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Effects of Parameters on the Setting Time of Fly Ash Based Geopolymers Using Taguchi Method

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Abstract

Geopolymers are the inorganic polymer materials possessing properties superior than the properties of conventional materials. Geopolymers are also environment friendly materials. This paper determines the effects of parameters such as silica to alumina (Si/Al) ratio, sodium to alumina (Na/Al) ratio, water to solid (W/S) ratio, and temperature on the setting of fly ash geopolymers. The experiments were designed using Taguchi model. The setting time was determined by Vicat Needle apparatus. The Si/Al - 2.2, Na/Al - 1.4, W/S - 0.30, and temperature of 40 °C increased the setting time and workability of the geopolymers. The Si/Al ratio of 1.8, Na/Al ratio of 1.0, W/S ratio of 0.20, and temperature of 80 ° C caused fast setting of geopolymers. The setting time of geopolymers can be optimized using Taguchi method for particular applications.

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Keywords: Fly ash, Geopolymer, Setting time, Parameters, Taguchi method.

1. Introduction

Geopolymers are a class of alkali activated aluminosilicate materials produced by alkali activation of aluminosilicate source materials. Metakaolin, fly ash, and slag as aluminosilicate materials and sodium hydroxide and potassium hydroxide as alkali solutions and/or sodium and potassium silicates as source of silica are used for synthesis of geopolymers. Fly ash is a by-product of coal thermal power plants and it contains appreciable amounts of silica and alumina. The use of fly ash in synthesis of geopolymers results in the benefits of saving of the land reserved for its disposal as well as the economic benefits by the sale of by-product for the synthesis of valuable products [1]. Geopolymers are being used in a variety of applications due to their properties better than the properties of conventional materials. Fast setting and attaining high compressive strength, resistance against fire and acids, and low CO_2 production are the main properties of geopolymers.

Setting time of geopolymers is associated with its workability. It is the time available for transportation, placing, and compaction. Setting of geopolymers is linked with the initial formation of sodium aluminosilicate hydrate gel (NASH) [2, 3] while formation of

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Nomenclature

FAGP	Fly Ash Geopolymers	Na/Al	Sodium to alumina
W/S	Water to solid	Si/Al	Silica to alumina
CSH	Calcium Silicate Hydrate	CAH	Calcium Aluminate Hydrate

this gel at later stages is involved in strength development. Setting time of geopolymers depends on several factors such as composition of the alkaline solution, alkaline solution to fly ash ratio [4], silica modulus, and Na_2O content etc. Several studies on setting time of geopolymers have been conducted. Karakoc et al [5] determined the effect of silica modulus and Na_2O concentrations on setting of ferrochrome slag (FS) and found that lower the silica modulus in the paste higher the setting time. The increasing of the Na_2O content also decreased the initial and final setting times. Chindaprasirt et al [6] determined the effect of SiO_2 and Al_2O_3 on high calcium fly ash based geopolymers and observed that increasing SiO_2 and Al_2O_3 contents decreased the setting time. Silva et al [2] determined the effect of SiO_2/Al_2O_3 on metakaolin based geopolymers and noticed that increasing this ratio from 2.5 to 5.01 increased the setting time. Hanjitsuwan et al [7] determined the effect of NaOH concentrations on the setting of geopolymers and observed that increasing NaOH concentration from 8 – 18 M increased the initial and final setting times of the paste. All of the above studies determined the effects of different parameters on the setting of geopolymers by varying only one parameter at a time. However, no such study has been conducted in which all the parameters would have been varied at the same time. The experimental design technique such as Taguchi method provides this facility to determine the effects of different parameters by varying all the parameters at a time and also provides guidelines for analysis of the data. The application of Taguchi model to geopolymers is limited to only a few studies [8-11]. Olivia and Nikraz [8] used Taguchi method to optimize the mechanical properties and durability of fly ash geopolymer concrete. Riahi et al [9] used Taguchi method to determine the effects of parameters on the compressive strength of fly ash based geopolymers. Nazari et al [10] used Taguchi method to determine the effects of parameters on the compressive strength of geopolymers produced using Portland cement as a source of aluminosilicate material.

This study determines the effects of parameters such as silica to alumina (Si/Al) ratio, sodium to alumina (Na/Al) ratio, water to solid (W/S) ratio, and temperature on setting time using Taguchi method. The setting time of geopolymers was determined using Vicat Needle. The setting time data was analyzed using response index based on signal to noise ratio (S/N) ratio principle [12] developed by Taguchi model.

2. Materials and methods

2.1. Materials

Fly ash (obtained from local thermal power plant) was used for synthesis of geopolymers. Fly ash contains Al_2O_3 - 43.25%, SiO_2 - 20.58%, Fe_2O_3 - 12.41, and CaO - 11.11%. Detailed composition of fly ash is given in another paper [13]. AR grade NaOH and Na_2SiO_3 (SiO_2 - 37.79% and Na_2O - 16.36%) purchased from R & M Chemicals, Malaysia were used for synthesis of geopolymers.

2.2. Methods

2.2.1. Designing of experiments

Taguchi experimental design method was used for designing of experiments. Four parameters such as silica to alumina (Si/Al) ratio, sodium to alumina (Na/Al) ratio, water to solid (W/S) ratio, and temperature were selected for this study. The parameters and their levels are shown in Table.1. The ranges and levels of the parameters were selected in a way to represent the best possible compositions based on the presented compositions in the literature [14-18]. We used one of the orthogonal arrays such as L9 (4^3) developed by Taguchi method to represent all the factor or parameter levels. Using Taguchi design expert software a total of 9 trials or samples were obtained. Chemical compositions of the samples are shown in Table.2.

Table.1: Factors and levels

Factors	Level 1	Level 2	Level 3
Na/Al ratio	1	1.2	1.4
Si/Al ratio	1.8	2.2	2.6