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Changes in the engineering properties of Slag-CB depending on curing temperature

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ABSTRACT

Slag-Cement-Bentonite (Slag-CB) cut-off wall is commonly used to block the flow or leak of polluted substances or underground water, to prevent seawater intrusion, and/or to repair old levees. This is called a method of constructing cut-off walls by replacing the original ground with a slurry of blast furnace slag, cement, bentonite, and water during the excavation of in-situ ground. Generally, for Slag-CB, 60-80% of the cement used is replaced with ground granulated blast-furnace slag (GGBS). The setting and strength of the mixtures with high levels of GGBS are obviously affected by curing temperature. In this study, slag-CB slurry walls with different GGBS replacement ratios (0-90%) were employed and the setting time under the highest average temperatures observed in each season in Korea for the past 50 years (14, 21, and 28 °C) was measured. Finally, the effects of changes in curing temperature on the setting characteristics of Slag-CB were thoroughly analyzed.

1. INTRODUCTION

To prevent seawater intrusion and to block the flow and leaking of pollutants or underground water, cement-bentonite (CB) cut-off walls are excavated with vertical trenches with a width of 0.6m. During the excavation of in-situ ground, the replacement with a CB slurry is conducted. The replaced CB slurry became a support for the excavation surface, and forms a wall of the required level of strength over time (Kim 2021). In addition, the advantages were easy and fast process, excellent performance by enabling the immediate replacement of the excavated area with CB slurry, and security of the uniformity of walls (Hwang 2016).

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CB slurry is composed of bentonite and Portland cement. However, cement requires a considerable amount of energy to produce a large amount of carbon dioxide. Consequently, a number of studies have been conducted to reduce the amount of carbon dioxide emission. One of the more widely accepted solutions was to replace a part of the cement with non-Portland materials such as ground granulated blast-furnace slag (GGBS) (Jefferis 2012).

Slag-Cement-Bentonite (Slag-CB), which replaces a part of the cement used for CB with GGBS, had excellent water repellency and strength compared to the conventional CB (Jefferis 1997; Evans 1999). In addition, GGBS replacement ratios of 0-60% did not bring significant changes in the uniaxial compressive strength and the coefficient of permeability, whereas replacement ratios of 70-80% drastically reduced the coefficient of permeability and increase strength (Opdyke 2005). Therefore, the GGBS replacement ratio must be less than 70% to use Slag-CB effectively.

If a large amount of GGBS was included, as with Slag-CB, setting and strength are greatly influenced by the curing temperature (Koh 2009). For countries with four distinct seasons such as South Korea, the curing temperature effects are critical construction issues. To identify the setting characteristics of Slag-CB by curing temperature, this study fabricated samples of Slag-CB cut-off walls with different GGBS replacement ratios of 0-90%. It measured the setting time under the highest average temperatures observed in each season in Korea for the past 50 years (14, 21, and 28°C) and analyzed the effects of changes in curing temperature by season on the setting characteristics of Slag-CB.

2. SAMPLE PREPARATION AND TESTING

To identify the setting time of Slag-CB by curing temperature, samples were fabricated, as shown in Table 1. The Slag-CB samples were produced based on the GGBS replacement ratio at which a part of the cement to be mixed for CB with cement, bentonite, and water is replaced with GGBS. A two-step mixing process was conducted; first, bentonite in the form of powder was mixed with water, and the second step involved adding cement in the form of powder into the mixture. The samples were deposited in a mold for the setting experiment, and were stored and cured in environmental chamber with different temperatures of 14, 21, and 28°C and humidity level of 100%.

The experiment was conducted as per the KS L ISO 9597, and the equipment used was Automatic Vicat apparatus shown in Figure 1. The setting was measured every 30 minutes, and the measurement interval was shortened by 30, 15, 5 , and 1 min. as the samples were expected to reach setting to identify the accurate setting time.

Fig. 1 Automatic Vicat apparatus

Table 1. Mixture proportion of Slag-CB

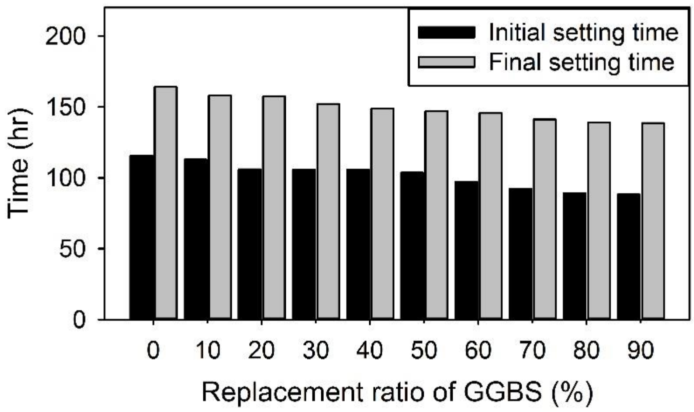
<table>
<tr><th rowspan="2">Mixture type</th><th colspan="4">Mixing ratio(kg/m^3)</th></tr>
<tr><th>Bentonite</th><th>Cement</th><th>GGBS</th><th>Water</th></tr>
<tr><td>S-0</td><td rowspan="10">60</td><td>200</td><td>0</td><td rowspan="10">To total volume of 1m^3</td></tr>
<tr><td>S-1</td><td>180</td><td>20</td></tr>
<tr><td>S-2</td><td>160</td><td>40</td></tr>
<tr><td>S-3</td><td>140</td><td>60</td></tr>
<tr><td>S-4</td><td>120</td><td>80</td></tr>
<tr><td>S-5</td><td>100</td><td>100</td></tr>
<tr><td>S-6</td><td>80</td><td>120</td></tr>
<tr><td>S-7</td><td>60</td><td>140</td></tr>
<tr><td>S-8</td><td>40</td><td>160</td></tr>
<tr><td>S-9</td><td>20</td><td>180</td></tr>
</table>

Note: GGBS is the ground granulated blast-furnace slag.

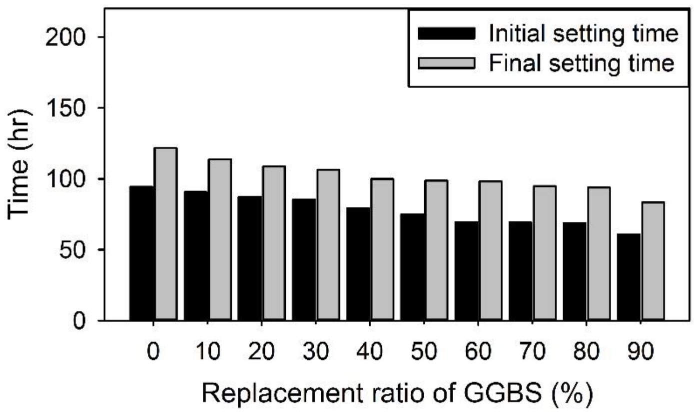
3. RESULTS AND DISCUSSION

Figure 2 presents the setting time of Slag-CB according to the curing temperature. After identifying the setting time of Slag-CB by curing temperatures, it was found that higher curing temperature led to faster setting. The differences were more evident from the final setting than the initial setting, and also were greater when comparing them at curing temperatures of 14 and 21°C than at curing temperatures of 21℃ and 28℃.

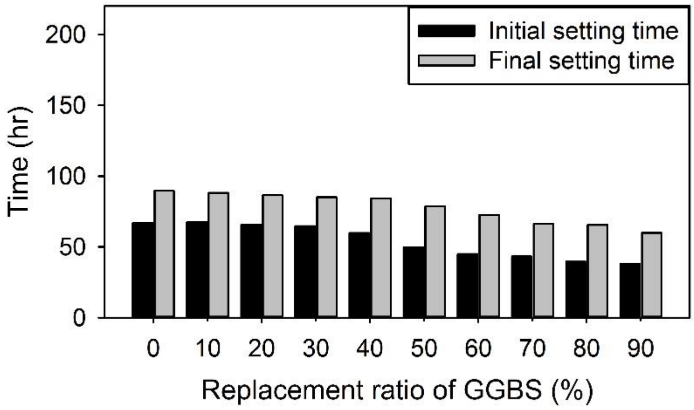
Moreover, under the same curing temperature, greater GGBS replacement ratios led to faster setting. Although there were no significant changes in the setting time at up to GGBS replacement ratios of 40%, shorter setting time was evident from the GGBS replacement ratio of 50%.



(a) Curing temperature is 14℃



(b) Curing temperature is 21℃



c) Curing temperature is 28℃

Fig. 2 Setting time of Slag-CB

4. CONCLUSIONS

To evaluate the effect of curing temperature on the setting time of Slag-CB, laboratory tests were carried out. The fast setting time of the Slag-CB at the higher the curing temperature was clearly observed. Moreover, the greater the replacement ratio of GGBS, the greater the influence of curing temperature. The difference in setting time by curing temperature was larger at the fInal setting time than at the initial setting time.

REFERENCES

Evans, J.C. and Dawson, A.R. (1999), "Slurry walls for control of contaminant migration a comparison of UK and US practices", *Proceedings of the Geo-Engineering for Underground Facilities Conference,* University of Illinois Urbana-Champaign, USA, June.

Hwang, J.S., Kim, S.W., Jung, J.G., Lee, S.J., Oh, B.S. and Baek, S.C. (2016), "Behavior characteristics of cement bentonite impervious walls related to mixing methods and curing time", *Journal of the Korean Geo-Environmental Society,* Vol. **17**(12), 45~54.

Jefferis, S.A.(1997), "The origins of the slurry trench cut-off and a review of cement-bentonite cut-off walls in the UK", *International containment technology conference and exhibition,* Florida, USA, February.

Jefferis, S.A.(2012), "Cement-Bentonite Slurry Systems", *Proceedings of the Fourth International Conference on Grouting and Deep Mixing*, New Orleans, Louisiana, USA, February.

Kim, T.Y. and Lee, B.J.(2021), ″The Estimation of Appropriate Mixing Amount of Cement-Bentonite Cutoff Walls for Repair and Reinforcement of Reservoir Embankments″, *Journal of the Korean Geo-Environmental Society,* Vol. **22**(6), 27-32.

Koh, K.T., Ryu, G.S., Kang, H.J. and Lee, J.H.(2009), ″Effect of Curing Temperature on the Properties of Concrete Incorporating High Volume Blast Furnace Slag″, *The 35th Korea Society of Civil Engineers Conference*, 1375-1378.

KS L ISO 9597(2019), ″Determination of setting time and soundness of cements″

Opdyke, S.M. and Evans, J.C.(2005), ″Slag-Cement-Bentonite Slurry Walls″, *Journal of Geotechnical and Geoenvironmental Engineering, ASCE,* Vol. **131**(6), 637-681.