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An Experimental Study of Properties of Fresh Mortar Produced by Two-Stage Mixing

by

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Abstract

Two-stage mixing is effective for decreasing the degree of bleeding and plastic viscosity of mortar/concrete. However, the quality improvement depends entirely on various manufacturing conditions, including factors that affect the quality of products, therefore, finding a stabilizing effect is not sufficient. In this study, the influence of mixing conditions such as the properties of fine aggregates, water cement ratio and S/C on the degree of bleeding and plastic viscosity of mortar is investigated. It is proved that grain size distribution, the fine powder content of fine aggregates, and water cement ratio affect mortar bleeding and the quality improvement by two-stage mixing. Moreover, it is confirmed that two-stage mixing is effective for decreasing the plastic viscosity of mortar.

Keywords: *Two-stage mixing method, Bleeding, mortar, Plastic viscosity*

1. *Introduction*

The two-stage mixing method is effective to improve an interfacial strength between aggregate -cement pastes in concrete [1]. Moreover, it is effective also to a decrease of the inner defect by the bleeding according to the segregation. For the various constructions, advantages such as improvement of the pumpability and decreases of the rebound in concrete had been reported.

However, the manufacturing conditions of the mixer, the material, and the mix proportion, etc. actually change greatly. Therefore, the above-mentioned effect of the quality improvement becomes unstable, and, according to circumstances, an opposite result might be shown. When you consider these situations, a finding necessary for stabilizing the effect of the quality improvement is an insufficient current state.

On the other hand, a part of bleeding water in concrete would be trapped under the coarse aggregate. Therefore, the bleeding rate tends to become small compared with the mortar of the same water-cement ratio.

In this study, the mixing test for mortar using fine aggregate that adjusted grain size distribution by grading and removed fine powder if necessary is executed to clarify the influence of the two-stage mixing method on an effect of the quality improvement of concrete. Hereby, it aimed to clarify both effects of the decrease of plastic viscosity, and the influence of various characteristics of the fine aggregate such as kind of aggregate, a grain size distribution, and fine powder contents, on the bleeding of mortar.

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2. *Materials and methods*

2.1 *Materials*

Table 1 shows the material used by this study. Three kinds of fine aggregate of a different percentage of water absorption was used. Fine aggregate was stored separately after dried, and graded. Then fine aggregate was blended to adjust three kinds of grain size distributions shown in Figure 1. In addition, fine powder in fine aggregate was removed adequately by using two kinds of sieves (150, 300 μ m).

Table 1 Materials

Material	Symbol	Kinds	Specific density (g/cm^3)	Absorption (%)
Cement	C	Ordinary Portland Cement	3.16	-
Fine Aggregate	S	Land Sand(LS)	2.60	1.54
		Crushed Sand(CS1)	2.62	1.67
		Crushed Sand(CS2)	2.60	1.95
Chemical Admixture	Ad	AE High Range Water Reducing Agent	1.04	-

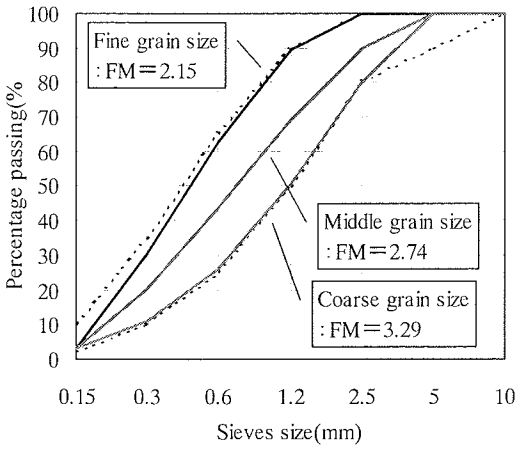


Fig.1 Grain size distribution of fine aggregate

2.2 *Mixing conditions*

The Hobart type mixer of ten liters was used for the mixing. The required mixing time is 105 seconds and be doing (see Figure 2). Moreover, volume of water should be added at the beginning in the two-stage mixing method (W_1: kg/m^3), was determined according to the restraint water rate of the fine aggregate (β_{OH}; %, was abbreviated later as "β_{OH}"), Water-cement ratio necessary to achieve capillary state of cement (α;%), and Equation (1).

$$W_1 = \frac{\alpha}{100}C + \frac{\beta_{OH}}{100}S \qquad (1)$$

Where,

α: Water-cement ratio necessary to achieve capillary state of cement (%)

C: Unit cement content (kg/m^3)

β_{OH} : restraint water rate of the fine aggregate (%)

S: Unit fine aggregate content (kg/m^3)

The dosage of superplasticizer has been adjusted so that flow value, measured according to JIS R 5201, of the mortar produced by conventional mixing method may become 230±20mm. The dosage of superplasticizer in the two-stage mixing method was matched to the case of the mortar produced by conventional mixing method.

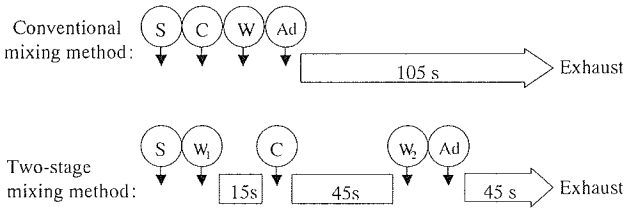


Fig.2 Mixing methods

2.3 *Centrifuge test and bleeding test*

β_{OH} was obtained by the centrifuge test. As for this test, first of all, both of fine aggregate and a decentralized material (cement paste which water-cement ratio is 45%), filled to the container shown in Figure 3, were dehydrated by prescribed centrifugal force (438G), and the volume of stored water of the fine aggregate is evaluated. The bleeding test followed JSCE-F532-1999.

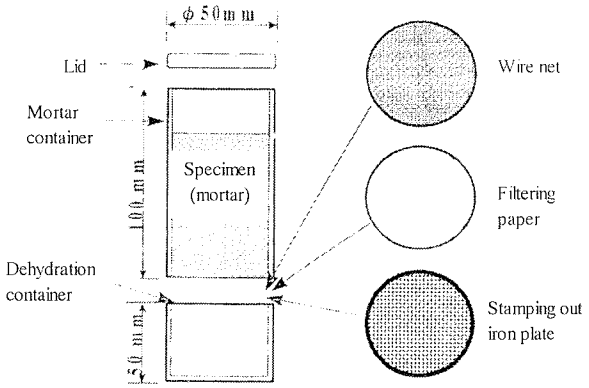
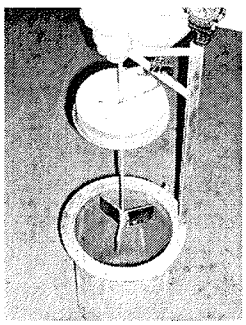
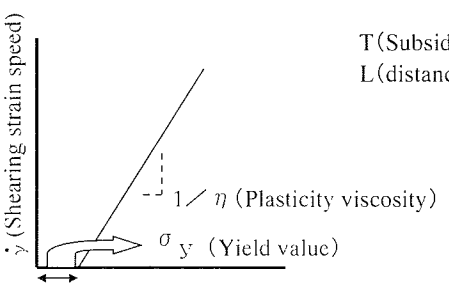


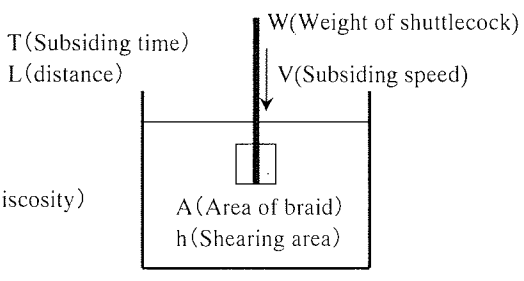
Fig.3 Container for centrifuge test

2.4 *Viscous test*

Figure 4 shows the externals photograph and the Schematic chart of the testing apparatus for viscous test.







a)Externals of testing apparatus b)Biorheology of bingham fluid c)Relation between measurements and plastic viscosity

Fig.4 Testing apparatus for plastic viscosity of mortar

The feature of this testing apparatus is to measure the plastic viscosity of mortar according to the subsidence speed when three braids subside to mortar by self-weight.

When mortar is considered to be a Bingham fluid, the plastic viscosity of mortar can be calculated by the reciprocal of the inclination of the graph in Figure 4. Consequently, the plastic viscosity can be calculated according to both the all up weight and the area of the braid, and the subsidence speed of the braids.

The experiment that used the silicon oil presumed that the plastic viscosity was almost equal to mortar beforehand was done. As a result, the calibration line was obtained.

3.*Results and discussion*

3.1 *Bleeding*

Table 2 shows the result of the percentage of water absorption of the fine aggregate, the percentage of restraint water, the flow value, and the bleeding rate, respectively. The water-cement ratio and the sand-cement ratio in all mix proportions were united to be 55% and 3.0 respectively.

Table 2 Properties of fresh mortar

Kind of sand	Grain size distribution	Fine powder content	Absorption (%)	β_{OH} (%)	Ad (C×%)	Flow value (mm)		Bleeding rate (%)	
						CM*1	TM*2	CM*1	TM*2
LS	Fine	All	1.54	0.96	0.6	235	235	2.4	2.7
	Middle	All	1.54	0.91	0.1	248	230	6.4	5.1
	Coarse	All	1.53	0.90	0.0	248	230	8.4	6.5
	Middle	<150	1.53	0.81	0.0	235	230	7.8	6.6
	Middle	<300	1.47	0.84	0.0	245	245	9.9	8.0
CS1	Fine	All	1.70	1.22	0.8	215	218	0.6	1.0
	Middle	All	1.67	1.17	0.3	225	230	4.3	3.3
	Coarse	All	1.67	1.13	0.0	225	220	6.9	5.0
	Middle	<150	1.62	1.13	0.2	235	225	5.3	4.1
	Middle	<300	1.54	1.02	0.1	225	225	7.1	4.8
CS2	Fine	All	1.98	1.64	1.2	218	210	1.7	0.9
	Middle	All	1.95	1.54	0.6	233	215	2.0	1.9
	Coarse	All	1.87	1.53	0.2	215	210	4.5	3.5
	Middle	<150	1.87	1.46	0.5	215	213	2.8	2.0
	Middle	<300	1.84	1.40	0.4	215	210	3.6	3.1

*1:conventional mixing method
*2:two-stage mixing method

Regardless of the kind of the fine aggregate, the dosage of the superplasticizer adjusted to obtain prescribed. liquidity (flow value) immediately after the mixing

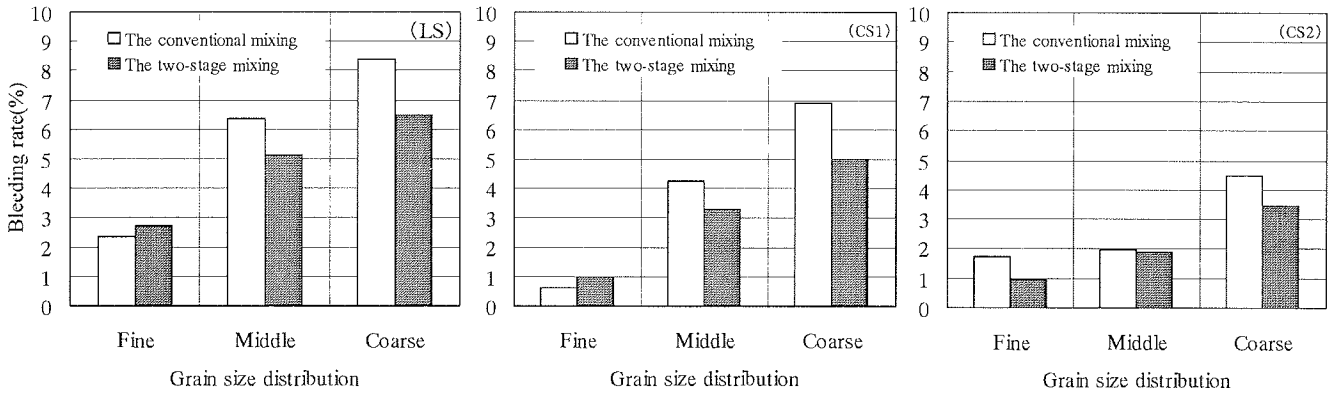


Fig.5 Influence of grain size distribution of fine aggregate on bleeding rate of mortar

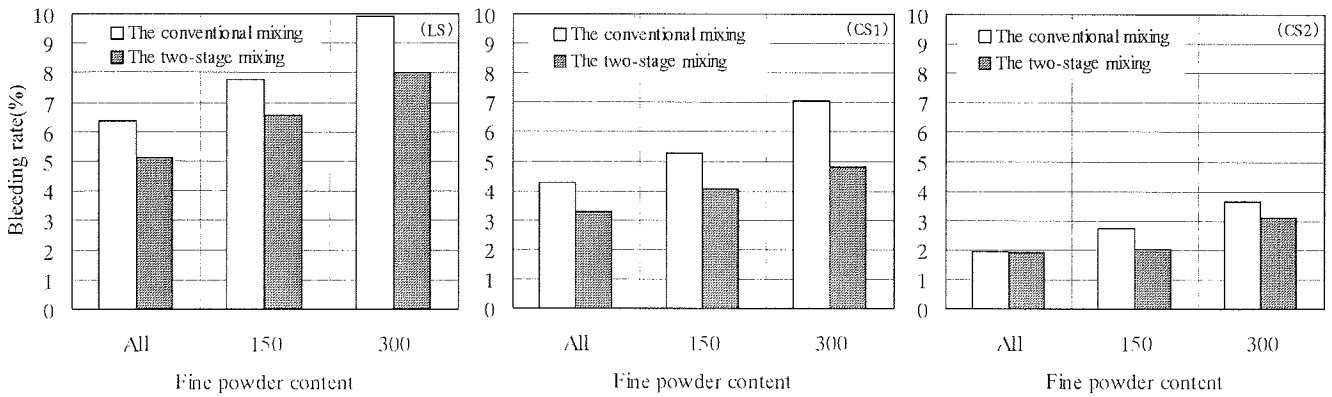


Fig.6 Influence of fine powder content in the fine aggregate on bleeding rate of mortar

ended tended to become small when the size of the particle was large. Moreover, the flow values of mortar produced by two-stage mixing method tended to be smaller than that of produced by conventional mixing method.

About each fine aggregate, the influence of the grain size distribution and fine powder content, on bleeding rate of mortar are shown in Figure 5 and Figure 6.As a result, in each fine aggregate, the bleeding rate of mortar showed the tendency to become large as the amount of fine powder content decreased, as the grain size distribution roughened.

In comparison on the case of mortar with coarse grain, of which the water-holding capacity by the effect of capillary on the space between the grains is weak, the influence of the difference of the fine aggregate on the bleeding rate of mortar is appreciable. The main reason why the bleeding rate of mortar with land sand is larger than the others are seemed that the particle shape coefficient is closer to 1.0. As other reasons, it likely considers to difference of hydrophile, minute gap and ditch on surface. However, the quantitative evaluation of each these influences are difficult in this status.

Then, it pays attention to β_{OH} that is the index expected that the effect of the above-mentioned each factor could be inclusively shown, the relation between the bleeding rate of mortar and β_{OH} of the fine aggregate shown in Figure 7. As a result, regardless of the mixing method, it was confirmed that the bleeding rate of mortar decreases as β_{OH} increases. In general, the bleeding phenomenon greatly depends on a surplus volume of water in mortar. Therefore, this result is guessed from a decrease of surplus water by an increase of β_{OH}.

On the other hand, the effect of the decrease of the bleeding rate by the two-stage mixing method also

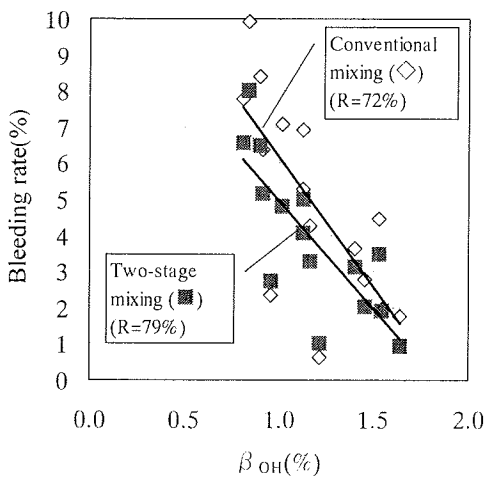


Fig.7 Relation between the bleeding rate of mortar and percentage of restraint water of fine aggregate (β_{OH})

shows the tendency to become small as β_{OH} increases similarly. As this cause, the accumulation rule is not approved between the effect of water retention by hull of cement paste around the fine aggregate formed by two-stage mixing method, and the effect of water retention based on properties of fine aggregate. Then it could be explained as "There is a limit in water (Restraint water) that can store around the particle. " Therefore, in the case of mortar with fine aggregate of small β_{OH}, the effect of the improvement of the water retention ability with the cement paste layer is large. Oppositely, in the case of mortar with fine aggregate of large one, it is guessed that the effect of the water retention ability of the cement paste layer becomes small.

3.2 *Plastic viscosity*

Figure 8 shows the calibration line for testing apparatus for plastic viscosity of mortar. The calibration line requested the test data for which the plastic viscosity used already-known silicon oil by the linear regression analysis. As the result, it was confirmed that this apparatus was effective to the quantification of the plastic viscosity of mortar.

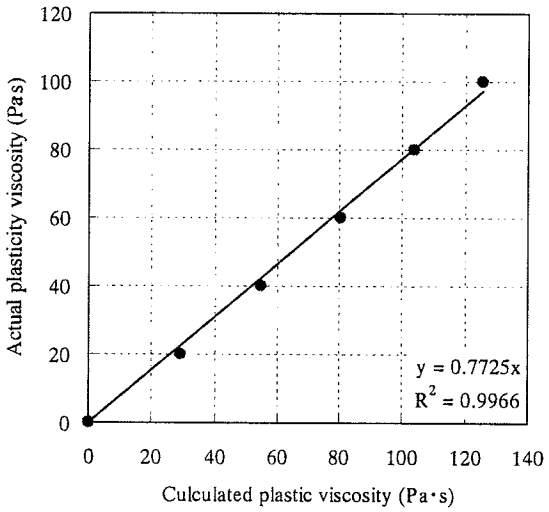


Fig.8 Relation between the bleeding rate of mortar

The effect of the two-stage mixing method on the plastic viscosity of mortar that uses the fine aggregate of two kinds (Land sand and Crushed sand) is shown in Figure 9 and Figure 10 respectively.

The tendency that the plastic viscosity rises so that the lower W/C was, the higher S/C was, were confirmed. It would be seemed that the friction between fine aggregates is a cause in an increase in the plastic viscosity of mortar. The amount of an increase, of the plastic viscosity when W/C decreased from 40% to

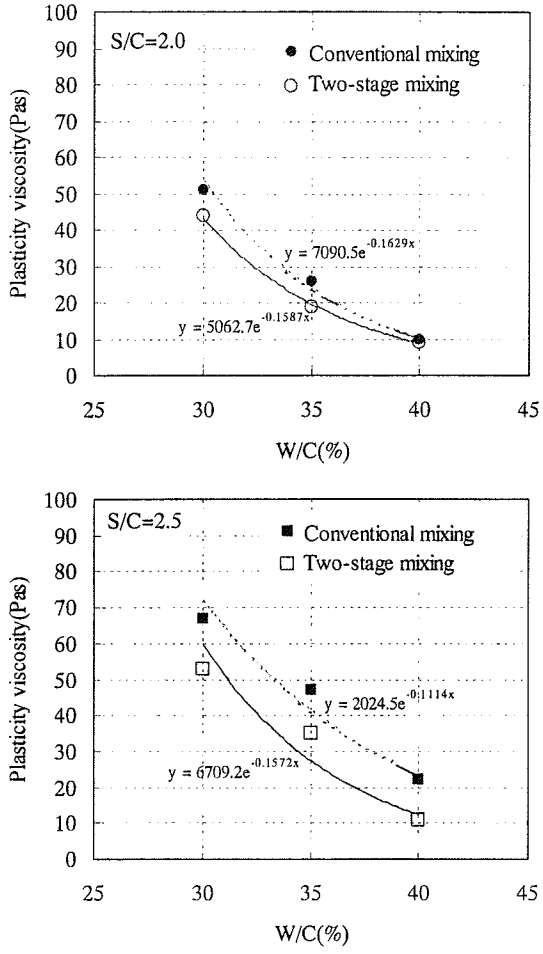


Fig.9 Effect of two-stage mixing method on plasticity viscosity of mortar (case land sand)

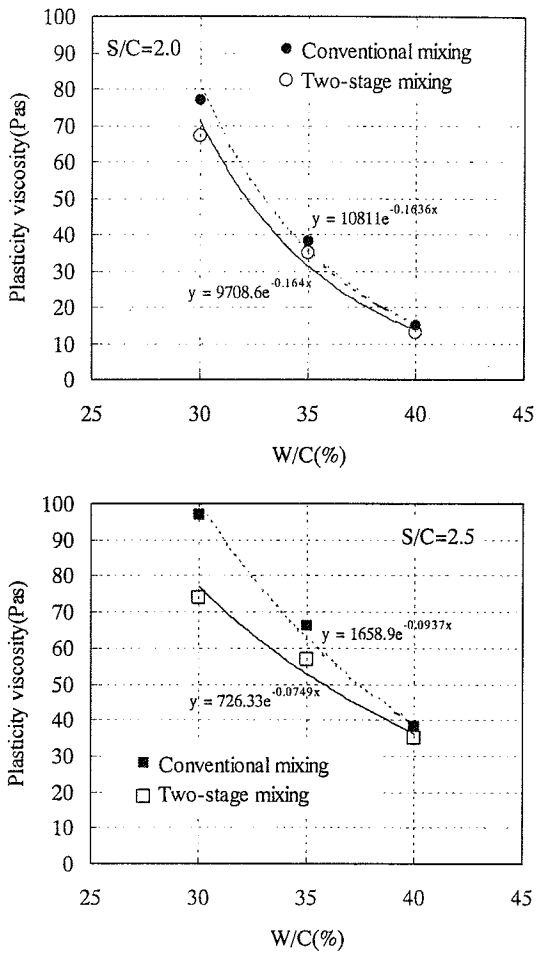


Fig.10 Effect of two-stage mixing method on plasticity viscosity of mortar (case crushed sand)

30%, was admitted that the case when S/C is lower was larger. This phenomenon is attributed to the influence of the increase of the cement paste viscosity. Moreover, it was confirmed that the plastic viscosity of mortar that used the crushed sand was high compared with the land sand. It seemed that it is a cause in the crushed sand because the aggregate shape is distorted that the friction between particles is large compared with the land sand.

In all the mixing conditions in this study, compared to conventional mixing method, it has confirmed that the two-stage mixing method is effective on reducing plastic viscosity of mortar. The hull of cement paste around the fine aggregate is formed by the two-stage mixing method[2]. It seems likely that this hull reduces the friction between minute aggregate particles, and it contributes to the plastic viscosity of mortar decrease.

In this study, the bleeding of mortar was hardly observed, under the condition of 40% or less W/C. However, though it was under the mixing condition without bleeding water, it is a new finding, that the effect of the two-stage mixing method was admitted.

4. *Conclusions*

The results of this research to investigate the influence of the mixing condition such as properties of fine aggregate, water cement ratio and S/C on the bleeding and plastic viscosity of mortar are summarized as follows,

(1) For each fine aggregate, the bleeding rate of mortar showed the tendency to become large when the amount of fine powder content decreased and the grain size distribution roughened.

(2) The difference of the bleeding rate between the conventional mixing and the two-stage mixing tended to become large as the amount of fine powder contend decreased, as the grain size distribution roughened, and the difference of 2.3% was admitted in the maximum.

(3) Regardless of the mixing method, it was confirmed that the bleeding rate of mortar decreases as β_{OH} increases.

(4) The effect of the decrease of the bleeding rate of mortar by the two-stage mixing method also shows

the tendency to become small as β_{OH} increases.

(5) The tendency that the plastic viscosity became larger when the W/C was lower and the S/C was higher, was confirmed.

(6) In all the mixing conditions in this study, compared to conventional mixing method, it has confirmed that the two-stage mixing method is effective on reducing plastic viscosity of mortar.

References

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