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Experimental Study on Improvement of Concrete Pumpability By External Injection Method

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ABSTRACT

In this study, a new method was proposed to improve concrete pumpability. The friction can be reduced by externally injecting a small amount of agent for lubricating layer, which is formed itself in the vicinity of the inside pipe wall. The agent reduces the pumping pressure by reducing viscosity of lubricating layer.

To investigate the effect of the method, real-scale concrete pumping tests were performed with 112, 137 and 514 m long pipelines. In the pipelines, the injection point was located in front of the pump, and the agent was injected into the pipe with 16-way nozzles located with uniform distance over one cross-section of the pipe. In the tests, three concrete mixtures were used, and the injection rate of the agent varied from 0.077 % to 0.284 % of concrete volume. As the injection rate increased, the pumping pressure was decreased. It was observed that the pumping pressure decreased from 26.6 % to 60.2 %. There was no significant change in the compressive strength due to the addition of the agent to the concrete.

1. INTRODUCTION

Concrete pumping is a casting method used in most construction sites because it has the advantage of being able to freely change of shape, distance and height of structure. Recently, large-scale concrete structures such as high-rise building, long-span bridge, long-distance tunnel are being constructed and efforts have been made to improve pumpability(flow rate and distance) of concrete. The factors influencing pumpability of concrete are the capacity of pump(maximum pressure and maximum flow rate), the diameter of pipe, the rheological properties(plastic viscosity and dynamic yield stress) of concrete, and the rheological properties of lubricating layer formed itself in the vicinity of the inside pipe wall(Kwon et al. 2013a, Kwon et al 2013b, Jo et al. 2012). The method of changing pump and pipe is economically and technically limited. In the real field, efforts are being made to improve rheological properties of concrete and lubricating

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layer through repetitive mixture design and to satisfy target pumpability(Lee et al. 2013, Lee et al. 2014). However, it is difficult to develop the optimized proportion of concrete due to locality and economic limitation.

According to existing studies, the plastic viscosity of lubricating layer is the most influential factor in concrete pumpability(Kwon et al. 2013a, Kwon et al. 2013b). Therefore, if the plastic viscosity can be reduced, the pumpability will be greatly improved. In this study, a new method of injecting viscosity reducing agent for lubricating layer into the vicinity of the inside pipe wall is proposed to improve concrete pumpability. To investigate the effect of the method, real-scale pumping tests were performed.

2. EXTERNAL INJECTION METHOD

Fig. 1 schematically describes the mechanism of external injection method. During pumping, the thin lubricating layer is formed itself between pipe wall and concrete. Since the plastic viscosity of lubricating layer is considerably lower than that of concrete, the velocity inside the pipe is mostly formed in the lubricating layer(Kwon et al. 2013a, Kwon et al. 2013b, Le et al. 2015). When the small amount of viscosity reducing agent is injected into the pipe, the plastic viscosity is further lowered. The decrease of the plastic viscosity means that the flow rate of concrete increases under the same pressure condition.

Fig. 2 provides a schematic description on the improvement of pumpability due to reduction of the viscosity. Relationship between pumping pressure and flow rate of concrete is linear. When the agent is injected into the lubricating layer, the slope of linear relationship is decreases. In other words, the flow rate increases at the same pressure, or the pressure to obtain the same flow rate decreases.

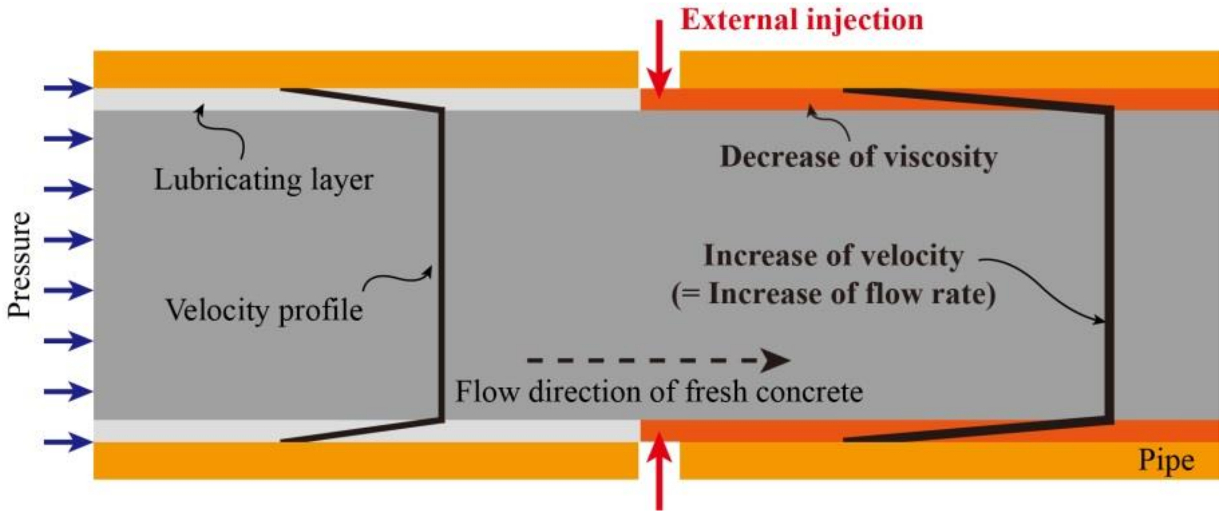

Fig. 1 Mechanism of external injection method

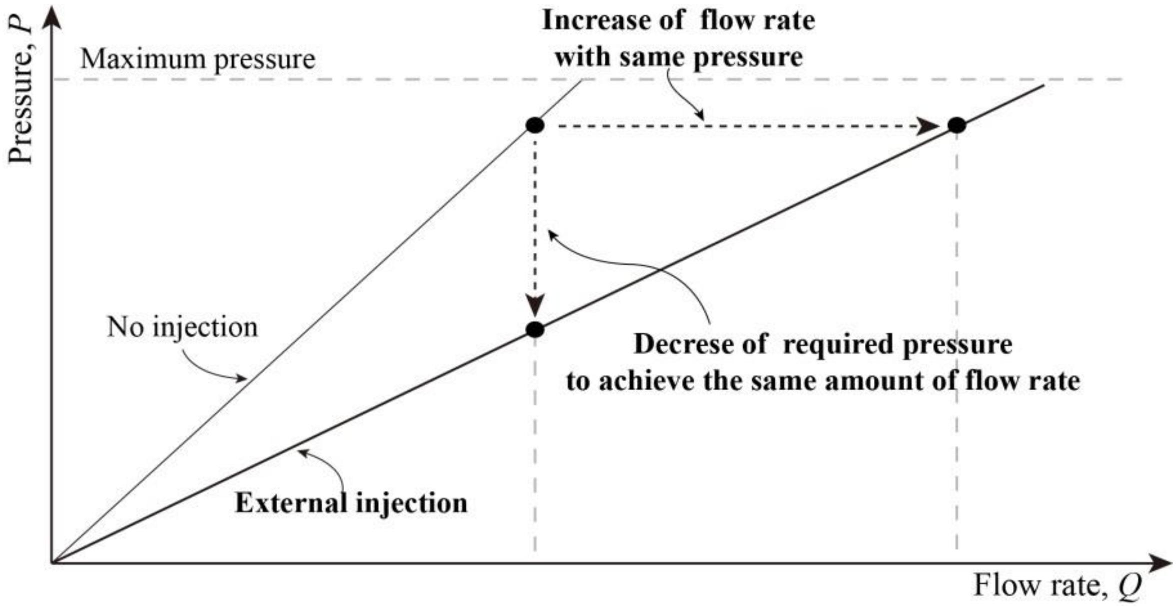

Fig. 2 Improvement of pumpability by injecting viscosity

Fig. 3 shows the injection device. The device consists of a control unit for injection speed and an injection unit for uniform placement of the viscosity reducing agent. The maximum injection pressure was 300 bar, and the injection rate was adjustable in the range of 1-10 L/min. In addition, 16-way nozzle was installed in the radial direction of the pipe so that the agent was uniformly placed inside the pipe.

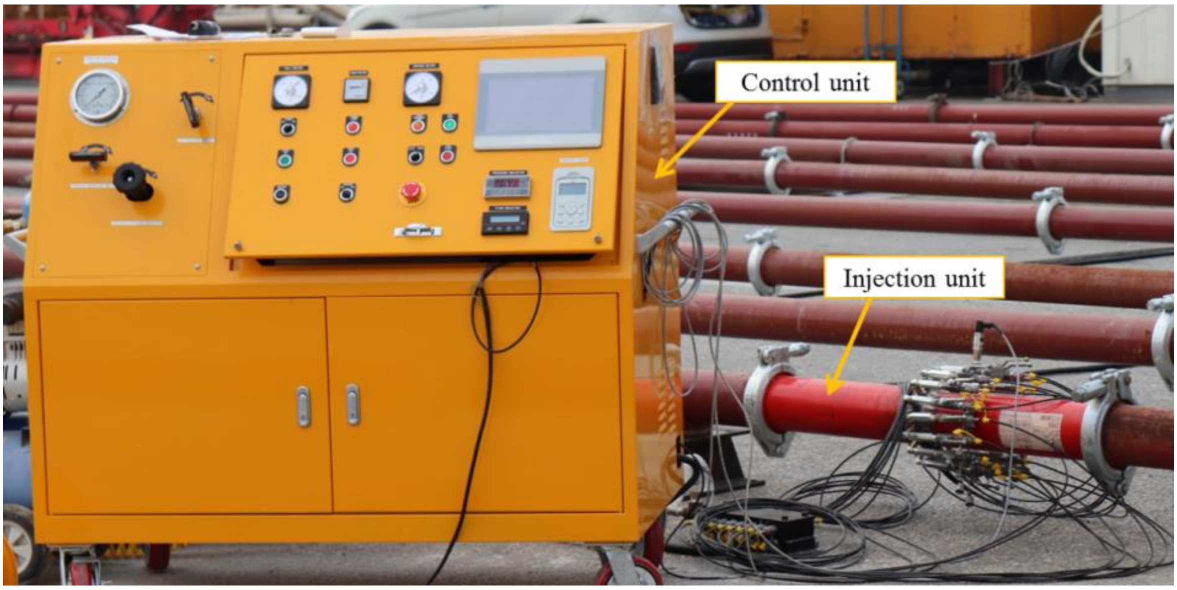

Fig.3 Installation of injection device in the pumping circuit

3. Real-scale pumping test

3.1 Concrete mixtures and viscosity reducing agent

Table 1 shows concrete mixtures used in pumping tests. Mix.1 and Mix.2 were concrete mixtures with low fluidity. Mix.3 was high flowable concrete mixture. The agent used in pumping tests was polymer surfactant.

Table 1 Mix proportions of concrete used in pumping tests

Material	Unit weight (kg/m$^{3)}$		
	Mix.1	Mix.2	Mix.3
Water	170	160	170
Cement	214	277	473
Granulated blast-furnace slag	66	85	159
Fly ash	49	64	0
Fine aggregate	893	827	693
Coarse aggregate (25 mm)	905	906	861
AD*	2.14	2.98	7.58

* Water reducing admixture

3.2 Pumping circuit

Concrete pumping tests were performed with the pipelines of three different lengths. Fig. 4 shows the installation view of 112 m long pipeline. Fig. 5 shows the details of the pipeline, location of pressure sensor, and injection point. Fig. 6 shows the installation view of 514 m long pipeline. Fig. 7 and Fig. 8 describes the detail of 137 m pipeline and 514 m pipeline, respectively.

3.3 Test method

Real-time pressure variations were measured using a pressure sensor during concrete pumping. In order to investigate improvement of pumpability according to injection rate, the amount of injection rate was varied from 0.75 to 2.00 L/min. Also, in order to confirm the influence of the agent on the compressive strength of concrete, compressive strength tests were performed using specimens. Diameter of specimen was 100 mm and height was 200 mm. The tests were performed at 28 days of age.

4. Experimental results and discussion

4.1 Pressure

Fig. 9 shows real-time pressure data measured from pumping test. After external injection of the agent, the pumping pressure gradually decreased and converged to a constant value after certain period time. In order to quantitatively evaluate pressure drop according to the amount of injection rate, the average pressure was calculated from measured pressure as shown in Fig. 10.

Fig. 4 Installation of 112 m pipeline

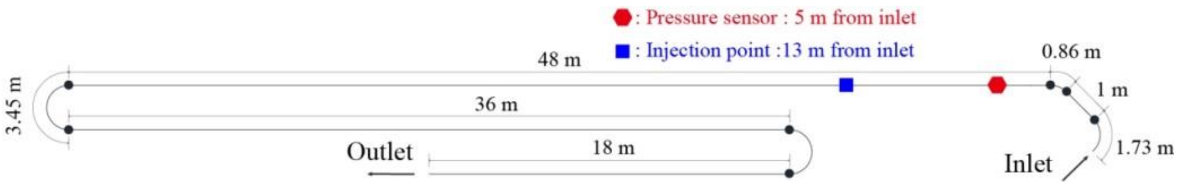

Fig. 5 Detail of 112 m pipeline(L1)

Fig.6 Installation of 514 m pipeline

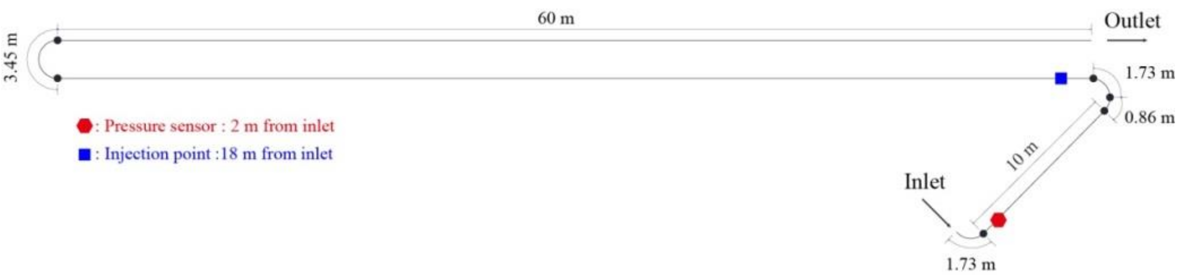

Fig. 7 Detail of 137 m pipeline(L1)

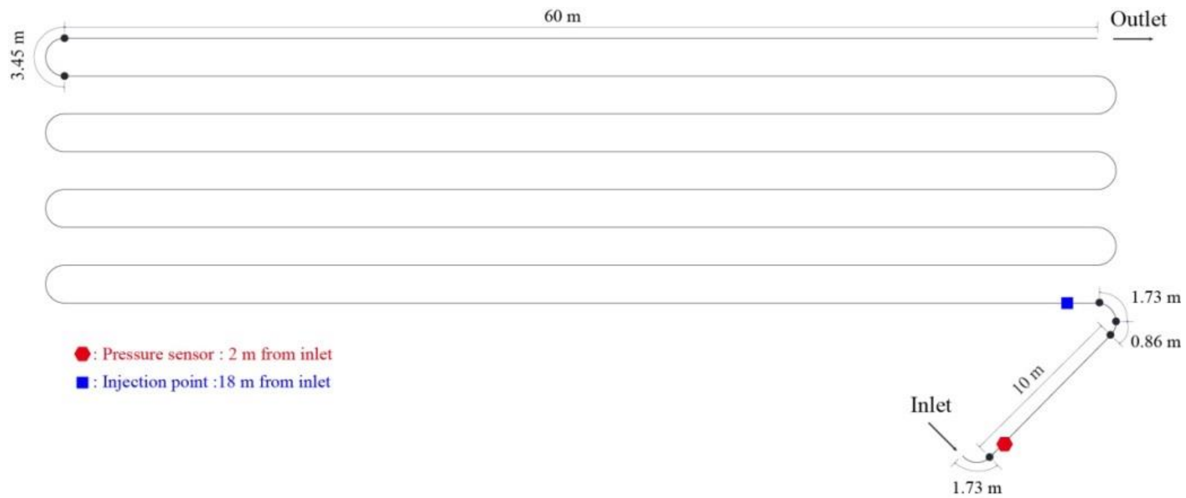

Fig. 8 Detail of 514 m pipeline(L3)

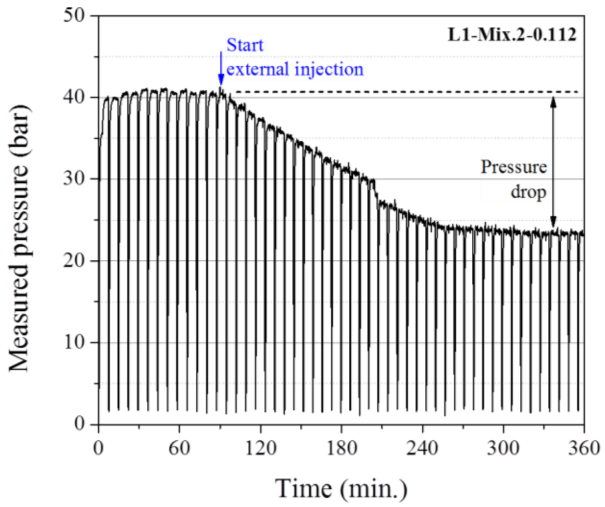

Fig. 9 Measured pressure during pumping

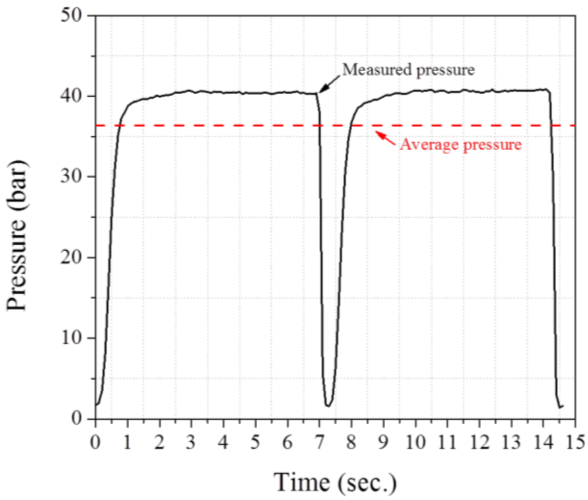

Fig. 10 Average pressure

Table 2 shows the ratio(ρ_c) of viscosity reducing agent volume to concrete volume, average pumping pressure before external injection, and average pressure after external injection. The pressure decreased greatly after external injection of the agent. The parameter ρ_c can be calculated as follows.

$$\rho_c = \frac{Q_a}{Q_c} \times \frac{60}{1000} \tag{1}$$

Where, Q_a is injection rate of viscosity reducing agent (L/min.), Q_c is flow rate of concrete (m^3/h).

Table 2 Average pressure before and after external injection

Type of pipeline	Type of concrete	Injection rate, ρ_c (%)	Average pressure (bar)	
			No injection	External injection
L1	Mix.1	0.088	29.6	18.6
		0.120	28.3	14.6
		0.136	16.0	7.9
	Mix.2	0.077	31.6	15.0
		0.112	33.0	15.1
		0.126	22.6	9.0
	Mix.3	0.129	42.4	30.2
		0.147	39.0	26.3
		0.192	31.8	17.6
L2	Mix.1	0.125	21.4	9.9
		0.188	24.0	10.3
		0.250	23.4	9.4
	Mix.3	0.123	75.2	55.2
		0.200	71.3	40.7
		0.284	100.3	52.3
L3	Mix.1	0.190	62.8	26.3

Fig. 11 shows the relation between ρ_c and pressure drop(r_p) according to concrete mixture. Pressure drop, r_p can be calculated following Eq. (2),

$$r_p = \frac{P_{NI} - P_{EI}}{P_{NI}} \times 100 \tag{2}$$

Where, P_{NI} is averaged pressure before external injection (bar), P_{EI} is averaged pressure after external injection (bar).

As injection rate increases, pumping pressure decreases further. The pressure decreased from a minimum of 26.6 % to a maximum of 60.2 %. In the same ρ_c, pumpability of Mix.1 and Mix.2 are greatly improved than Mix.3.

4.2 Strength

Fig. 12 shows variation of compressive strengths according to injection rate ρ_c. Mix.1 and Mix.2 have no change in compressive strength even when ρ_c increases. Compressive strength of Mix.3 was slightly reduced when ρ_c was greater than 0.2 %. However, considering inevitable experimental error or uncertainty of concrete property, the compressive strength due to external injection seems to be unchanged.

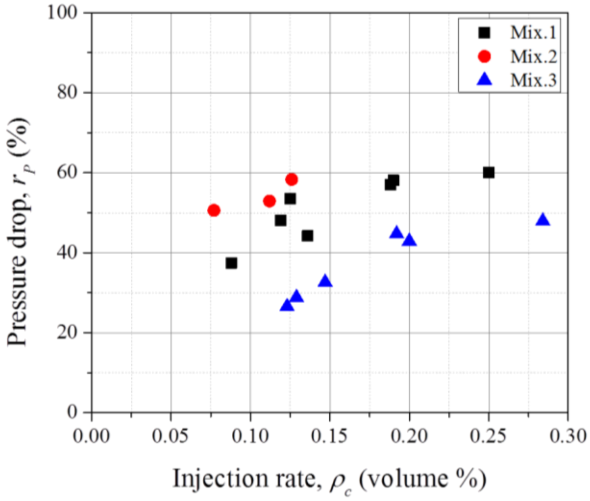

Fig. 11 Relationship between injection rate(ρ_c) and pressure drop(r_p)

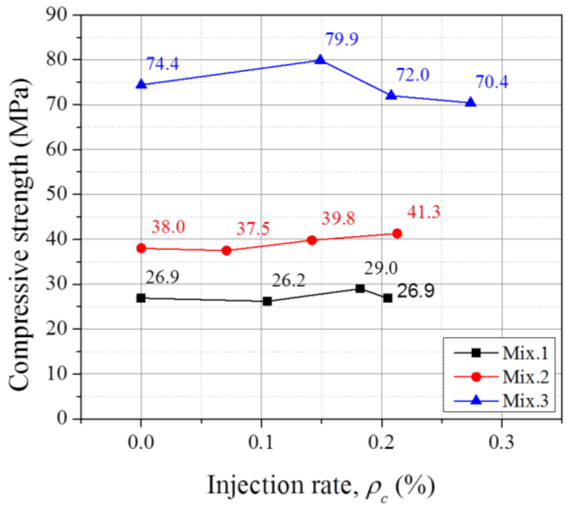

Fig. 12 Variation of compressive strength according to injection rate

5. CONCLUSIONS

Based on the results of this experimental investigation, the following conclusions are drawn:

1. In this study, a new method to externally inject viscosity reducing agent for lubricating layer was proposed.
2. Real-scale pumping tests using three concrete mixtures were performed and real-time pressure was measured during the pumping. It was confirmed that the pumping pressure significantly decreased from 26.6 % to 60.2 % after injecting the agent.
3. Compressive strength of concrete mixtures were measured at 28 days of age. The change in compressive strength due to external injection was insignificant.

6. ACKNOWLEDGEMENT

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REFERENCES

Jo, S. D., Park, C. K., Jeong, J. H., Lee, S. H., and Kwon, S. H. (2012), “A Computational Approach to Estimating a Lubricating Layer in Concrete Pumping”, *Computers, Materials and Continua*., **27**, 189-210.

Kwon, S. H., Park, C. K., Jeong, J. H., Jo, S. D., and Lee, S. H. (2013a), “Prediction of Concrete Pumping: Part I–Development of New Tribometer for Analysis of Lubricating Layer”, *ACI Material Journal.*, **110**, 647-656.

Kwon, S. H., Park, C. K., Jeong, J. H., Jo, S. D., and Lee, S. H. (2013b), “Prediction of Concrete Pumping: Part II–Analytical Prediction and Experimental Verification”, *ACI Material Journal*., **110**, 657-668.

Le, H. D., Kadri, E. H., Aggoun, S., Vierendeels, J., Troch, P., and Schutter, G. D. (2015), “Effect of Lubrication Layer on Velocity Profile of Concrete in a Pumping Pipe”, *Materials and Structures.*, **48**, 3991-4003.

Lee, S. H., Kong, T. W., Lee, H. B., Kang, M. G., Kim, S. H., and Jeon, H. K. (2014), “The Evaluation Before and After Pumping Lightweight Concrete According to the Type of Lightweight Aggregate”, *In Proceedings of the Korea Concrete Institute.*, 347-348.

Lee, T. W., Moon, H. J., Kim, Y. H., Kim, G. D., Choi, Y. S., and Heo, J. U. (2013), “Evaluation of Concrete Properties at the Stage of Before and After Pumping under Different Binder Contents”, *In Proceedings of the Korea Concrete Institute*., 59-60.