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INFLUENCE OF CURING CONDITIONS AND ALKALI HYDROXIDE ON STRENGTH OF FLY ASH GEOPOLYMER CONCRETE

KHOA TAN NGUYEN[1], TUAN ANH LE[2], AN THAO HUYNH[1], and NAMSHIK AHN[3]

[1]*Dept of Architectural Engineering, Sejong University, Seoul, S. Korea*
[2]*Dept of Civil Engineering, Vietnam National University of Ho Chi Minh City, Ho Chi Minh City, Vietnam*
[3]*Dept of Architectural Engineering, Sejong University, Seoul, S. Korea*

Geopolymer concrete is known as an alternative to Portland cement, with low carbon dioxide emissions compared with the conventional building materials. In this research, the influence of curing conditions and alkali hydroxide were investigated, using curing temperatures between 40 to 100℃, curing times from 4 to 12 hours, and various types of hydroxide and concentrations of sodium hydroxide solution. Geopolymerization needs energy and time to occur, and higher curing temperatures resulted in larger compressive strength, while longer curing times resulted in higher compressive strength. At the same curing temperature, longer curing time resulted in a higher compressive strength because the longer curing time extends the chemical reaction. For geopolymer concrete, sodium hydroxide is a better property than potassium hydroxide, because the atomic size of sodium anion is smaller than potassium. Further, the strength of concrete increased when the concentration of sodium hydroxide increased. In conclusion, geopolymer concrete is suitable for traditional building materials. Finding renewable materials to satisfy the increasing demand for building structures will be the primary challenge in future.

Keywords: Portland cement, Alternative, Concrete curing, Curing time, Hydroxide solution, Concentration.

1 INTRODUCTION

Concrete is an essential building material for infrastructures worldwide. Concrete usage around the world is second only to water (Hardjito 2005). Although Portland cement is a main component of concrete, production of this cement depletes an immense amount of natural resources and emits greenhouse gases into the atmosphere. Emissions of greenhouse gases, such as CO_2, into the atmosphere by human activities are precisely what are being seen to cause global warming. Among the greenhouse gases, CO_2 contributes about 65% to global warming. The cement industry is responsible for about 6% of all CO_2 emissions because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere (Davidovits 1999). Due in part to the production of Portland cement, it is estimated that by 2020, CO_2 emissions will rise by about 50% from the current levels (Davidovits 1979). Therefore, to preserve the global environment from the impact of cement production, it is imperative to replace conventional Portland cement concrete by developing a concrete material that is environmentally friendly yet remains an efficient construction material (Davidovits 2011). To this end, geopolymer concrete is a revolutionary development as an alternative, using novel, low-cost and environmentally-friendly materials (Duxson 2005).

The object of this study is to evaluate the following properties of fly ash-geopolymer concrete: the effects of curing time and temperature, types of hydroxide solution, and concentrations of sodium hydroxide solution on compressive strength.

2 MATERIALS AND METHODS

2.1 Materials

The materials used for making fly ash-based geopolymer concrete specimens are low-calcium dry fly ash as the source material, aggregates, alkaline liquids, and water.

2.1.1 *Fly ash*

The fly ash used was low-calcium (ASTM class F) dry fly ash from the F power station as shown in Figure 1. The chemical composition of fly ash is presented in Table 1. The specific gravity of this type of fly ash is 2500 kg/m^3.

2.1.2 *Alkaline liquid*

The alkaline liquid was a combination of sodium silicates solution and sodium hydroxide solution. The sodium silicate solution included Na_2O and SiO_2 of about 36% to 38% by mass. Potassium hydroxide (KOH) was used as the replacement chemical. Potassium hydroxide (KOH) was mixed with a sodium silicate solution such as sodium hydroxide (NaOH).

2.1.3 *Aggregates*

The aggregates used were 20 mm and 10 mm coarse aggregates and fine aggregates in saturated surface dry condition. The ratio between coarse and fine aggregates was 40% (20 mm), 30% (10 mm) and 30% (fine aggregate). The specific gravity of coarse aggregates was 2700 kg/m^3 and 2650 kg/m^3 for fine aggregates

2.2 Test Methods

The compressive strength of geopolymer concrete specimens was measured with a testing cylinder 100 mm in diameter and 200 mm in height, with the ASTM C39/C 39M-99.

Some of these results have already been reported in several publications. Based on these studies, three different mixture proportions were formulated for making concrete specimens. The mix proportions per m^3 for concrete are given in Table 1.

Table 1. Mixture proportions.

Mix proportion	Aggregate			Fly ash (kg)	Sodium hydroxide solution (NaOH) (kg)	Water glass (kg)	Water (kg)
	20 mm (kg)	10 mm (kg)	Fine (kg)				
GF1	375	450	675	500	100	120	131
GF2	375	450	675	500	48	120	156
GF3	375	450	675	500	120	48	152

3 TEST RESULTS AND INVESTIGATIONS

The test results cover the effect of water content and types of hydroxide solution on compressive strength, sulfate resistance, and corrosion rate. Test specimens were made using geopolymer concrete, denoted as GF1, GF2, and GF3.

3.1 Influence of Curing Temperature

Figure 1 shows the effect of the curing temperature on the compressive strength for GF1, GF2, and GF3 after curing the specimens in an oven for 10 hours.

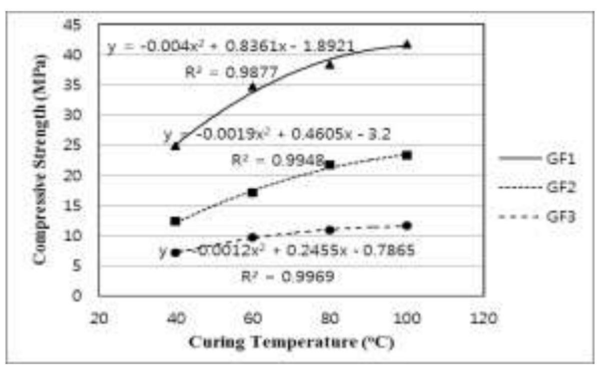

Figure 1. Effect of curing temperature on compressive strength (Khoa et al. 2013).

When the temperature was increased from 40°C to 100°C, all specimens had a greater compressive strength value. However, the speed of the increase in compressive strength of three mix proportions was different. Higher curing temperatures resulted in larger compressive strengths, although an increase in the curing temperature beyond 60°C did not increase the compressive strength significantly.

Geopolymerization needs energy to occur. If this energy is great enough, a great deal of polymer is produced. These polymers connect together to become a long chain that creates the compressive strength for geopolymer concrete. As a result, the more polymers that are created, the higher the compressive strength of the geopolymer concrete. In terms of application, we can increase the compressive strength of geopolymer concrete based on this property, which is in complete contrast to Portland cement concrete.

3.2 Influence of Curing Time

Figure 2 shows the effect of curing time on the compressive strength for GF1, GF2 and GF3 after curing the specimens in an oven at 80°C at 4, 8 and 12 hours, respectively.

According to Figure 2, the compressive strength of geopolymer concrete increased when the curing time was longer. For GF1, the compressive strength increased to 68.8% when the curing time increased from 4 to 12 hours, while that of GF2 and GF3 increased 63%, and 53.7%, respectively.

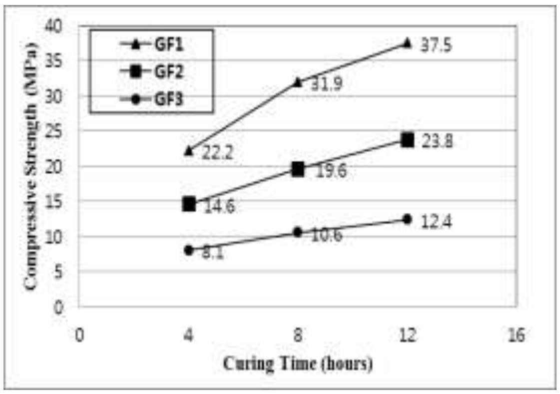

Figure 2. Effect of curing time on compressive strength (Khoa et al. 2013).

From 4 to 8 hours, the compressive strength values of geopolymer concrete increased faster than those from 8 to 12 hours. For example, the compressive strength of specimens GF1 cured for 8 hours increased 43.7% in comparison to that of specimens cured for 4 hours. However, this tendency increased only 17.4% for those cured for 12 hours. This trend was the same for GF2 (34.4% and 2.3% respectively) and GF3 (30.9% and 17.4% respectively).

At the same curing temperature, longer curing times resulted in a higher compressive strength because the longer curing time extends the chemical reaction. By comparison, geopolymer concrete and ordinary Portland cement concrete have increased compressive strength according to the curing time (Khoa et al. 2013).

3.3 Influence of Types of Hydroxide Solution

Potassium hydroxide (KOH) has similar properties to sodium hydroxide (NaOH). In this case, KOH will replace NaOH in specimens of GF1, GF2 and GF3. The test specimens were cured for 10 hours at 80°C and tested after being cured for 7 days. The results are shown in Figure 3.

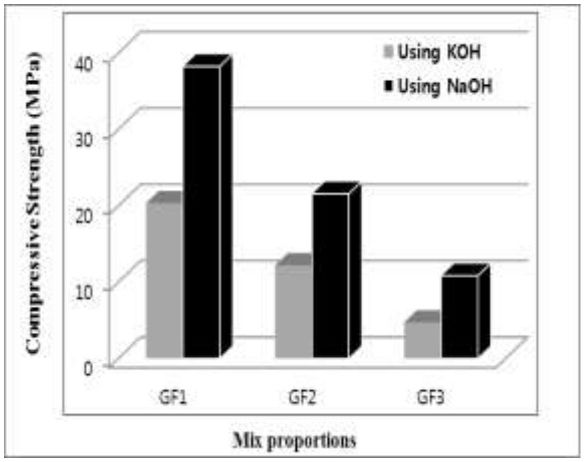

Figure 3. Effect of types of hydroxide solution on compressive strength.

The results presented in Figure 3 indicate that the compressive strength of geopolymer concrete using KOH is lower than that of NaOH geopolymer concrete. For example, the specimen of GF1 using KOH had compressive strength 53% lower than that of specimens using NaOH; this trend is the same with GF2 and GF3.

Using K^+ cations to replace Na^+ cations causes the compressive strength of geopolymer concrete to decrease.

3.4 Influence of Concentration of Sodium Hydroxide Solution

Figure 4 shows the effect of concentration of sodium hydroxide solution on the compressive strength for GF1, GF2, and GF3 with 4M, 8M, 11M, 15M, and 18M NaOH, respectively. According to Figure 4, at the same concentration of solution GF1 has the highest compressive strength. When the concentration of solution increases from 4M to 18M, the compressive strength of geopolymer concrete also increases. However, the percentage increase differs by mix proportion. GF1 increases 4.5 times, GF2 3 times, and GF3 5 times.

A possible explanation is that when as concentration of sodium hydroxide increases, large quantities of OH^- appear. These anions catalyze the dissolution of Si and Al from source materials, and from that the geopolymerization process has more raw materials to create the structure of geopolymer concrete.

4 CONCLUSION

The properties of geopolymer concrete depend on geopolymerization, which needs energy to occur. If the energy is sufficient, the properties or compressive strength of concrete are increased. Thus, higher curing temperatures and longer curing times produce a greater compressive strength. As the dimensions of K^+ are bigger than Na^+, it is difficult for K^+ to connect to tetravalent Al. Thus, using NaOH solution shows a higher compressive strength than KOH solution. The compressive strength of geopolymer concrete is higher when the concentration of sodium hydroxide solution increases.

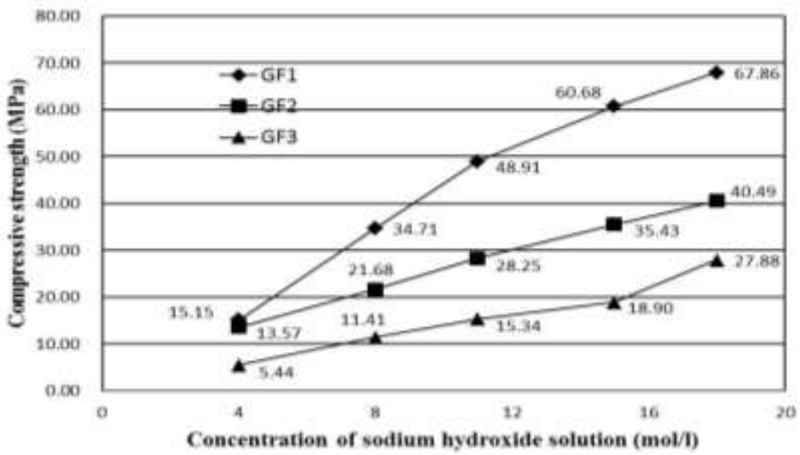

Figure 4. Effect of concentration of sodium hydroxide solution on compressive strength.

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