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A Study on the High-Flowing Concrete with Low Unit Weight of Cement

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Most compressive strengths commonly used in the construction field are in a range of 240 to 300 kgf/cm^2 at 28 days. To get this rage of strengths, however, high-flowing concrete requires cementitious binders more than 400 to 450 kg/m^3 for preventing segregation and sedimentation of aggregates. This amount of cementitious binder generates a large emission of excessive hydration heat, which may consequently induce harmful cracks in concrete structure. In order to reduce excessive hydration heat, thus, this paper aims at fabricating a high-flowing concrete under the condition that cement content is kept as low as 350 kg/m^3 by using viscose agents. In a parametric study, effects of cement types such as a ternary blended cement and Type V on the physical characteristics of high-flowing concrete were evaluated. In addition, the influence of viscosity was also investigated by applying two different viscose agents, one in a range of 6,000 to 10,000 cps and the others of 10,000 to 14,000 cps. In terms of chemical admixtures used in concrete mixture, the superplasticizer was Sulfonated Melamine-Formaldehyde Condensate with about 30,000 of molecular weight, and main component of viscose agent was HPMC (Hydroxy Propyl Methyl Cellulose). Slump flow was fixed at 50cm with different dosages of superplasticizer in weight.

Key words: High-flowing concrete, Viscose agent, Cement content

I. Introduction

The high performance concrete is generally defined as a concrete satisfying high strength, high durability and high fluidity simultaneously. In spite of specific meaning of this concrete, Europe and America have mainly concentrated on the development of high strength, but Asian countries have done on high fluidity.[1)]

In general, the high fluidity in high performance concrete can be related to a fabrication of concrete significantly improved on fluidity without material segregation in fresh concrete. In order to expect the improvement of fluidity accompanying with material segregation resistance, most widely used methods will be the increase of binder material contents, the addition of viscose agent, or both.

This study aims at developing high performance concrete, especially high-flowing concrete with low use of cement amount and the application of viscose agent. For this study, two different types of cements such as Type V cement (sulfate resistant cement) and ternary blended cement were used. Superplasticizer used was Sulfonated Melamine Formaldehyde Condensate, and Hydroxy Propyl Methyl Cellulose(HPMC) with 10,000 cps at 25°C and 2% solution with Brookfield viscometer was used as a viscose agent.

This study also has objectives of analyzing rheologically the effect of mixing properties on the material characteristics, and consequently of fabricating high-flowing concrete which has less slump loss with elapsed time

II. Experiments

2.1. Materials

In order to evaluate the fluidity of fresh concrete or mortar, various consistency-testing methods have been suggested by many researchers[2,4,5,7)] and a special trial has been taken for the standardization of these methods.[6)] In addition, a method to approach by investigating rheologically cement and mortar has ever been tried to get more precise characteristics of the fluidity.[5)] But a confirmative method is not defined yet.

The slump test, which is known to be one of the most popular tests used to measure the fluidity of concrete, is a method of only measuring a yield point in view of fluid mechanics, so it can not present a filling property of concrete. Enhancement of the filling property requires the maintenance of viscosity enough for cement paste or mortar not to create arching effect, but to keep fluidity. These yielding points or viscosity can be generally characterized and evaluated numerically through only various experiments.

This study paid attention to the phenomenon that viscosity of cement paste or mortar shall be developed by chemical interaction between water and a viscose agent, and the change of fluidity associated with the increase of viscosity can be controlled by the amount of superplasticizer addition. Based on this concept, at first, the response of fluidity and segregation resistance of concrete was investigated with different application of viscose agent. The types of vis-

Table 1. Types of Viscose Agents

Designated viscose agents	Viscosity
H1	6,000~10,000 cps
H2	10,000~14,000 cps

Table 2. Mixing Proportion of Concrete

W/C (%)	s/a (%)	G_{max}	Unit Weight (kg/m^3)				
			C	W	S	G	V.A*
49	52	25	350	171.5	885	856	0.343

where, C=cement, W=water, S=sand, G=gravel, V.A=viscose agent

cose agent used are listed in Table 1, and mixing proportion is shown in Table 2.

In this study, the value of a slump flow was fixed at 50 cm in consideration of pumpability in the field and economical problem. The decrease of slump flow due to viscose agent was controlled by addition of the superplasticizer of a Sulfonated Melamine-Formaldehyde Condensate, which has 40% of solid retention and 30,000 of molecules approximately. Main component of viscose agent was HPMC. Antifoaming admixture for the control of air content was added during mixing. Since large sizes of air bubbles were formed in concrete due to the addition of viscose agent, Vinsole resin-typed AE (air-entraining) surfactants were used for this control. The amount of air entrained in the concrete was fixed in the range of 4±1% in accordance with Korean Concrete Specification.

Type V cement for sulfate resistant and ternary blended cement were used and compared each other. In the case of ternary blended cement, but, it should be noted that only AE surfactant without any antifoaming admixture was applied to control the air entraining since sufficient air content was not observed in the mixture. Parametric study was carried out with different additions of viscose agent to basic mix proportion shown in Table 2.

2.2. Mixing procedure

Since interaction between constituent materials in concrete has a great influence on the fluidity of high-flowing concrete, mixing time and the order of adding constituents are most important.

In terms of mixing procedure, cement, sand and viscose agent powder measured were poured together in a forced-circulating mixer first. Then the mixer was operated for 2 minutes with speed of 38 rpm. Water mixed thoroughly with superplasticizer and air entraining agent was then added in the mixture. After operating the mixer for 1 minute, the gravel measured in a weight was finally added and then mixed for 2 minutes. Total time of mixing was 5 minutes. The procedure of pouring materials and mixing time are shown in Fig. 1.

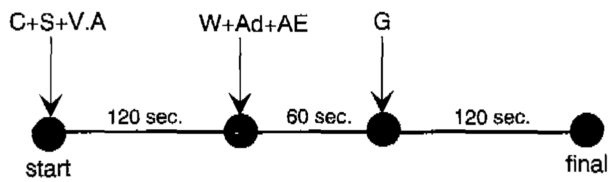

Fig. 1. Procedure and mixing time.

Table 3. Types of Tests and Measurement Items

Types of tests	Measurement items
Slump flow	Slump flow values (fixed at 50 cm)
U-typed re-bar penetration test	Re-bar spaces 7 cm
Slump loss test with elapsed time	30 min., 60 min.
Air content (Air receiver method)	4±1%
Compressive strength test	7 days, 28 days
Washing test of fresh concrete	Sampling of concrete 1 kg within the Dia. of 20 cm and 1 kg outside just after slump flow testing

III. Testing

After mixing, slump flow test was immediately carried out for measuring the fluidity of concrete and slump loss tests was performed after 0.5 to 1.0 hour are elapsed. Penetration resistance test was performed using a U-typed device spaced every 7 cm with reinforcing bars. Material segregation resistance was measured by washing the fresh concrete sampled after slump test. Specimens of ϕ10×20 cm were fabricated for compressive tests at 7 and 28 days. Kinds of tests and measurement items are listed in Table 3.

IV. Test Results and Discussion

4.1. Fluidity

In Type V cement, use of H1 and H2 viscose agents resulted in additional application of superplasticizer of 1.7 and 2.0% respectively in cement weight in order to get the slump flow of 50 cm. Meanwhile, ternary blended cement yielded additional superplasticizer of 0.2% to get the same value of slump flow. Both cements showed that slump loss was 3 cm after 30 minutes and 7 cm after 60 minutes, respectively. When superplasticizer of 1.7% in cement weight was applied without viscose agent, however, initial slump was measured to be 21 cm in both cements and slump loss was more than 15 cm when 30 minutes were passed. The reason for these differences may be explained by that hydration of concrete added with viscose agent can be delayed because HPMC is a sort of levulose, and the amount of water required for the chemical hydration can be significantly reduced due to the effect of water retention of viscose agent, accordingly slump loss can be greatly decreased. Setting tests were carried out to verify this assumption, and it was observed that initial and final setting time of the concrete not applied with viscose agent were shortened more than 3 hours in compare with the case of applying viscose agent.

Both cements also revealed that the use of H2 agent required much more superplasticizer than that of H1 agent to get an identical consistency, and showed less slump loss as time elapsed. When Type V cement was used, slump loss was much less but the deviation of setting time was much larger than ternary blended cement.

Under the condition of not applying viscose agent, additional dosage of superplasticizer to concrete mixture was increased the size of slump but the condition of consistency was harsh.

Thus, it can be concluded from this study that proper amount of viscose agent should be applied so that a better quality of high-flowing concrete is to be fabricated with low application of cement.

4.2. Bar penetration test using U-typed device

Both of Type V and ternary blended cements showed almost similar results for bar penetration test when same viscose agent was used. But different characteristics of fluidity were observed depending on the types of viscose agents. When H1 agent was used, the speed of flowing inside U-typed device was faster than the case of H2 agent. But the fluidity was decreasing gradually, and finally due to effect of arching, it was halted suddenly after a certain time elapsed. The use of H2, in the meanwhile, showed continuous flowing of concrete for about 10 minutes without arching. It may be inferred that similar results irrespective of cement types may be due to that the bar penetration is not a function of material property depending on the cement types, but of the cement grading or other physical characteristics. The Result of Bar penetration test using U-typed device are listed in Table 3.

4.3. Air content

Air content was greatly dependent upon the types of cements used. Blended cement contained less air content than Type V cement. In the case of using ternary blended cement, therefore, the air content prescribed in this study could be easily accomplished by only addition of AE surfactant without the use of antifoaming admixture. However, Type V cement needed both of AE surfactant and antifoaming admixture to meet the prescribed air content, because the use of only antifoaming admixture resulted in the existence of larger sizes of air bubbles.

4.4. Washing Test of Fresh Concrete

When the concrete stopped moving in a slump flow test, approximate 1 kg were sampled within a flow diameter of 20 cm and the same amount were selected from outside. These samples were washed out thoroughly with running water on the #4 sieve, then were dried up and finally the ratio of the weight of aggregates sampled from inner diameter to outside was measured. When the viscose agents of H1 and H2 were applied, the ratios were about 95% and 97%

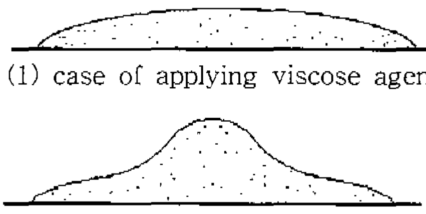

Fig. 2. Shapes of slump flow.

Table 4. The Results of Slump Loss

Cement	Viscose agent	The amount of superplasticizer (%)	Slump loss (cm)	
			30 min	60 min
Type V	H1	1.7	3.0	7.0
	H2	2.0	2.8	6.5
ternary blended cements	H1	1.9	2.5	7.0
	H2	2.2	2.3	6.5

Table 5. The Result of Bar Penetration Test Using U-typed Device

Viscose agent	Type V (cm)		ternary blended cements (cm)	
	5 min	10 min	5 min	10 min
H1	6.3	4.0	6.5	3.7
H2	7.3	2.5	7.5	2.2

respectively. But the ratio of the case not using viscose agent was less than 75%. Shapes of slump flow in these cases are shown in Fig. 2.

(1) case of applying viscose agent (2) case of not applying viscose agent

4.5. Strength

In early aged concrete, compressive strength of ternary blended cement was slightly larger than that of Type V. Averaged compressive strength at 7 day ages were 110 kgf/cm^2 for Type V cement and 120 kgf/cm^2 for blended cement. But, at 28 days strengths of both cements were same as 325 kgf/cm^2. As for the addition of chemical admixture, the effect of viscose agent or superplasticizer on the strength was not observed in this study. The reason of lower strength when Type V cement was used may be due to that in compare with blended cement, Type V cement contains smaller amount of C_3A which is one of chemical components in cement and is mainly related to early hardening of cement. It is inferred that this may cause a slower development of early strength accordingly.

V. Conclusions

1. When high-flowing concrete is to be made with low application of cement content, viscose agent should be necessarily applied. The amount should be properly deter-

mined depending on the viscosity of agent and capacity of water retention associated with the purpose, applying method, and others.

2. Not much differences between Type V and ternary blended cement were observed in fabricating high-flowing concrete, but some differences were in air content. Blended cement had a larger compressive strength at early age.

3. In terms of slump loss, viscose agent(HPMC) and SMF(Sulfonated Melamine-Formaldehyde Condensate) worked well in a mutual incorporation. The slump loss had a close relation between the amount of superplasticizer and the viscosity of viscose agent.

4. Type V cement showed less slump loss, but larger deviation of setting time than blended cement. Therefore, it can be concluded that the quality control of concrete at early age is easier in Type V, while productivity is much better in ternary blended cement.

5. The greater viscosity was, the less the material segregation. The same phenomenon could be observed in filling property also.

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