopolymerisation mechanism is not described by normal hydration and pozzolanic reaction that functions in cement. It involves the formation of 3D cross linked structures by dissolution of Si and Al in alkaline solution, orientation of dissolved species and polycondensation [2]. The basic forms of alumino-silicate structures are of three types as Poly(sialate) (–Si–O–Al–O–), Poly (sialate–siloxo) (Si–O–Al–O–Si–O) and Poly(sialate–disiloxo) (Si–O–Al–O–Si–O–Si–O). The composition of geopolymer is generally written as $nM_2O{\cdot}Al_2O_3{\cdot}xSiO_2{\cdot}yH_2O$, where M represents an alkali metal and n, x and y are repeating units [3].

Geopolymer has almost similar properties to ordinary cement with reference to strength, hardness and chemical stability. It provides excellent resistance to fire and to acid attacks [4]. It has low creep, low shrinkage and early setting time without the loss of compressive strength [5]. Geopolymer has also good potential for development of green and environmental friendly material by utilizing environment polluting by-products. It can be utilized as environmentally friendly stabilized pavement material due to its numerous benefits [6].

Rice husk, an agriculture by-product obtained by processing of rice paddy is generally 20% of the weight of rice paddy [7]. During burning of rice husk, 25% weight of this husk is converted into ash and termed as rice husk ash (RHA) [8]. RHA consisting 90–95% silica content is used as alternative cementitious binder in place of conventional cementitious binder [9]. The type, composition, reactivity of raw material and dosage of alkali activator plays a major role in the process of preparing and controlling the properties of the geopolymer. Hence, present study aims to investigate the effect of AAB ratio and molarity on manufacturing of RHA based geopolymer.

2. Geopolymer preparation

2.1. Material used

Rice husk ash, sodium hydroxide and sand were used as raw materials. RHA (Fig. 1) was obtained from the industry where rice husk alone was burnt as a source of energy and passed through the

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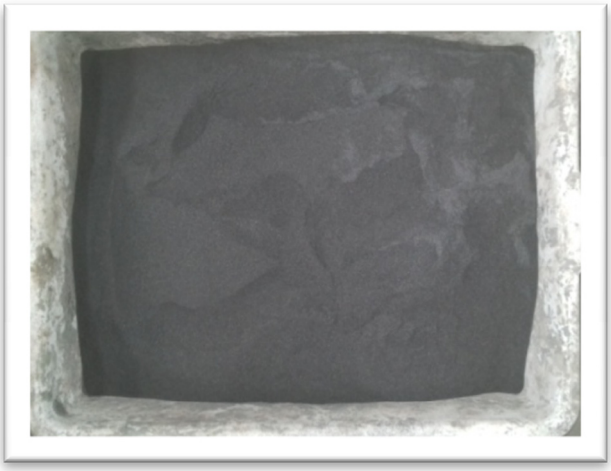

Fig. 1. Rice husk ash.

Fig. 2. NaOH pellets.

90 μm sieve. Sodium hydroxide (NaOH with 98% purity) flake form used as alkaline activator collected from local supplier as shown in Fig. 2. River sand passing through the 2 mm sieve and retained on 90 μm was used as fine aggregate.

The X-ray diffraction pattern of RHA used is shown in Fig. 4. The X-ray diffraction investigation reveals that main constituent was SiO_2 in the form of quartz and cristobalite. The major peaks of quartz and cristobalite was seen on 2θ scale.

The major peaks of quartz were observed at 20.75° and 26.8° and other major peaks of cristobalite were observed at 21.7°, 28.9°, 31.2° and 36°. The RHA found in amorphous form. The composition of RHA depends upon the temperature used for burning and method adopted for burning.

Fig. 3. Alkaline activator solution.

The geopolymer mortar was synthesized with variation of 50%, 60% and 70% alkaline activator relative to the content of RHA. One litre of sodium hydroxide solution of molarity 12 M, 14 M and 16 M was prepared by dissolving 480 g, 560 g and 640 g NaOH pellets in water, respectively. The sodium hydroxide solution was prepared 24 h prior to use as shown in Fig. 3. The ratio of RHA to sand and water to binder ratio was fixed at 1:3 and 0.35 respectively. The mix proportions of samples are given in Table 1.

2.2. Preparation of specimen

At first, RHA and alkaline activator were hand mixed for 15 min until the mixture become homogenous as shown in Fig. 5. After this, content of sand and appropriate amount of water was added, mixed thoroughly as shown in Fig. 6. The mixture was cast in mould to prepare specimens of 70.6 × 70.6 × 70.6 mm to determine the compressive strength as depicted in Fig. 7. The compressive strength was determined at the ages of 3 days, 7 days, 14 days and 28 days. The geopolymer mortar specimens were cured at 80 °C temperature for 24 h in the oven after casting. Then, all specimens were demoulded after the thermal curing of 24 h and were kept at ambient curing until testing.

3. Compressive strength and microscopic investigation

The compressive strength was determined by using Universal Testing Machine (UTM) as shown in Fig. 8. The specimen was kept between the compressive plates and gradually load was applied till

Table 1
Mix proportion of samples.

Sample	Molarity	RHA (g)	Sand (g)	AAB ratio	NaOH solution (g)	Solids in NaOH solution (g)	Extra water (g)
K1	12 M	200	600	0.60	120	43.20	22.27
K2	14 M	200	600	0.50	100	40.40	39.14
K3	14 M	200	600	0.60	120	48.48	28.17
K4	14 M	200	600	0.70	140	56.56	17.20
K5	16 M	200	600	0.60	120	53.28	33.54