Development of Geopolymer Concrete with Mixing Condition

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Summary

This study investigated the strength development of cementless geopolymer concrete, which used ground granulated blast furnace slag (GGBS) as a source material, based on the mix proportions for alkali activated (AA) mortar from previous research. Cementless geopolymer concrete exhibited excellent early strength development, and the strength was about 1.5 to 3 times higher than ordinary portland cement (OPC) at age 1 and 3days. As strength property with mixing condition, the compressive strength was higher as water-to-binder (W/B) ratio was lower. Although the early strength was higher as the value of alkali quality coefficient Q_A was higher, the relationship did not continue in the long-term age. The equation proposed from investigation of AA mortar was applied to cementless geopolymer concrete with a slight modification and without additional variable analysis process, and the compressive strength predicted by this modified equation at 28 days corresponded well with experimental results.

Keywords: cementless geopolymer concrete, alkali quality coefficient, mixing condition, strength property, ground granulated blast furnace slag

1. Introduction

Concrete has been used widely as main construction material for architectural and civil engineering structures for the past two centuries. However, cement which acts has the binder of the concrete, requires enormous energy consumption over 1300℃and emissions great quantity of carbon dioxide, the mainly responsible for greenhouse effect. Thus, the concrete industry is aware of this problem and is trying to reduce the quantity of cement for concrete. There have been active researches on alkali activated concrete, which uses ground granulated blast furnace slag (GGBS) or fly ash (FA) as a substitute for cement. Before investigating the concrete itself, alkali quality coefficient Q_A, was proposed as an indicator of the chemical composition of raw material and activator through a study of alkali activated (AA) mortar. Then, neural network and multiple regression analysis were used to propose an evaluation model for initial flow and compressive strength of AA mortar.

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2. Experimental

Sixteen alkali-activated concrete mixes were prepared. The quantity of sodium oxide (Na_2O), potassium oxide (K_2O) and barium oxide (BaO), which directly affects the composition of sodium silicate, potassium silicate and barium hydroxide, respectively, water-to-binder (W/B), and fine aggregate-to-total aggregate (S/A) were selected as the concrete variables through preliminary tests of mortar and concrete. Then, alkali quality coefficient Q_A of sodium silicate is predicted as Equation (1) by the chemical composition of the materials. And in Chapter 3, alkali quality coefficient Q_A of potassium silicate and barium hydroxide will be discussed.

Concrete is mixed forcefully in a mixer of 60 litre capacity as shown in Figure 1. And three cylindrical test specimens of ø100mm x 200mm size dimension are produced by each age in accordance with KS F 2403[6]. According to the concrete compressive strength test specification of KS F 2405, compressive tests were performed at ages of 3, 7, 28 and 56 days

3. Test results and analysis

3.1 Compressive strength at 28 days (f_{ck})

$$(f_{ck})_{28} = 1480\left[\frac{Q_A \times (S_A / S_{A0} + k_1)^{0.3}}{(W/B)}\right]^{1.23} \times k_2 \qquad (1)$$

Where, k_1 is $(A/B)^{0.5}$ for S/B≤2.5 and $(A/B)^{-0.5}$ for S/B>2.5, and k_2 is $(S/A)^{0.6}$.

3.2 Alkali quality coefficient (Q_A)

$$(Q_A)_{SS} = \left(\frac{Na_2O}{(SiO_2)^2} \cdot Al_2O_3 \cdot CaO\right) / B \quad \text{(by weight)} \qquad (2\text{-}1)$$

$$(Q_A)_{PS} = \left(\frac{K_2O}{(SiO_2)^2} \cdot Al_2O_3 \cdot CaO\right) / B \quad \text{(by weight)} \qquad (2\text{-}2)$$

$$(Q_A)_{BH} = \left(\frac{BaO}{SiO_2} \cdot Al_2O_3 \cdot CaO\right) / B \quad \text{(by weight)} \qquad (2\text{-}3)$$

4. Conclusion

This study is basic research on the strength model of AAG concrete using GGBS instead of cement as a source material.

First, AAG concrete with sodium silicate, potassium silicate and barium hydroxide as the alkaline activator was tested. The main variables of AAG concrete were water-to-binder (W/B) and dosage of sodium silicate (Na_2O/B)/potassium silicate (K_2O/B)/barium hydroxide (BaO/B). Using mix proportions with main variables, it is investigated the mix properties and material properties. Then the test results were compared with properties of OPC concrete and it is proposed strength model of AAG concrete.

Second, it is proposed alkali quality coefficient according to the alkaline activator type (potassium silicate, barium hydroxide), and calculated compressive strength of AAG concrete based on AAG strength model. The prediction values based on the AAG strength model was generally similar to test results. In this study, the strength model of AAG concrete could be used the same strength model irrespective of alkaline activator if the alkali quality coefficient of AAG concrete were defined.