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# A STUDY OF GROUTING MATERIAL BLEEDING PROPERTIES FOR PRESTRESSED CONCRETE

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This study investigates the workability, bleeding, and volumetric change of grout widely used in Korea for securing the quality of grout applied in prestressed concrete (PC) bridges. The results reveal that the workability satisfies all the criteria for the grout specified in Korea. It appears that bleeding increases by 5.7 to 6.7 times when the tendon is arranged, regardless of the quality of grout, and that the height and inclination of the grout sample significantly affect bleeding. Furthermore, the arrangements of tendons were seen to prevent expansion even in grout using expansive aluminum powder, but was also seen to let shrinkage occur with a significant increase in bleeding. The conclusion is that it is necessary to establish a new testing method and apply high-performance grout for securing the quality of the grout used in PC bridges.

*Keywords*: Grout, Workability, Expansion, Strand, Fluidity.

## 1 GENERAL APPEARANCE

Grout in prestressed concrete (PC) structures secures the bond force between the member's concrete and the tendon, and protects the inserted tendon from external harmful substances like chlorides and water. For the grout to develop such functions, it must completely fill the tendon. Numerous examples have been reported on the degradation of PC structures due to the defective or insufficient filling of the grout (Woodward 2001, Lee et al. 2010). These cases have not been reported on PC structures to date in Korea. However, since the construction of PC structures has seen a sudden increase in the 1990s, one cannot claim there is no risk of degradation due to the corrosion of the PC tendon (Corven Engineering 2001, PTI 2003)). Korea is still ignoring the importance of the quality and construction technology of the grout and dedicated research is very scarce. Therefore, this paper investigates the workability, bleeding and volumetric change of the grout widely used in Korea for securing the quality of the grout applied in PC bridges.

## 2 TEST DESIGN

### 2.1 Adopted Materials and Mix Composition

Table 1 introduces the chemical composition of the PC grout admixtures and cement used in this study. Among these admixtures, product A included a comparatively large content of aluminum powder $Al_2O_3$ with 8.8%, while products B and C were relatively rich in magnesium MgO with respective contents of 16.7% and 10.4%. All of these products presented a very high loss on ignition (LOI) from 19.9% to 45.1%. Despite AASHTO specifications prohibiting the use of gas-forming materials like aluminum powder in the grout for PC bridges, Korea adopts admixtures including metallic powders for the grout with unfortunately poor investigation.

In this study, products A, B and C were mixed with ordinary Portland cement at respective ratios of 1%, 0.45% and 2.5% of grout admixture taking into account the recommendations of the manufacturers. A water-to-binder ratio of 0.40 was basically applied for the grout.

Table 1. Chemical composition of grout admixtures and cement.

| Type | | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | $Na_2O$ | $K_2O$ | LOI |
|---|---|---|---|---|---|---|---|---|---|---|
| Grout admixture | A | 33.1 | 8.8 | 1.7 | 26.1 | 1.3 | 1.9 | 0.4 | 2.3 | 19.9 |
| | B | 0.7 | 2.5 | 0.6 | 30.7 | 16.7 | 1.1 | 0.0 | 0.1 | 45.1 |
| | C | 4.5 | 4.8 | 0.3 | 24.0 | 10.4 | 17.3 | 0.7 | 0.0 | 33.9 |
| Cement | | 21.0 | 6.4 | 3.1 | 61.3 | 3.0 | 2.3 | – | – | 1.4 |

### 2.2 Test Method

The fluidity of the grout was estimated by means of the time of flow as shown in Figure 1. In Korea, the bleeding and expansion rate of the grout are evaluated by filling a polyethylene bag without steel strands with grout up to a height of about 200 mm. However, the bleeding resulting from such test method has been reported to be underestimated in the case where strands are arranged like in PC bridges.

In this study, the bleeding and volumetric change were evaluated according to the presence or absence of steel strands in compliance with the modified ASTM 940 as shown in Figure 2.

Figure 2. Test of fluidity for grout.

Figure 3. Test of bleeding and expansion for grout.

## 3 TEST RESULTS AND DISCUSSION

### 3.1 Effect of Grout Product Type

Figure 3 compares the fluidity of each of the grout products. No particular difference can be observed according to the grout product. All of the products considered in this study satisfy the fluidity criteria for grout in Korea that have flow times shorter than 60 sec and flow lengths longer than 225 mm.

Figure 4 compares the bleeding rate resulting from the tests by type of grout product. The bleeding was seen to be larger by 5.7 to 6.7 times for the grout with tendon arrangements than the grout without tendons, regardless of the type of grout product. This can be explained by the fact that the gap between the tendons makes a channel through which water can pass inside the grouting, and results in the material separation of water and cement during the injection of the grout.

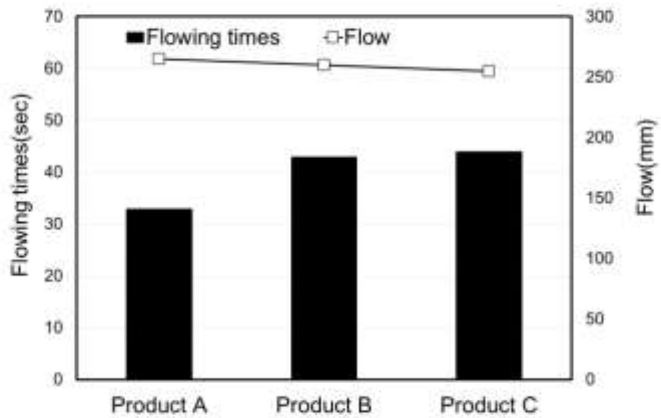


Figure 3. Comparison of fluidity by grout product.

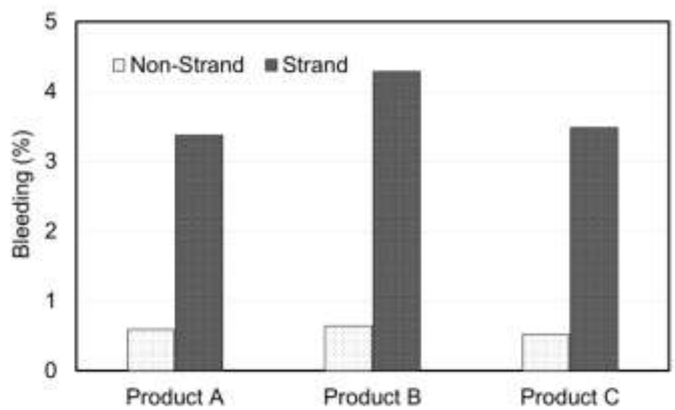


Figure 4. Comparison of bleeding ratio by grout product.

### 3.2 Effect of Height of Grout Sample

Figure 5 presents the effect of the height of the sample on the bleeding ratio of the grout. For the samples without tendons, the bleeding ratio decreases with the larger height of the sample. This can be attributed to the concentration of water near the surface following the material separation, which makes bleeding occur mainly near the surface, and reduces significantly the effect of the height of the sample.

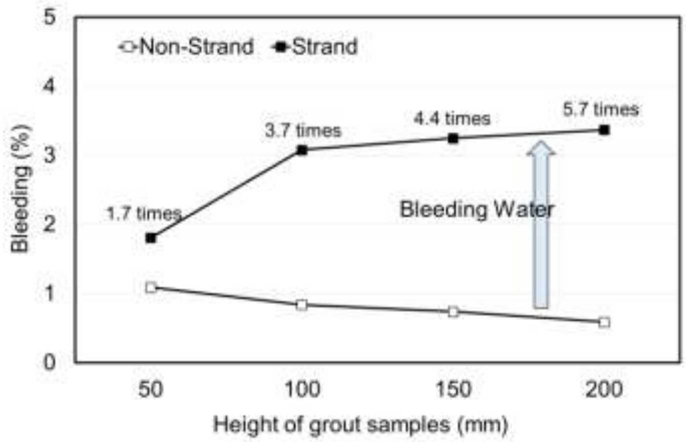


Figure 5. Effect of the height of the grout sample on the bleeding ratio.

On the other hand, for the samples with tendons, the bleeding ratio increased with the larger height of the sample. This increase of bleeding can be explained by the wick-effect, in which the bleeding water concentrates on the surface along the gap between the tendon wires throughout the height of the sample.

### 3.3 Effect of Inclination of Grout Sample

Figure 6 examines the effect of the inclination of the grout sample on the bleeding ratio considering inclinations of 30° and 90°, adopting samples with tendon arrangements and a height of 200 mm. Products A and B exhibited larger bleeding for the vertical configuration (90°) than the samples with inclination of 30°. This was due to the larger action of the gravity on the vertical configuration of 90° than on the configuration with an inclination of 30°.

In the case of product C, the bleeding appeared to be higher for the sample at 30° than the vertical sample of 90°. This result was caused by the formation of bleeding pockets all over the sample, because the bleeding water was unable to rise to the surface in the vertical sample of 90°.

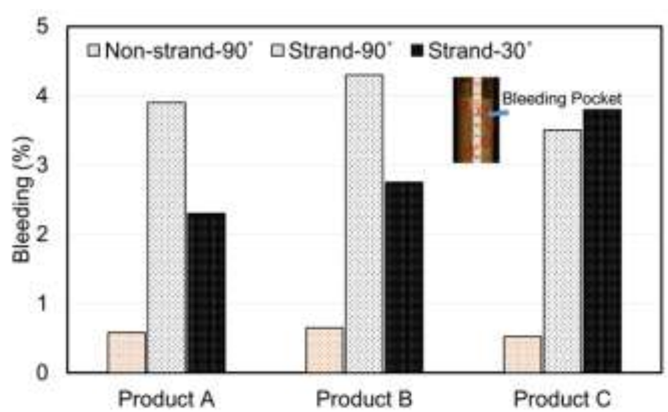


Figure 6. Effect of the inclination of the grout sample on the bleeding ratio.

### 3.4 Relation between the Bleeding Ratio and Expansion Ratio of Grout

Figures 7 and 8 relate the bleeding ratio and expansion ratio of the grout with respect to the eventual arrangement of tendons. As shown in Figure 7, the grout without arrangement of tendon experienced a bleeding ratio of 0.79% and an expansion ratio of 4.83%. This observation can be attributed to the use of expansive aluminum powder in the admixture of the grout.

In addition, for the grout with tendon arrangements in Figure 8, the bleeding ratio is 6.35% and the expansion ratio is –0.39%, indicating on the other hand that shrinkage has occurred. This seemingly contradictory result can be explained by an increase by a factor of more than 8 in the bleeding, due to by the wick-effect of the tendons. This increases the bleeding relatively despite the use of expansive aluminum powder, and results in the shrinkage of the sample. In other words, the arrangement of tendons results in opposite bleeding ratio and expansion ratios.

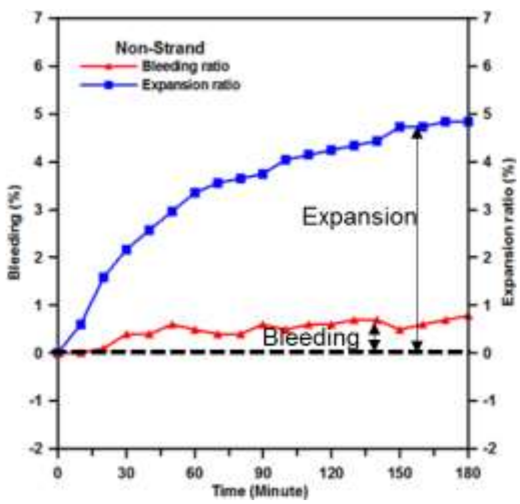


Figure 7. Bleeding ratio-expansion ratio relation of grout without tendon.

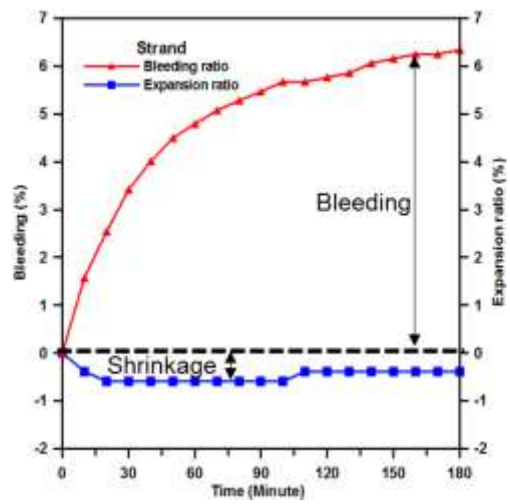


Figure 8. Bleeding ratio-expansion ratio relation of grout with tendon arrangement.

## 4 CONCLUSIONS

This study undertook an investigation on the workability, bleeding, and volumetric change of the grout widely used in Korea in order to secure the quality of the grout applied in prestressed concrete bridge. In terms of workability, all of the samples considered in this study satisfied the criteria for the grout specified in Korea. The grouts with tendon arrangements (regardless of the grout product) showed an increase of bleeding by 5.7 to 6.7 times. In addition, the height and inclination of the grout samples were seen to have significant effect on the bleeding. The arrangement of tendons appeared to result in significant increases in the bleeding and shrinkage without expansion, even if expansive aluminum powder was used in the grout. Accordingly, it is necessary to establish a new testing method and to apply high-performance grout for securing the quality of the grout used in prestressed concrete bridges.

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