Change in Flowability of Self-Compacting Concrete due to Pumping

Jiro SaAKUE and Masahiro OUCHI
Kochi University of Technology, JAPAN

***ABSTRACT*:** The mechanism of the reduction in the flowability of self-compacting concrete due to pumping was clarified. Compressive and shearing force were applied to the mortar of self-compacting concrete. 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 the larger surface area of the particles, and then the repulsing effect by the superplasticizer can be reduced. The chemical analysis was carried out to prove the hypothesis. BET surface area and the amount of adsorption of the superplasticizer were measured. Also, the compressive strength was tested. The hypothesis was proved.

KEYWORDS: self-compacting concrete, pumping, external force, dispersion of cement particles

1. INTRODUCTION

Large improvement of execution is expected by pumping of self-compacting concrete. However the change in flowability of self-compacting concrete due to pumping has become one problem related to the construction of the concrete. Flowability improves or reduces adversely. It is a premise that self-compacting concrete fills up formwork only for action of gravity. Therefore the flowability change may hinder the construction. Various types of change in the flowability have been reported, but the mechanism responsible for this phenomenon has not been clarified.

The purpose of this research is to clarify the mechanism of the change in the flowability of SCC due to pumping. Above all, the author performed mechanism elucidation of a flowability decrease.

It is asuumed that both compressive and shear stress are generated in the mortar during pumping. The authors have set up a new testing method by which the stress generated in the mortar due to pumping may be reappeared. The concept is shown in **Fig.1**. Compressive force was applied to the mortar due to pressurizing bleeding vessel. And re-mixing after the mixing was done for the shearing stress. As it turned out, the change in flowability can be reappeared by applying these two types of force [1]. Assuming that the dispersed cement particles have an effect, they have an effect on the reduction in the flowability due to action of compressive stress and shearing stress. Therefore the authors examined it from the measurement of the compressive strength, amount of superplaticizer adsorped to cement particles and the specific surface area of the cement particles by BET.

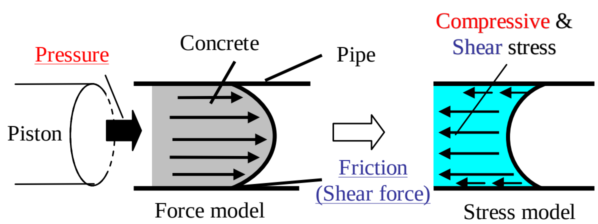

Fig. 1 Stress generated in concrete due to pumping

Table 1 Mix proportions

No.	W/C	s/m	SP/C	Unit weight (kg/m^3)			
	(%)	(%)	(%)	Water	Cement	Fine aggregate	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

Table 2 Materials

Material	Specifications
Low-heat portland cement	Specify gravity: 3.22
Crushed sand	Specify gravity: 2.72; FM:3.00
Superplasticizer	Polycarboxylate type

2. METHODOLOGY

2.1 Materials and mix proportions

The mix-proportioning of the mortar is shown in **Table 1** and the materials are shown in **Table 2**. The practical mix-proportioning of self-compacting concrete's mortar was assumed.

2.2 Apply of external force to mortar

The pressure to the SCC's mortar was 8.8 MPa with the pressurizing bleeding vessel to generate compressive stress in the mortar. Also, re-mixing speed was 125 rpm on the axis and paddle revolved at 285 rpm to generate shear stress in the mortar. The duration of the pressure and re-mixing was one, three or five minutes respectively.

2.3 Test method for flowability of mortar

First, mortar was mixed. The mixing speed was 125 rpm on the axis and paddle revolved at 285 rpm. Next, the mortar was kept still afterwards at up to 30 minutes assuming the time between the batching plant and the casting site. After that the mortar was divided into two portions. One portion was subjected to pressurization test and re-mixing for compressive and shear stress. Another portion was kept still.

After that, flow and funnel tests were carried out for each portion of the mortar. These tests were carried out at almost the same time so that the influence of the time may be minimized. And, the flowability of the two pars of mortar was compared. The influence of the external force was evaluated by comparing the two pairs of flowability test results.

(1) Deformability Gm and Viscosity Rm

The mortar flow employed the mortar flow corn (**Fig. 2**). And the deformability was obtained with **(1)**. The discharging time through funnel was measured using the funnel test (**Fig. 3**). And the index for the viscosity was obtained with **(2)**. The evaluation of flowability used two indexes [3].

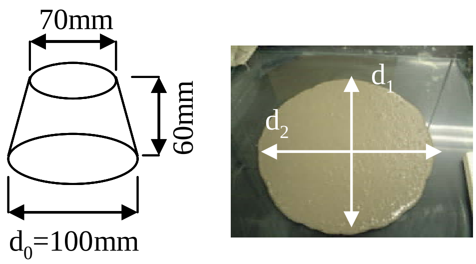

Fig. 2 Mortar flow test

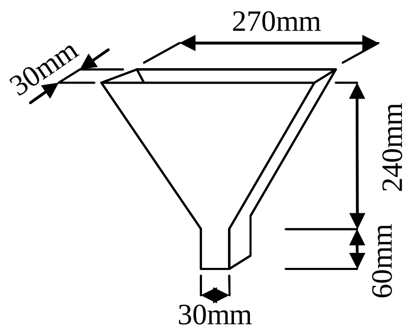

Fig. 3. Mortar funnel test[2)]

$$Gm = (d_1 * d_2 - d_o^2)/d_o^2 \quad (1)$$

$$Rm = 10/t \quad (2)$$

d_1,d_2: diameter of mortar flow (mm)

d_o: diameter of flow corn (mm)

t: discharging time through funnel (sec)

(2) Compressive strength test

The compressive strength was tested for the cylinder of ϕ 50 * 100 mm at the age of 7 days in the standard curing method.

(3) Amount of superplasticizer adsorbed to cement

Chemical structure of superplasticizer is shown in **Fig. 4**. The amount of superplasticizer adsorbed to cement was measured for per cement 1g by the measurement of the amount of carbon included in the fluid phase of the mortar. The fluid phase of mortar was triggered with the gravity of about 7000 G for five minutes with a centrifuge to extract it, and it was measured by the total organic carbon measurement.

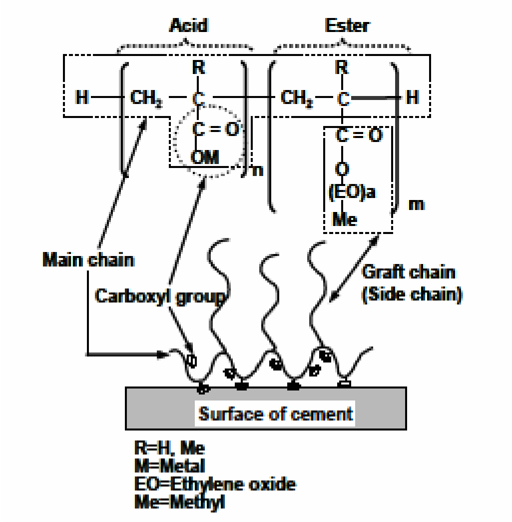

Fig. 4 Molecular structure of superplasticizer

(4) Specific surface area of cement

The specific surface area of the cement was measured by BET method. Firstly hydration reaction of mortar was stopped by the acetone. Secondly it was dried in at 40 degrees centigrade for 24 hours. Finally cement of less than 75mm diameter was sampled. The specific surface area was measured for A-1 and A-2.

3 EXPERIMENTAL RESULTS

3.1 Influence on flowability due to external force

The change in the flowability of the mortar due to the external force is shown in **Fig. 5** to **7**. The changes in the flowability due to the external force were different by the dosage of SP or the unit water content of the mortar.

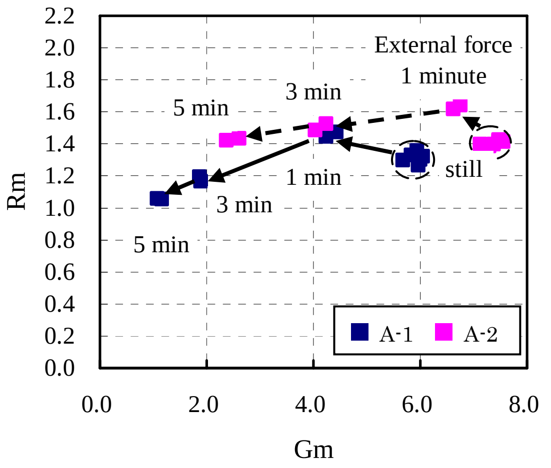

Fig. 5 Change in flowability due to external force: difference in SP dosage

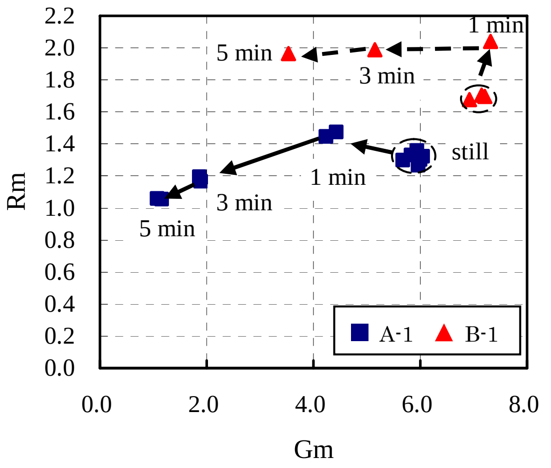

Fig. 6 Change in flowability due to external force: difference in water to cement ratio

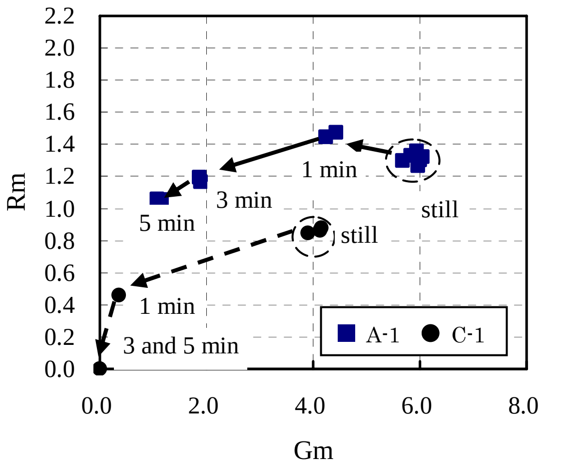

Fig. 7 Change in flowability due to external force: difference in water to cement ratio

The relationship between the duration of applying the external force and the rate of change in the deformability is shown in (**Fig. 8**). The deformability was reduced due to the external force. When the water to cement ratio or the dosage of SP was high, the reduction in the deformability was small. It was found from the result that when Gm was large, the influence of external force was small. If the viscosity before applying external force was low, the change in Gm was also small.

The rate of change of Rm is shown in **Fig. 9**. Rm of C-1 was reduced remarkably after one minute as well as Gm.

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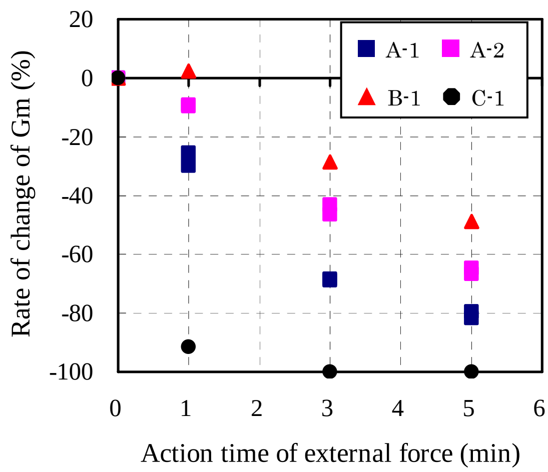

Fig. 8 Rate of change in deformability due to external force

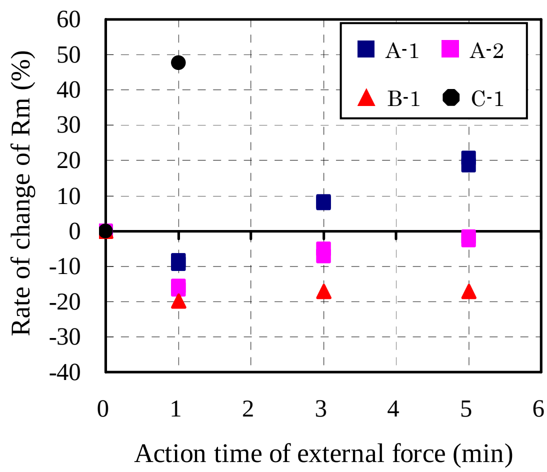

Fig. 9 Rate of change in viscosity due to external force

3.2 Influence on compressive strength

The relationship between the duration of applying the external force and the compressive strength is shown (**Fig. 10**). The compressive strength was increased with the increase of the duration of applying the external force despite of the type of the mix-proportioning. It is assumed that the external force dispersed the coagulated cement particles and it promoted the hydarion of the cement particles, which resulted in the higher compressive strength [4].

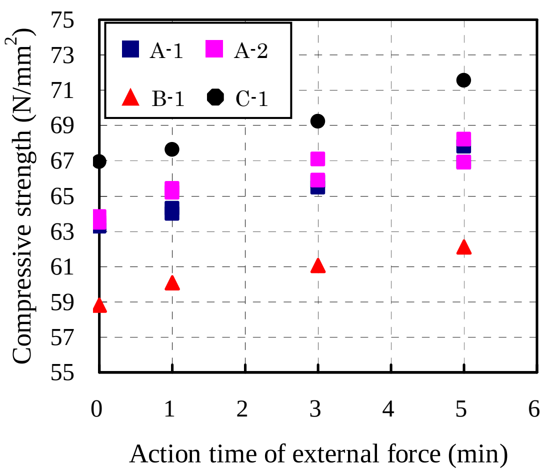

Fig. 10 External force increased compressive strength

3.3 Specific surface area of a cement particle due to action of external force

The external force increased the amount of superplasticizer adsorbed to cement (**Fig. 11**). However, the deformability was reduced although the deformability was reduced.

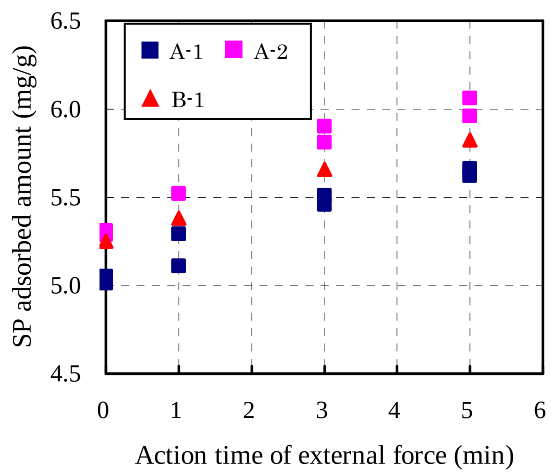

Fig. 11 External force increased adsorption of superplasticizer to cement

Also, the specific surface area of cement particle was measured for A-1 and A-2 (**Fig 12**) by BET method. The specific surface were increased greatly due to the external force. It was found from the result that the cement particles were dispersed due to the external force. That is, it is possible that the dispersion of cement particles influenced the change in the flowability.

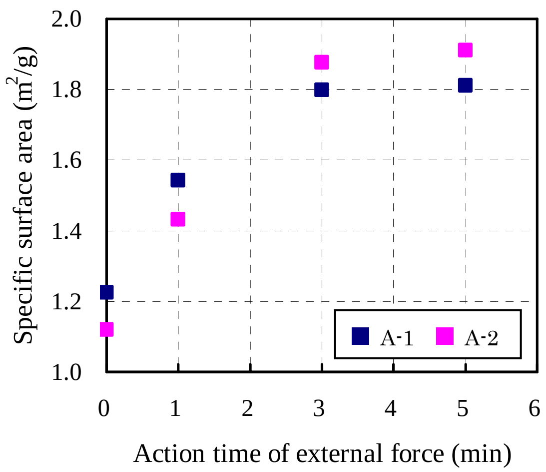

Fig. 12 External force increased surface area of cement particles

The relationship between the amount of superplasticizer adsorped to the cement particles and the specific surface area was examined (**Fig. 13**). Increased total surface area of the cement particles reduced the amount of the superplasticizer adsorbed to cement particles per unit surface area. It was concluded that dispersion of cement particles decreased the effect of superplasticizer.

According to the previous research, the reduced amount of superplasticizer adsorped to cement per unit surface also reduced the flowablity of the mortar [5]. ,which corresponded to the result in this study.

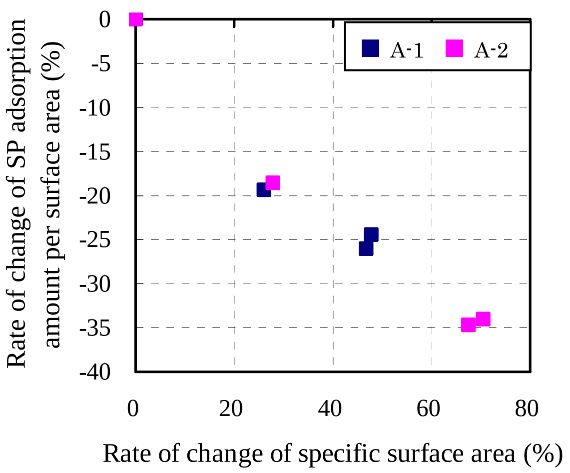

Fig. 13 Reduction in adsorption of superplaticizer to unit surface area of cement

4 CONCLUSIONS

The purpose of this research is to clarify the mechanism of the change in the flowability of SCC due to pumping. The results were summarized as follows:

(1) If deformability of the mortar was high, the influence of the external force was reduced.

(2) Compressive strength of the mortar, the amount of superplasticizer adsorped to cement and the BET surface area were measured. The dispersion of cement particles was increased due to the external force.

(3) It was concluded that dispersion of cement particles decreased the effect of superplasticizer due to the decrease in the amount of superplasticizer adsorbed to cement particles per unit surface area and that it resulted in the reduction in the flowability of mortar in SCC.

5 REFERENCES

1) Sakue J, Ouchi M: Reappearance of Change of Flowability of Self-Compacting Concrete due to Pumping, fib, 2006

2) Okamura H, Maekawa H, Ozawa K: High performance concrete, Gihodoshuppan, 1993.9

3) Ouchi M, Hibino M, Sugamata T, Okamura H: Quantitative evaluation method for the effect of superplasticizer in self-compacting concrete, Proceedings of the Japan Concrete Institute, Vol.21, No.1, pp.129-134, 1998

4) Fukaya Y, Tuyuki N: Cement Concrete Materials Science, The House of technical book, pp.68-99, 2003.10

5) Sugamata T, Edamatu Y, Ouchi M: Quantitative evaluation for retaining in diepsersing effect by superplasticizer, Proceedings of the Japan Concrete Institute, Vol.22, No.2, pp.163-168, 2000