SELF-COMPACTABILITY OF FRESH CONCRETE IN TERMS OF DISPERSION AND COAGULATION OF PARTICLES OF CEMENT SUBJECT TO PUMPING

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1. INTRODUCTION

The purpose of this paper is to clarify the mechanism of the change in the flowability of SCC due to pumping. Reduction in the self-compactability of fresh concrete due to pumping has been reported and it has become one problem on the construction of the self-compacting concrete.

It is laborious and dangerous to take the sample of concrete just after pumping. The authors assumed that both normal and shear stress are generated in the mortar during pumping of the concrete (**Fig. 1**). The shear stress is supposed to be generated due to the friction between the concrete and the wall of the pumping pipe resulting in the distribution of the speed of the concrete through the pipe.

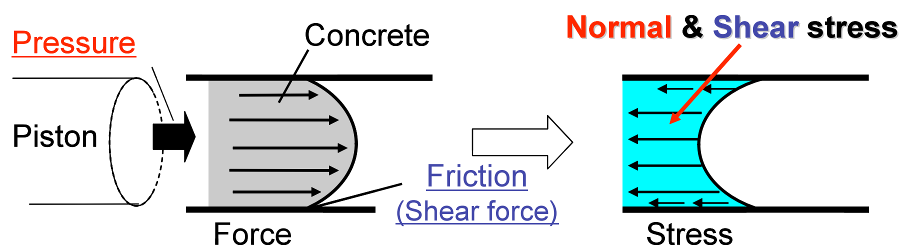

Fig. 1 Stress generated in mortar of self-compacting concrete due to pumping

In this paper, the mechanism of the change in the flowability of self-compacting concrete, especially in the reduction of the deformability was clarified in terms of the dispersion and coagulations of particles of cement and the amount of adsorption of superplasticizer to the cement.

2. HYPOTHESIS FOR MECHANISM OF REDUCTION IN DEFORMABILITY AND REDUCTION IN PLASTIC VISCOSITY OF MORTAR OF SCC

The authors have set up the hypothesis for the mechanism of reduction in the deformability of the mortar of SCC due to pumping, in which the coagulated particles of the cement was dispersed due to the stress resulting in the reduction in the amount of the superplasticizer adsorbed to the surface of the particles of the cement and also the increased free water from the coagulated particles of the cement reduced the plastic viscosity of the mortar (**Fig. 2**).

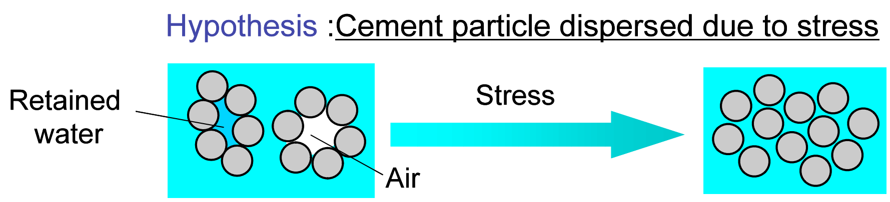

Fig. 2 Particle of cement dispersed due to stress

3. METHODOLOGY TO VERIFY HYPOTHESIS

The authors have set up a new sampling method of the mortar of the self-compacting concrete subject to pumping not in the real construction site but in the laboratory because the sampling of the mortar after pumping is very laborious and dangerous. The normal stress was generated by applying the normal force to the mortar in the pressurized bleeding test's vessel at 8.8 MPa and the shear stress was generated by re-mixing of the mortar at 285 rpm that has already been mixed (**Fig. 3**). The authors have already verified the effectiveness and efficiency of the method [**1**].

The influence of the stress was examined by comparing between the mortar with subject to the stress and that without subject to stress at the same time after the initial mixing (**Fig. 4**).

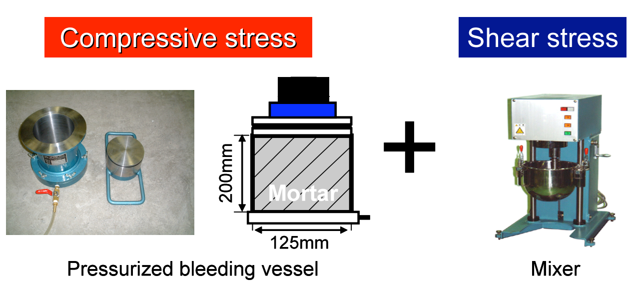

Fig. 3 Method to reappear stress generated in mortar

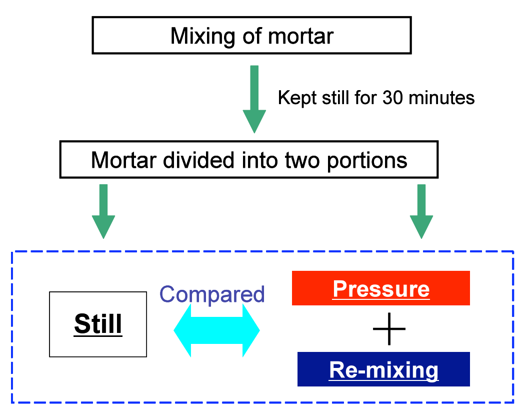

Fig. 4 Method to examine influence of stress

The flowability of the mortar was tested by mortar flow and funnel tests (**Fig. 5**). The indices for the flowability were the relative flow area ***Gm*** and the relative funnel speed ***Rm*** defined by Okamura and Ozawa, in which

$$\boldsymbol{Gm} = (d_1 * d_2 - d_o^2)/d_o^2$$

d_1, d_2: diameter of mortar flow (mm); d_o: diameter of flow corn (mm)

$\boldsymbol{Rm} = 10/t$; t: discharging time through funnel (sec).

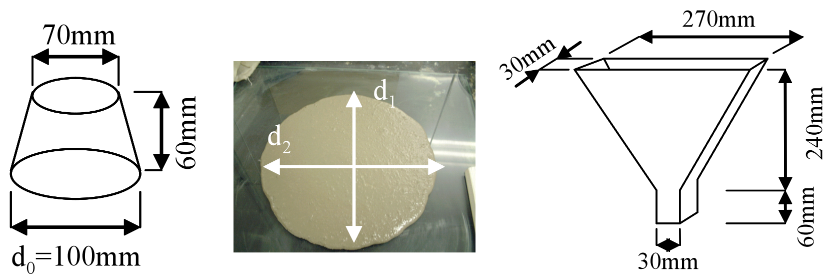

Fig. 5 Flow and funnel tests for SCC

The dispersion of the particles of cement was examined by the specific surface area by BET and also the compressive strength was tested. The amount of superplasticizer adsorped to the particles of cement was measured by the total organic carbon measurement (TOC).

The mix-proportioning of the mortar is shown (**Table 1**) by applying the typical mix-proportioning of SCC used in Japan. **A-1** was the standard mix and **A-2** had higher dosage of superplasticizer (SP). **B-1** and **C-1** had higher and lower water to cement ratio respectively. The cement in use was low-heat portland cement (specific gravity of 3.22 g/cm^3) with high belite content, the fine aggregate was crushed sand (2.72 g/cm^3; F.M. of 3.00) and poly-carboxylate type of superplasticizer was employed.

Table 1 Mix-proportioning

No.	W/C (%)	s/m (%)	SP/C (%)	Mix-proportioning (kg/m^3)			
				W	C	S	SP
A-1	28.6	45	0.78	264	922	1224	7.19
A-2	28.6	45	0.85	264	922	1224	8.76
B-1	29.8	45	0.78	269	904	1224	7.05
C-1	27.0	45	0.78	256	947	1224	7.39

4. EXPERIMENTAL RESULTS

4.1 Change in Flowability due to Stress

The influence of the duration of applying force (For example, "1 minute" means 1 minute compressive force and then 1 minute shearing force) was clear despite of the difference in the mix-proportioning. Longer duration of applying force resulted in much smaller deformability (***Gm***) and slight reduction and then increase in the plastic viscosity (inverse of ***Rm***) of the mortar (**Fig. 6**).

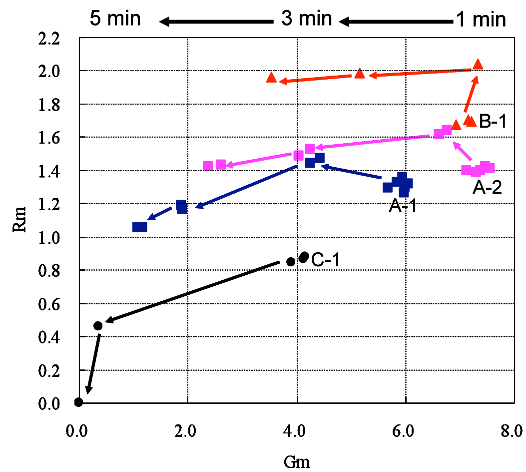

Fig. 6 Change in flowability due to normal and shear stress

4.2 Dispersion of Particles of Cement

The compressive strength at the age of 7 days was tested for the mortar subject to each duration of applying force to expect the change in the dispersion of the particles of the cement due to the stress. Higher duration of applying force resulted in higher strength. It is possible that the particles of cement were dispersed more due to the stress.

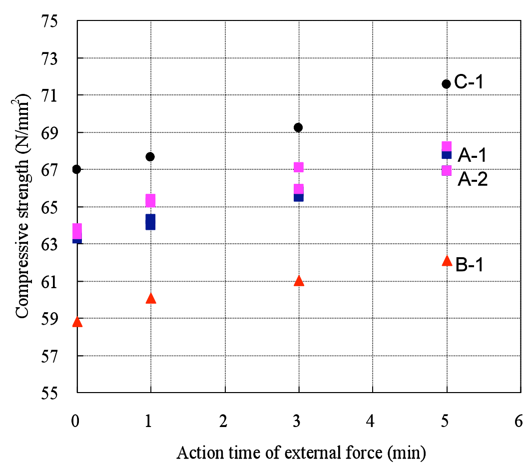

Fig. 7 Larger duration of applying force resulted in higher strength

4.3 Amount of Superplasticizer adsorped to Cement per Unit Surface Area of Particles of Cement

The amount of superplasticizer adsorped to the surface of the particles of cement was obtained by total organic carbon measurement (TOC) (**Fig. 8**). Longer duration of applying force resulted in the larger amount of superplasticizer adsorped to the cement. Also, the change in the specific surface area of the particles of cement was measured by BET (**Fig. 9**). Larger duration of applying force resulted in the larger surface area of the parcticles of cement. Finally, the amount of superplasticizer adsorped to cement per unit surface area of particles of cement was obtained by using the data obtianed above.

Larger duration of applying force resulted in the smaller amount of superplastuicizer adsorped to the unit surface area (**Fig. 10**).

According to the previous research, smaller amount of superplasticizer adsorbed to unit surface area of the particles of cement resulted in the smaller deformability of the mortar of SCC as shown in **Fig. 6** [2]. That corresponded to the result obtained in this study. The hypothesis was proved.

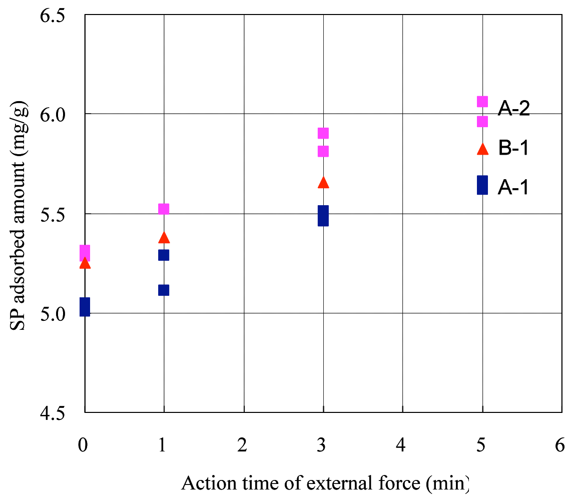

Fig. 8 Longer duration of applying force resulted in larger amount of SP adsorbed to particles of cement

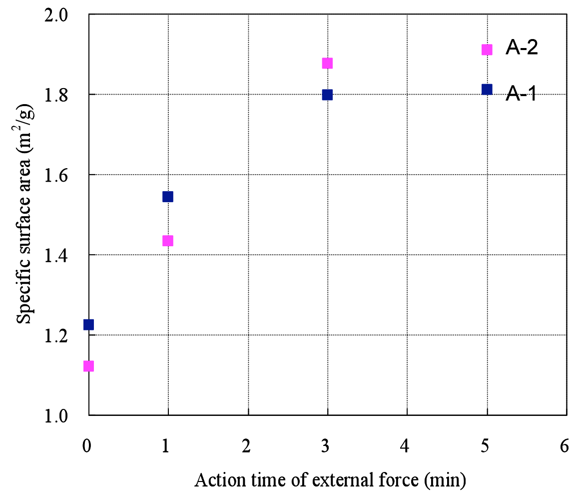

Fig. 9 Longer duration of applying force resulted in larger surface area resulting from higher dispersion of particles of cement

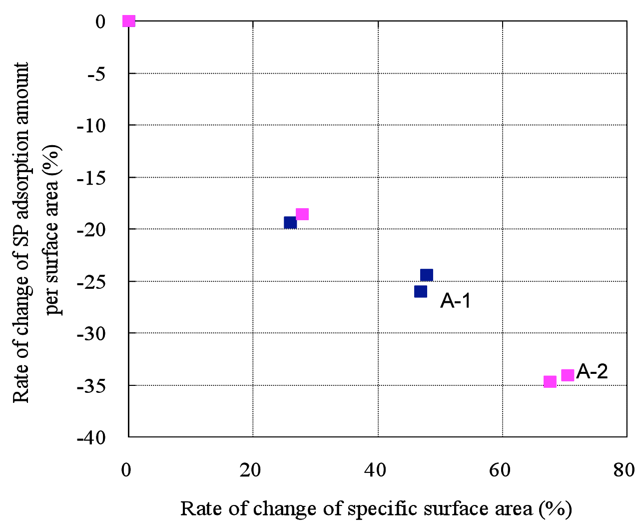

Fig. 10 Larger surface area of particles of cement resulted in smaller amount SP adsorbed to unit surface area of cement despite of increase in total amount of SP adsorbed

5. CONCLUSIONS

The purpose of this research was to clarify the mechanism of the change in the flowability of SCC due to pumping. The authors have set up a hypothesis for the mechanism, in which the particles of the cement in the concrete can be dispersed more resulting in both the larger surface area of the particles and the more free water, and the repulsing effect by the superplasticizer can be reduced. The mortar was subject to both simulated normal and shear stress in the laboratory and the mechanism was examined in terms of the dispersion of the particles of cement and the adsorption of superplasticizer in order to prove the hypothesis. BET surface area and the amount of adsorption of the superplasticizer were measured. It was found that the amount of superplasticizer adsorbed to the unit surface area of cement subject to the stress was reduced corresponding to the reduction in the deformability of the fresh mortar of SCC. The hypothesis was proved.

REFERENCES

[1] Sakue, J., and Ouchi, M.: Reappearance of change of flowability of self-compacting concrete due to pumping, Proceedings of the 2nd fib Congress (CD-ROM), ID: 13-40, Napoli, 2006.

[2] Sugamata, T., Hibino, M., Ouchi, M., and Okamura, H.: A Study of the Particle Dispersion Effect of Polycarboxylate-based Superplasticizers, Transactions of the Japan Concrete Institute (JCI), Vol. 21, pp.7-14, 2000.