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An experimental study on the physical properties variation of grout materials by the installation of Anti-Agglomeration equipment

*Sung-Pil Hwang[1)], Jae-Hyeung Jeoung[2)] and Chang-Yong Kim[3)]

[1), 2), 3)] *Geotechnical Engineering Research Institute, KICT, Goyang-si, Korea*
[1)] hsp@kict.re.kr

ABSTRACT

When mixing the cement in powder form with water, the particles tend to cohere each other. Once they cohered, the particle size tends to become larger while injection efficiency becomes lower. This study, in a bid to reduce the cohesion of cement, the screen was set inside the grout mixer so that the cement particles are separated while vibrating them. To validate the effect of vibration screen, comparison test was conducted by using ordinary portland cement, slag cement and micro cement. Viscosity test, bleeding test and grain-size analysis indicated that the characteristics varied significantly after passing through the vibration screen.

1. INTRODUCTION

Grouting is reinforcement or cutoff method which uses the hardening agent which is typically represented by portland cement and injected into the ground or the structure. Grouting was first used in France in 1802, using clay and lime suspension, for the purpose of filling the cavities at the bottom of sluice gate or reinforcing the surrounding alluvial layer, and then the application has been further extended since 1887 when liquid grout using sodium silicate and calcium chloride was first used in Germany. Since 1900s when the equipment including pump required for grouting, grouting technologies have been developed as well and in Korea, it's first used by foreign experts for foundation of multi-purpose dam in 1960s which has been further applied to underground structure such as subway construction (Lee, 2015) Recently, it's use has been expanded to restoring or reinforcing land subsidence in urban area which has drawn keen attention from the people across the nation.
Grouting material is classified into suspension type, colloid type using polymeric material and liquid type. As injection method, low pressure or high pressure may be selected at the site, depending on type of material and reinforcement requirements. It's important to have a certain amount of firming agent mixed properly for the use to reach to the specific point. Various fundamental studies to improve the injection performance have been underway(Chun, 2000). Kim Jong-seon et al (2009) evaluated injection characteristics of cement by introducing parallel plate injection test in a bid to evaluate the injection characteristic in the gap and crack and Lee. Moon-seon et al (2009) attempted to enhance the penetration characteristics by modifying the injection method

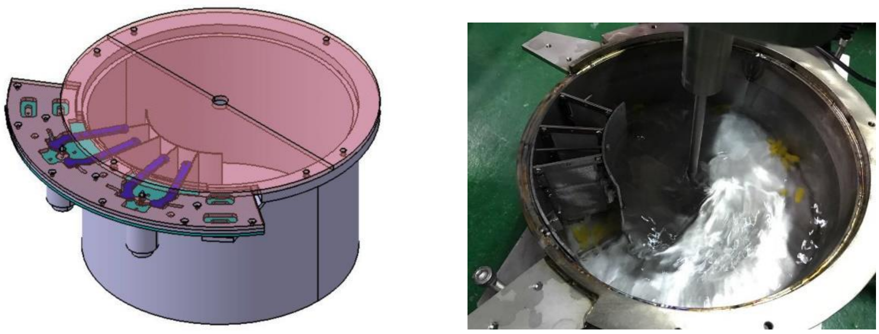
while vibrating the injection tube. Furthermore, Chung, Jae-hyung et al (2016) suggested injection characteristics depending on viscosity of injection material in powder form which has been commonly used domestically to micro cracks for the purpose of evaluating the micro cracks sized 0.25mm or less.

Though many previous studies pointed out the injection problems, few of them presented the solution. This study is intended to propose the solution that reduces the coherence. To that end, vibration screen was set inside the mixer and after mixing, viscosity and bleeding test and grain size analysis were conducted using mixed suspension to verify the effect of the device.

2. Test for grout injection performance evaluation

2.1 Grout mixer with vibration screen

A grout mixer is the common equipment to mix the cement with water for grouting. Cement particles tend to adhere among them during the mixing process which makes it difficult to inject them into micro cracks. In this study, a screen was set inside the grout mixer to deal with cohesion among cement particles (Fig 1) Referring to screening test, a vibrator was set on screen inside the mixer so as to separate the particles stuck on screen. A vibrator was set outside for waterproof and vibration was transferred by the conveyor. Motor rpm was set to be adjustable and the motor with maximum 1,600rpm was used for mixing. Motor rpm was measured using Tachometer at every test to maintain a constant rpm.



(a)Drawing (b) Test product

Fig 1 Grout mixer

2.2 Test material

This study is intended to evaluate the reduction in coherence using ordinary portland cement, slag cement and micro cement in a bid to enhance the penetration performance by reducing the coherence.

Ordinary portland cement (OPC) has been commonly used to construction project since chemical grouting was introduced but because of large grain size, 15~20 ㎛ on average and 80~100 ㎛ in maximum, injection was limited, causing a low penetration of cement particles (Kim, 1999)

Slag cement (hereinafter called slag) is manufactured by mixing slag with cement at a certain ratio which is competitive in price when comparing with ordinary portland

cement and it's advantages include high long-term strength, low hydration heat, high chemical-resistance, seawater-resistance, heat-resistance and water resistance.
Micro cement (hereinafter called Micro) has ultrafine grains and contains the components that control the initial hydration reaction pace and has the grains smaller than ordinary portland cement. It has the superior penetration performance, high strength and durability and as inorganic grouting material which is harmless to groundwater and soil, is used for dam or reservoir grouting, cutoff or reinforcement for tunnel fractured zone. Micro cement used for the test has the fineness 8,000 and has mean grain size, 5 ㎛ and maximum grain size, 25 ㎛.
Chemical properties of ordinary portland cement, slag cement and micro cement used for the test are as Table 1 as proposed by the manufacturer.

Table 1 Chemical properties

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	SO_3	Ig.loss
OPC	22.8	4.6	3.4	62.3	3.0	1.0	2.1	0.8
Slag	24.7	8.5	1.8	54.1	4.9	0.2	3.1	2.7
Micro	27.5	11.2	1.7	51.3	4.8	0.4	2.1	1.0

2.3 Test summary
To eliminate the uncertainties from lab test environment, temperature and HR were maintained at 20℃ and 40% ~ 60%, respectively. Mixer rpm was set at 600rpm for low sped and 1100rpm for high speed and mixing time was set at 3 minutes uniformly. And viscosity and bleeding test and wet grain size analysis were conducted with mixed grout. Wet grain size analysis was carried out with ordinary portland cement only. The types of test conducted are as Table 2 below.

Table 2 Types of test

<table>
<tr><th>Classification</th><th>Speed (rpm)</th><th>Screen</th><th>Test</th></tr>
<tr><td rowspan="4">OPC</td><td rowspan="2">600</td><td>○</td><td rowspan="2">① Bleeding
② Viscosity
③ Grain size analysis</td></tr>
<tr><td>×</td></tr>
<tr><td rowspan="2">1,100</td><td>○</td><td rowspan="5">① Bleeding
② Viscosity</td></tr>
<tr><td>×</td></tr>
<tr><td rowspan="2">Slag</td><td rowspan="2">600</td><td>○</td></tr>
<tr><td>×</td></tr>
<tr><td>Micro</td><td>600</td><td>×</td></tr>
</table>

2.3.1 Viscosity

It refers to the viscosity of the fluid and to measure the viscosity of the grout after mixing, LVDV-II viscometer manufactured by American company B (Fig 2) was used and the viscosity was measured bt 2sp at 100rpm.

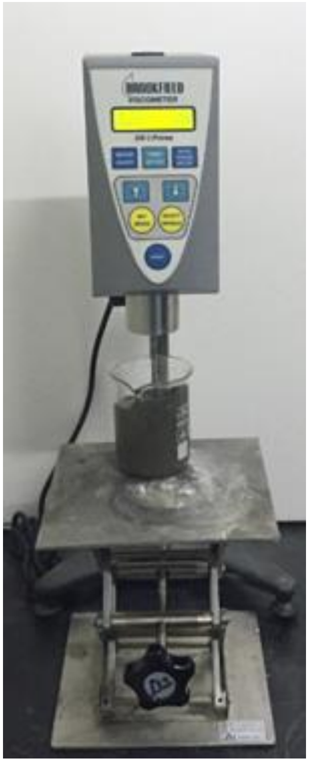


Fig 2 LVDV-Ⅱ viscometer

2.3.2 Bleeding ratio

Table 3 shows the bleeding test standards by country. In Korea, KS F 2433 "Standard test method for bleeding and expansion ratios of grouting mortar" is available and thus the test was conducted to measure bleeding ratio according to KS F 2433. A 1000ml cylinder was filled with 800ml grout and the variation in grout volume over time was measured.

Table 3 Bleeding test standards

Test standard	Specimen height	Quality requirement	Country
KS F 2433	20 cm	0%@20Hr	Korea
JHS 420	150 cm	0.3% or less @3Hr	Japan
ASTM C 940	50 cm	0%@3Hr	USA
BS 445	500 cm	0%@24Hr	UK

2.3.3 Grain size analysis

To verify the cohesion reduction effect on cement particles, wet grain size analysis was performed with the grout at 600rpm which is applied to ordinary portland cement with / without the screen. A wet grain size analysis is classified into laser diffraction and scattering method, electrical resistance method and centrifugal method (Table 4) In this study, the test was conducted by laser diffraction method according to KS A ISO 13320.

Table 4 Comparison of wet grain size analysis methods

Principle	Specimen	Specimen required	Measurement range
Laser diffraction and scattering method	Scattering to proper medium	1 g (powder), 5 mL (liquid)	0.6 nm ~ 7 ㎛ 0.017 ㎛ ~ 2000 ㎛
Electrical resistance method	Particles scattered to medium	5-10 mL	0.4 ㎛ ~ 1600 ㎛
Centrifugal method	After scattering the particles depending on density & size by rotation, analysis is made using laser	5-10 mL	5nm~70 ㎛

3. Test result

Bleeding test result indicating the viscosity of the fluid and material segregation is as Table 5 below.

Table 5 Viscosity and bleeding ratio test result

Classification	Mixing speed (rpm)	Screen	Bleeding ratio (%)	Viscosity (cPs)
OPC	600	○	27.2	55
		×	29.6	52
	1100	○	21.8	61
		×	25.4	56
Slag	600	○	15.6	84
		×	17.8	78
Micro	600	×	0.8	198

3.1 Viscosity

Viscosity of the grout measured by LVDV-Ⅱ viscometer according to test method is as Table 5. Micro cement indicated the lowest value 198 cPs and the viscosity was in order of slag cement, high speed ordinary portland cement and low speed ordinary portland cement. It indicated the grain size was distributed more uniformly when the grain size was smaller and thus shearing resistance caused by rotation of viscometer was reduced.

3.2 Bleeding ratio

Bleeding ratio was measured by mixing ratio and compared in 180 minutes. As seen in Table 5, in the test with screen, bleeding ratio was reduced and when it comes to micro cement, very few bleeding was monitored in 180 minutes which seemed to be attributable to a larger contact area with water because of smaller cement grain, causing a faster solidification than other specimens. When it comes to slag cement, bleeding ratio was reduced by 2.2% when passing the screen while it was reduced by 3.6% and 2.4%, respectively, in case of ordinary portland cement. Bleeding ratio was reduced by 5.4% and 4.2%, respectively, depending on mixing speed, which indicated the bleeding ratio was affected by mixing speed.

3.3 Grain size analysis

A wet grain size analysis was conducted with the grout produced by mixing the ordinary portland cement and the laser diffraction method was used. A mean size of the grout which passed through the screen was 21.2 ㎛ and that failed to pass through was 22.8 ㎛. Grain size of the grout that passed through 10% pass was 6.3 ㎛, 50% pass was 15.7 ㎛ and 90% pass was 42.4 ㎛. When it comes to the grout that failed to pass through the screen, grain size for 10% pass was 6.8 ㎛, 50% pass was 16.9 ㎛ and 90% pass was 46.4 ㎛. Grain size analysis result was as Fig.

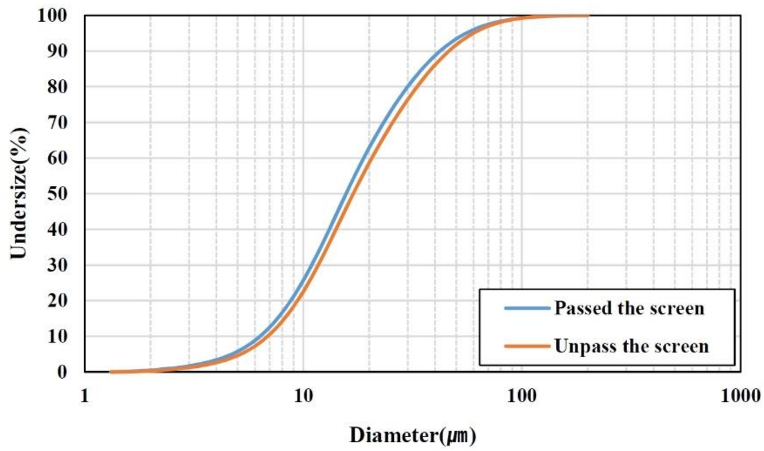


Fig 3. Grain size analysis of the grout

4 Conclusion

To reduce the cohesion among the particles during cement mixing, vibration screen was set inside the grout mixer to verify the effect. Consequently, folliwng result was obtained.

1. Micro cement indicated the highest viscosity, 198 cPs and viscosity when using the screen was significantly higher than the case without the screen, verifying the effect in viscosity.

2. As a result of measuring the bleeding ratio, micro cement indicated very few bleeding and the grout which passed through the screen had a less bleeding than the grout which failed to pass through the screen.

3. A wet grain size analysis using the grout mixed with ordinary portland cement indicated the smaller grain size which would possibly reduce the cohesion.

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