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The non-shrinkage grout to use ground fly ash as admixture

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This study uses fly ash for non-shrinkage grout in order to develop strength of grout and improve its durability. We grind fly ash to the extent of 7,000 cm^2/g and use ground fly ash and raw fly ash respectively at the proportion of 10%, 20%, 30% instead of OPC and compare the results drawn on the condition of each proportion. As a mixed material of grout, EVA and water-reducing agent is added in order to prevent bleeding and improve segregation resistance, CSA is added with a view to preventing drying shrinkage and improving early strength property. In regard to flow and flow time test for analyzing and evaluating workability, it is revealed that grouts of all mix proportions except raw fly ash 30% mix proportion satisfy all performance criteria. With regard to length change rate, grout with no admixture shows the highest shrinkage rate, but the rate is 0.0005%, extremely insignificant rate. As material age increases, compressive strength of two grouts, that is to say ground fly ash 10% and 20%-used grouts, exceed that of grout with no admixture or show high-level compressive strength.

Key words: Non-shrinkage grout, Fly ash, Workability, Length change.

Introduction

Recently, deterioration and new installation of facilities has gradually expand the grout market. The size of the Korean grout market exceeds 700 billion won and the size of the material market exceeds 100 billion won [1].

Grout is used for repairing a foundation of machinery, a support and join part of bridge and various structures. As the cement-based material, it is used to disperse a weight of a upper part to a lower part by integrating the upper structure and the lower structure through filling a gap between the lower part of concrete structures [2]. Additionally, it is mainly used when high strength is required through setting for a short time such as grouting the ground or the underground in order to improve the quality of the soil before excavation. Thus, the requirements should be met such as improvement of workability, reduction of drying shrinkage volume, development of early strength and adjustment of setting time.

Generally, to satisfy the above requirements, non-shrinkage grout uses blast furnace slag, fly ash, silica fume, desulfurized gypsum and bentonite by mixture [3-4]. In particular, 8 million tons of fly ash is generated annually, thus it is very ease to recycle it [5].

Therefore, this study grinds fly ash generated from a thermoelectric power plant {GFA(Ground Fly Ash)}, increases its particle energy and uses GFA as the admixture for non-shrinkage grout and finds out how to make an optimal non-shrinkage grout by comparing and analyzing GFA-used grout with Raw Fly Ash(RFA)-used grout.

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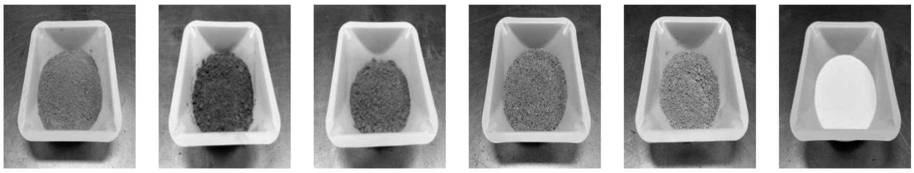
Experimental Method

This study conducts the experiment in order to look into non-shrinkage grout's flow time, flow, setting time, bleeding rate, length change rate and compressive strength in accordance with KS F 4044. Ordinary portland cement, calcium sulfo-aluminate (CSA) and fly ash (GFA and RFA) are used as a main material of the activated particle non-shrinkage grout. 6th-sized fine aggregate is used. water-reducing agent and ethylene-vinyl acetate (EVA) are used as an additive.

CSA is used for the purpose of accelerating setting, improving early strength and preventing drying shrinkage in the process of setting. The activated particle is ground to fineness of 7,000 cm^2/g by a vibration mill. GFA and RFA are used with a view to accelerating pozzolanic reaction and improving durability. A water-soluble polymer EVA[6] and a liquid water reducing agent are used as the additive with the intention of reducing cement quantity per unit, improving workability, preventing bleeding, improving compactibility and improving segregation resistance.

Table 1 shows mix condition of the non-shrinkage grouts using GFA. GFA and RFA are used at 10%, 20% and 30% respectively instead of cement. Fine aggregate is used at 61% to cement. CSA is controlled at 5%. EVA is fixed at 1% and the water-reducing agent is controlled at 0.8%.



OPC | Ground Fly Ash | Raw Fly Ash | Sand | CSA | EVA

Fig. 1. Base material of non-shrinkage grout.

Table 1. Mix conditions of grouting materials.

(Unit : OPC weight ratio (%))

No.	OPC	GFA	RFA	SAND	CSA	EVA	Water-reducing agent	Water
Ref	100	–	–					
G1	90	10	–					
G2	80	20	–					
G3	70	30	–	61	5	1	0.8	39
G4	90	–	10					
G5	80	–	20					
G6	70	–	30					

Before mixing for GFA non-shrinkage grout, fully mix ground particles and fine aggregate. After fully mixing the mixed water and the water-reducing agent, make a specimen in accordance with KS F 4044 rule on the condition of temperature 20 ± 2 °C and humidity 65 ± 20%.

Result and Discussion

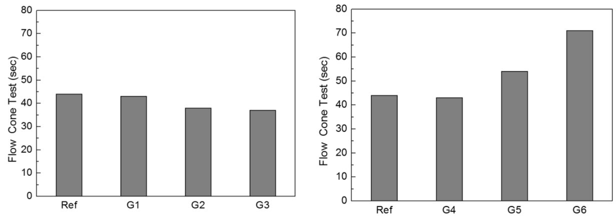
Slurry characteristic

Table 2 indicates the flow value measured depending on GFA and RFA content. To carry out the test, fill the flow cone put above the center of the flow table with the completely mixed grout, make the surface of the flow table even and remove the flow cone right now. Conduct the test twice and obtain average measurement value.

Under all the mix conditions, we obtain the flow value (Fig 3. (a)) exceeding the maximum diameter of the flow table without segregation, which meets the performance criteria (over 225 mm) of the non-shrinkage grout. We infer that ball bearing effect of fly ash, optimal mix proportion to prevent segregation, namely proper proportion of the mixed water and the effect of the additive leads to the satisfying result mentioned above. However, we have a difficulty in analyzing workability characteristic depending on GFA

Table 2. Flow of Non-Shrinkage Grout (Flow Table Method).

No.	Ref	G1	G2	G3	G4	G5	G6
Flow	255 mm over						



(a) Ref & GFA (b) Ref & RFA

Fig. 2. Test for flow of non-shrinkage grout (Flow cone method).

(a) Flow Table Test (b) Flow Cone Test

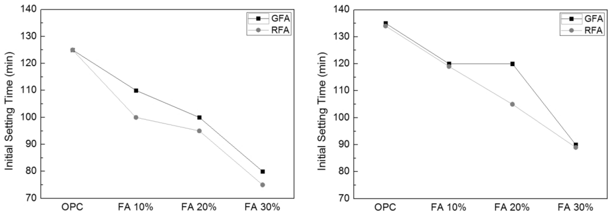
Fig. 3. Workability test methods of non-shrinkage grout.

and RFA content in the flow test. Thus we conduct the flow time test, which is useful for easy analysis of workability characteristic.

Fig. 2 shows the flow time measured depending on GFA and RFA content. Adjust the height control gauge of the funnel for the flow time test in accordance with the required condition. Conduct the flow time test within one minute after completing the mix of the grout. Like the flow table test, conduct the test twice and obtain average measurement value.

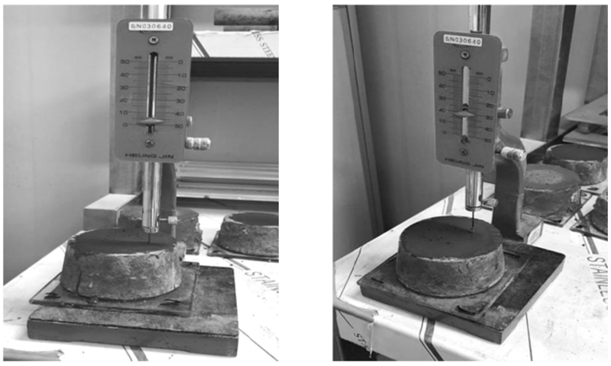
The measurement value obtained from the flow time test of Ref is at 44 seconds, which meets the performance criteria of the non-shrinkage grout (less than 60 seconds). The values obtained from the flow time tests of the mix condition G1, G2, G3 and G4 are similar to the value obtained from the flow time test of Ref. The value of G5 is 10 seconds longer than the value of Ref. The value of G6 is at 71 seconds, 27 seconds longer than the value of Ref. The values of G6 does not meet the performance criteria of the flow time test.

The results of the flow time test measured depending on GFA and RFA content are in stark contrast with



(a) Initial Setting Time (b) Final Setting Time

Fig 4. Setting time of non-shrinkage grout.



(a) Initial Setting Time (b) Final Setting Time

Fig. 5. Non-Shrinkage grout setting time measuring by vicat needle.

each other. Usually, as fly ash has a good adhesion to a chemical admixture, thus the use of fly ash is not helpful to improvement of workability characteristic, accordingly workability deteriorates. Particularly, this study uses the very high proportion in terms of the chemical admixture content compared to the proportion of normal mortar (0.1~0.5%) [7]. In this study as well, as fly ash content increases (G4~G6), the flow time increases, namely workability deteriorates. However, the flow time of G1~G3 changes slightly. We infer that this is because the volume of the ground fly ash increases relatively more than that of the raw fly ash, accordingly cement content contained in the same volume of the grout decreases, namely the amount of cement to enable the hydration reaction decreases.

Slurry setting characteristic

Fig. 4 shows the value of the non-shrinkage grout setting test measured depending on GFA and RFA content. Regarding the grout setting test. We define the initial setting time as when the needle for the initial setting stop 1mm deep from the upper side of the bottom board. We record the measurement value every 5 minutes. In addition, we define the end setting time as when the needle for the end setting leaves no mark on the surface of the grout and write down the measurement value every 15 minutes.

It is confirmed that Setting time meets the performance criteria of the non-shrinkage grout in all the mix conditions (the initial setting time: more than 1hour, the end setting time: less than 10 hours).

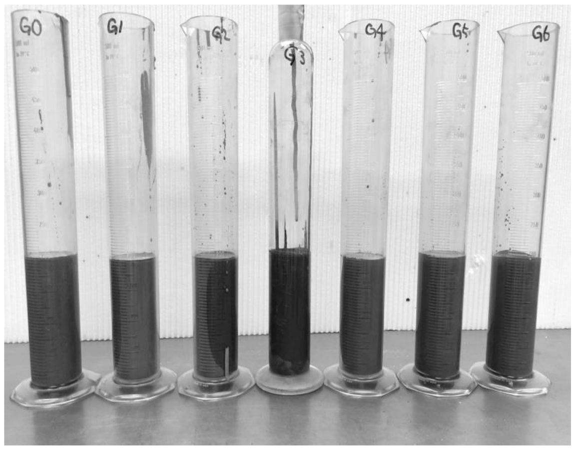


Fig 6. Bleeding test of non-shrinkage grout.

Regarding setting time, as GFA and RFA content increase, the initial setting time and the end setting time diminish slightly. Though setting times measured depending on GFA and RFA content show insignificant difference, compared with the initial and end setting time of GFA-used grout the initial and end setting time of RFA-used grout is slightly shorter. We infer that as described above the reason is because of the use of a great deal of the chemical admixture and the diminishing amount of cement in the same volume of grout caused by the increasing content of fly ash.

Fig. 6 shows the bleeding test of the non-shrinkage grout. The polyethylene cylinders of the diameter of roughly 50 mm and the height of more than 500 mm are used as a test container. After pouring the grout mixed depending on the mix condition into the cylinders by 200 mm, seal the top of the cylinders with paraflim to prevent evaporation of bleeding water.

We intended to measure the amount of the bleeding water 3 hours after the beginning of the measurement, but the bleeding never occurred in all the mix conditions.

Length change and compressive strength

To perform the length change test and the compressive strength test, the specimen is made according to the mix condition shown in Table 1 by using 40 × 40 × 160 mm mold for the specimen.

Remove the mold 24 hours after staying the specimen inside the mold at 20±2 ºC of temperature and more than 90% of humidity in a thermohygrostat in order to make the specimen available to the length change test and the compressive strength test. Afterwards, cure the specimen for the length change test in the thermohygrostat after the measurement and cure the specimen for the compressive strength at 20 ± 3 ºC in a constant-temperature water bath.

As indicated in Fig. 7, the 14-day cured specimens shrink to Ref = 143 μm, G1 = 131 μm, G2 = 126 μm, G3 = 100 μm, G4 = 130 μm, G5 = 130 μm and G6 =

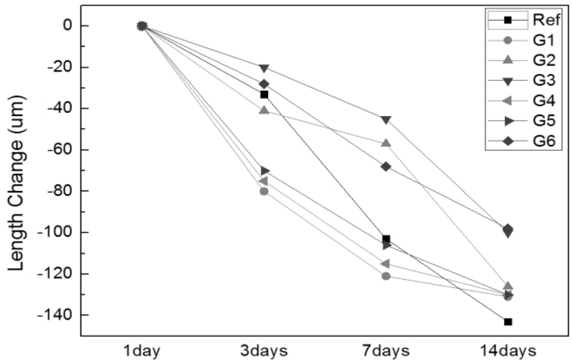


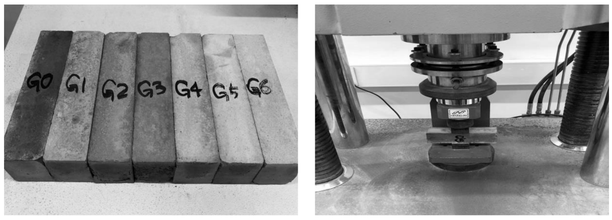
Fig. 7. Total length change test value (1-14 days).

(a) Length Change Test Specimens (b) Length Change Measuring Instrument

Fig. 8. Length change test of non-shrinkage grout.

98 μm. Through this measurement value, we observe the fact that as GFA and RFA content increases, the length change rate decreases and the maximum length change rate(Ref) is mere 0.0005%. Compared with the length change measured depending on the curing period of the normal mortar [8-9], the measurement value is confirmed to be excellent.

We infer that the reason of very low length change rate is because cement affecting the length change is replaced by fly ash and the expansion effect caused by CSA hydration reaction is mostly offset by cement drying shrinkage in the length change of the grout specimen [10].

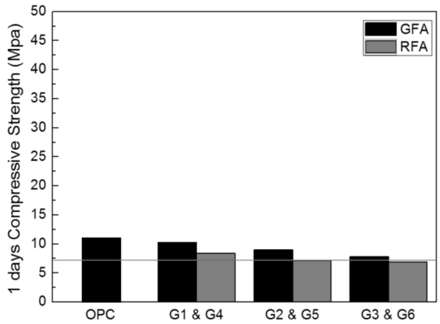


(a) Compressive strength Test Specimens (b) Compressive strength Measuring Instrument

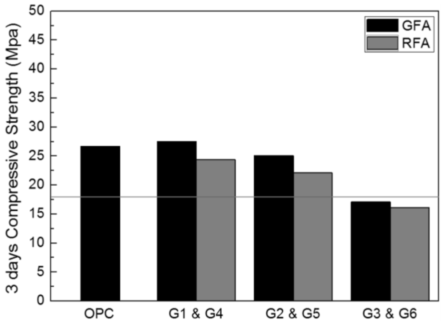
Fig. 10. Compressive strength test of non-shrinkage grout.

Fig. 9 indicates the result of the compressive strength test measured depending on the curing period of the non-shrinkage grout.

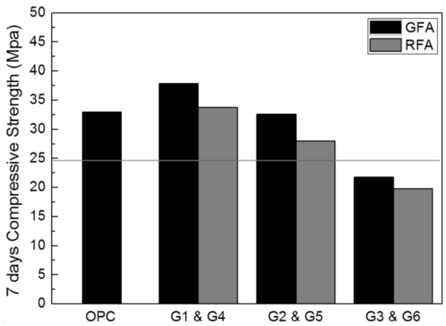
It is confirmed that both G3 and G6 fall short of the performance criteria in terms of the compressive strength. It is inferred that excessively adding fly ash instead of cement as the admixture did not induce the early strength of the grout. When fly ash is used as the admixture, as fly ash content increases, compressive strength gradually decreases. RFA-used grout is lower than Ref and GFA-used grouts in all the ages in terms of compressive strength. It is confirmed that from 3 days G1 becomes similar to Ref in compressive strength, from 7 days G1 and G2 is similar to or higher than Ref in terms of compressive strength. It is deduced that pozzolanic reaction of fly ash has an effect on development of the compressive strength. We



(a) 1 day



(b) 3 days



(c) 7 days

Fig. 9. Compressive strength according to age (days) of non-shrinkage grout.

thought GFA triggers relatively more active pozzolanic reaction described below than RFA.

$$Ca(OH)_2+[SiO_2\ Al_2O_3]=3CaO\ 2SiO_2\ 3H_2O \text{ or } 3CaO\ Al_2O_3\ 6H_2O$$

Conclusions

This study used fly ash as the admixture of the non-shrinkage grout in order to reduce environmental pollution, make effective use of resources and secure economic feasibility by replacing cement with fly ash. We conducted the several tests with the intention of examining flow, flow time, setting, bleeding, length change rate and compressive strength with 7 mix proportions, namely various proportions of the used fly ash. The conclusion is as follows.

1. Judging from the result of the Flow Table Test conducted in order to evaluate workability, the non-shrinkage grout satisfied the performance criteria in all the mix conditions. In regards to the additional flow time test conducted to grasp the workability characteristic, GFA-used grout shows insignificant difference in the flow time, meanwhile regarding RFA-used grout, as the RFA content increases, the flow time increases.

2. When it comes to slurry setting characteristic of the GFA non-shrinkage grout, bleeding did not occurred in all the mix conditions. As fly ash content increases, the setting time decreases. The setting time of GFA-used grouts is slightly longer than that of RFA-used grouts. In addition, slurry setting characteristic of the GFA non-shrinkage grout meets the performance criteria in all the mix conditions.

3. As fly ash content increases, the length change rate slightly decreases, we think that it is because the amount of cement affecting drying shrinkage diminishes. Ref, the grout without fly ash, shows the longest length change rate, 0.0005%, among the grouts made in accordance with the mix conditions indicated in Table 1.

4. As the material age increases, 10% GFA-used grout(G1) and 20% GFA-used grout(G2) become similar to or get higher than Ref in terms of compressive strength.

Judging from the results mentioned above, Both G1 and G2 satisfy all the performance criteria. In particular, It is confirmed that compared with Ref in terms of compressive strength, both G1 and G2 surpass Ref, namely exceed 100% in activity.

In summary, we believe that G1 and G2 are the most effective mix conditions using fly ash as the admixture replacing cement in seeking the improvement of workability and the development of strength with the non-shrinkage grout.

Acknowledgments

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