Construction and Building Materials 123 (2016) 581–593

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Effect of cement addition, solution resting time and curing characteristics on fly ash based geopolymer concrete performance

Ali A. Aliabdo [a], Abd Elmoaty M. Abd Elmoaty [a], Hazem A. Salem [b,*]

[a] Structural Engineering Department, Faculty of Engineering, Alexandria University, Egypt
[b] Faculty of Engineering, Alexandria University, Egypt

HIGHLIGHTS

- Portland cement addition, fly ash content and solution resting time were studied.
- The study focused on curing temperature and curing period.
- Performance and mechanical properties of GPC were evaluated for all factors.
- Portland cement addition up to 15% improves GPC properties except workability.
- Solution resting time for 30 min yields higher performance.

ARTICLE INFO

Article history:
Received 26 March 2016
Received in revised form 21 June 2016
Accepted 15 July 2016

Keywords:
Geopolymer concrete (GPC)
Fly ash
Portland cement
Solution resting time
Curing period
Curing temperature
Alkaline solution
TGA

ABSTRACT

Fly ash based geopolymer concrete (GPC) is an environmentally friendly concrete made from alkali activated aluminosilicate and aggregate. Generally, geopolymer concrete needs several approaches before and after casting which limits its applications. Development of geopolymer concrete became a necessity to widen its applications beyond precast concrete. This paper intends to examine the influence of fly ash content, additional Portland cement content, alkaline solution resting time, curing period and curing temperature on fly ash based geopolymer concrete. The evaluated properties of (GPC) were workability, compressive strength, splitting tensile strength, modulus of elasticity, absorption and thermal gravimetric analysis (TGA). The study results show that, generally, adding cement improves all fly ash based geopolymer properties except workability. The increase of fly ash content enhances geopolymer concrete properties. Using 30 min resting solution has a significant effect on geopolymer properties compared with using 24 h resting solution. Geopolymer concrete properties significantly affected by curing approaches which are represented in curing time and temperature.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Concrete has become one of the largest production materials with an annual global production of about one cubic meter for every person on earth [1]. Concrete is a composite mixture containing cement paste and aggregates as its main components. Portland cement is conventionally used as primary binder to produce concrete. The production of cement is increasing about 7% annually. Portland cement is manufactured using limestone and clay mixed in definite proportions to produce chemical reaction burnt at very high temperature. To produce one ton of Portland cement, 1.6 tons of raw materials are needed and the extraction of raw materials from the earth is 20% faster than the earth replenishing it, so raw materials consumed in 12 months will take 14.4 months to be filled back [2]. Ergo, the production of cement is becoming the source of environmental degradation.

On the other hand, in the last decades the climate change due to global warming has become a major concern. The global warming is caused by the emission of greenhouse gases to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming [3]. The cement industry is held responsible for some of the CO_2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere [4]. Approximately, the contribution of cement industry to the CO_2 emissions is about 5–7% of the global CO_2 emissions [5].

The reduction of cement production rate will reduce the degradation of raw materials and also reduce the amount of released CO_2 to the atmosphere which will affect the hazard of global warming.

* Corresponding author at: Gamal Abd El-Naser St., Alexandria 21526, Egypt.
E-mail address: hazemsalem1987@yahoo.com (H.A. Salem).

http://dx.doi.org/10.1016/j.conbuildmat.2016.07.043
0950-0618/© 2016 Elsevier Ltd. All rights reserved.

The blended cement (cement mixed with pozzolanic or non pozzolanic materials) is used to reduce the amount of produced cement. The blended materials to cement, in most cases, are waste materials which they causes also environmental problems.

Fly ash is considered one of these materials. Fly ash which is widely available worldwide also possesses pozzolanic properties and it is rich with alumina and silicate and yet its usage to date is very limited. Fly ash is a by-product of burning anthracite or bituminous coal. Although coal burning power plants are considered to be environmentally unfriendly, the extent of power generated by these plants is on the increase due to the huge reserves of good quality coal available worldwide and the low cost of power produced from these sources.

Nevertheless, a technique of geopolymer is used to reduce the amount of produced cement. Geopolymer concrete is a type of polymer concrete which is made without Portland hydraulic cement. Inorganic polymer which is used in production of geopolymer is aluminum-silicate polymer [6]. Fly ash and other mineral admixture are considered rich sources of aluminum and silicate. So, not only does geopolymer concrete reduce the CO_2 emissions by the cement industries, but also it utilizes the waste materials such as fly ash. Hence, the development of geopolymer concrete is an important vision towards the production of environmentally friendly concretes.

In 1979, Joseph Davidovits created and applied the term geopolymer because polymerization process takes place in which Si and Al, present in the source material, react with the alkaline liquid to produce binders. In geopolymer, polymerization is a condensation polymerization in which water is released during chemical reaction. In geopolymerization, the polycondensation of alumino-silicate oxides (Si_2O_5, Al_2O_2) with alkaline activators takes place producing Si—O—Al bonds [7]. The chemical reaction follow three steps [8] (see Fig. 1):

- Dissolution of Si and Al atoms from the source material through the action of hydroxide ions.
- Transportation or condensation of precursor ions into monomers.
- Setting or polycondensation/polymerization of monomers into polymeric structures.

Geopolymer concrete showed good properties such as high compressive strength, low creep, good acid resistance and low shrinkage [9]. Fly ash-based geopolymer also provides better resistance against aggressive environment. Hence, it can be used to construct structure that is exposed to marine environment [10]. Also, fly ash-based geopolymer displays increase in strength after temperature exposure as a proof for its good fire resistance [11].

Several reports can be found in the literature on the properties and applications of geopolymers. Previous studies show that water plays an important role in geopolymer concrete not as much as in normal concrete. The use of water in geopolymer is to improve the workability, but it will increase the porosity in concrete due to the evaporation of water during the curing process at elevated temperature [12]. Compressive strength is an essential property for all concrete where it also depends on curing time and curing temperature for geopolymer concrete. When the curing time and temperature increase, the compressive strength also increases with curing temperature in range of 60°–90 °C for 24–72 h [10]. Curing process of geopolymer concrete shows a great influence on the development of the mechanical characteristics of geopolymer [10] which make it not applicable for usage in situ. Also, the interaction between geopolymer and Portland cement as addition need more investigation.

This present work aims to study some suggested parameters such as adding cement, fly ash content, solution resting time, curing temperature and curing time on the performance of workability, mechanical properties and thermal gravimetric analysis of fly ash-based GPC.

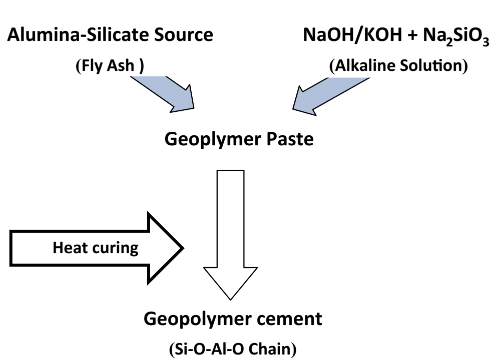

Fig. 1. Geopolymer manufacturing process.

2. Experimental program

2.1. Materials

Geopolymers are formed by a dissolution and precipitation process using aluminosilicates as precursor materials such as thermally treated kaolin and fly ash in alkaline media and silicate solutions [13].

In this study, fly ash (ASTM Class F) was used as the main source material for aluminosilicates of geopolymer binder. The used fly ash had a specific gravity of 2.2 and 95% of fly ash was passing through the 45 μm sieve. Type I Ordinary Portland cement according to ASTM C 150 was used in this research as additive in some mixes. The chemical composition of used fly ash and cement is presented in Table 1. Natural siliceous sand with fineness modulus of 2.43 and crushed pink limestone of 9.5 mm nominal maximum size were used as natural aggregates. Tables 2 and 3 present the physical properties and sieve analysis of the used aggregates.

A mixture of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions were used as the activator solution. Sodium hydroxide solution of desired concentration was prepared by mixing 97–98% pure NaOH pellets with tap water. The concentration of sodium hydroxide solution was kept constant (16 M) for all mixtures. The specifications of sodium silicate are shown in Table 4.

Naphthalene-based chemical admixture (ASTM Type F) as high range water reducer and accelerator was used to improve the workability of the fresh concrete.

2.2. Test parameters

Four parameters were considered in this research program. These parameters included studying the interaction between

Table 1
The chemical composition of fly ash and cement.

Chemical composition %	Fly ash	Cement
Silicon dioxide (SiO_2)	62.30%	19.1%
Iron oxide (Fe_2O_3)	2.10%	3.42%
Aluminum oxide (Al_2O_3)	28.10%	5.10%
Calcium oxide (CaO)	0.50%	62.1%
Magnesium oxide (MgO)	1.00%	3.03%
Sulfur trioxide (SO_3)	0.40%	2.20%
Na_2O	0.50%	–
K_2O	1.00%	–
Loss on ignition (LOI)	2.50%	2.4%

Download English Version:

https://daneshyari.com/en/article/255784

Download Persian Version:

https://daneshyari.com/article/255784

Daneshyari.com