Study on the Rheological Properties of Fresh Mortar under Vibration

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***Abstract*—In this study, the rheological property of fresh mortar were measured under the static condition and vibration. Also in the case with various unit water of fresh mortar, the case with measured in different flow value caused by change quantity of additive, and mixed of different materials. As a result, the viscosity of the fresh mortar got increased and the yield value got decreased under the vibration compared with static condition. The fresh mortar which has small flow shows large change of rheology under vibration, in addition the case that fresh mortar with different material and mixing proportion has same flow showed varied change amount of rheological property by vibration.**

***Index Terms*—fresh mortar, Bingham fluid, rheology, workability, vibration, mortar flow**

I. Introduction

Using much amount of reinforcing bar, high workable concrete and precast concrete products have being used to obtain enough strength, durability and seismic-resistant performance of structures. However, there is a problem which is the increase of the material cost. Fresh concrete which has the slump of 8 to 12cm has being used to build various structures with appropriate vibration from viewpoints of compaction and prevention of segregation of the fresh concrete [1]-[5]. Slump test has been widely used to evaluate basic workability of fresh concrete [6], but technology level of chemical admixture has been dramatically developed so far, that means it is possible to control the slump value of fresh concrete even with different type of material and mix proportion. If material and mixing proportions were different, it is expectable that these fresh concrete show each different workability. However, if the slump test was the only criterion for the workability of concrete, the expectation of these fresh concrete can be neglected. There is a method called U-shaped box filling test to measure the workability of fresh concrete, but it is possible only evaluating the clearance passing property of fresh concrete.

On the other hand, lots of methods and experiments on the rheological character of fresh concrete and mortar considering as Bingham fluid by many kinds of viscometer exists [7]. However, these methods have some problems on the view of accuracy [8]-[10], and complication of methods. Moreover, these many expects are being applied under only non-vibrated condition.

In this study, rheological character of the fresh mortar were measured by blades viscometer and table vibrator. In addition, relationship between effect of the vibration to the fresh mortar and mixing conditions of mortar were concerned.

TABLE I. Materials Used

Material		Properties
Cement	N	Ordinary portland cement: Density 3.15g/cm^3
	BB	Portland blast-furnace cement: Density 3.04g/cm^3
	L	Low heat Portland cement: Density 3.22g/cm^3
	H	High early strength Portland cement: Density 3.14g/cm^3
Fine aggregate	y	Mountain sand from Kimitsu Chiba: Density 2.61g/cm^3
	s	Crushed sand from Ome Tokyo: Density 2.60g/cm^3
Chemical admixture	Ad	High-performance AE reducing agent: (Polycarboxylic acid base)

II. Experimental Procedures

A. Materials

Material used are shown in Table I. 4 kinds of cement as Ordinary Portland cement (here in after ”N”), Portland Blast-furnace slag cement (here in after “BB”), Low heat Portland cement (here in after “L”), High early Portland cement (here in after “H”) and 2 kinds of fine aggregate as Mountain sand from Kimitsu Chiba (here in after “y”), Crushed sand from Ome Tokyo (here in after “s”) were used. It is expected that the shape and size of particle of each cement and fine aggregate are differ each other and it can be effected to the change of rheological property by vibration. Polycarboxylic acids-based high performance AE reducing agent was used for chemical admixture.

B. Mix Proportions

Table II shows the mixing proportion and flow value of fresh mortar. The value of unit water were set as like 264kg/m^3, 279 kg/m^3, 294 kg/m^3 which suppose the unit water in mix proportion of normal strength concrete (i.e.

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W=157kg/m³, 164 kg/m³, 175 kg/m³). The combination of 50% of water cement issue and mountain sand were mainly tested in this experiment. Crushed sand and 40% of water cement issue were tested when the Ordinary Portland cement was used for comparison. 3 levels of flow value of fresh mortar were set by changing amount of chemical admixture to be verified the effect of flow value to rheological character.

TABLE II. MIX PROPORTIONS

W/C (%)	S/C	Type of cement	W (kg/m³)	Type of sand	Ad (C×%)	Flow (mm)
50	2.81	N	264	y	1.0,1.5,2.0	152,173,178
	2.54		279		0.5,1.0,1.5	172,183,193
	2.31		294		0.0,0.5,1.0	164,207,254
50	2.78	BB	264	y	1.0,1.5,2.0	170,165,188
	2.51		279		0.5,1.0,1.5	165,169,197
	2.28		294		0.0,0.5,1.0	150,177,201
50	2.83	L	264	y	1.0,1.5,2.0	182,176,195
	2.56		279		0.5,1.0,1.5	194,199,226
	2.32		294		0.0,0.5,1.0	186,200,240
50	2.81	H	264	y	1.0,1.5,2.0	154,198,203
	2.54		279		0.5,1.0,1.5	170,201,216
	2.30		294		0.0,0.5,1.0	147,190,251
40	2.08	N	264	y	1.0,1.5,2.0	168,190,174
	1.87		279		0.5,1.0,1.5	162,219,216
	1.68		294		0.0,0.5,1.0	156,198,250
50	2.80	N	264	s	0.0,0.5,1.0	152,197,245
	2.53		279		0.15,0.5,0.75	191,247,269
	2.30		294		0.0,0.25,0.5	204,239,262

C. Outline of Experiment

1) Mortar flow test

Influence of various type of materials and change amount of chemical admixture into the primitive performance i.e. the flow value of fresh mortar was investigated (according to JIS A 5201) in this experiment.

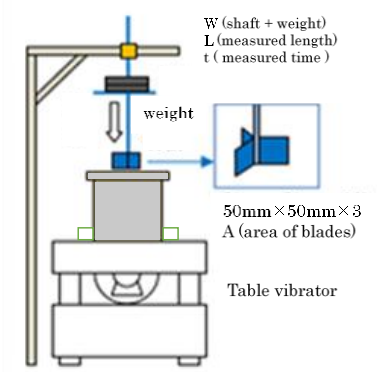

Figure 1. Explanation of the viscometer.

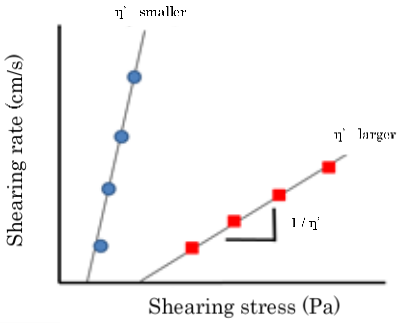

Figure 2. Behavior of Bingham fluid.

Figure 3. Situation of experiment.

2) Rheology test

Fig. 1 shows the outline of a viscometer which was used in this experiment. A thin steel shaft which has 3 thin steel plates goes down into the fresh mortar by weight of itself and apparent plasticity viscosity can be calculated from the relation of the shearing velocity and total shearing stress which includes both of shaft and weight. The calibration curves for modifying from apparent plasticity viscosity to plasticity viscosity have been gotten in previous study. Fig. 2 shows behavior of the Bingham fluid. Fresh mortar is being considered as a Bingham fluid. Measuring the shearing velocity is supposed to be done 4 to 5 times with different levels of weight for accuracy. In addition, surface of the all blades should be put into the shallow part of fresh mortar before it starts going down to get equivalent effect of blades surface are and influence of buoyancy. A table vibrator (acceleration 42.0 m/s^2, frequency 70Hz) was used when the measurement under vibration. Fig. 3 shows that the situation of experiment. The total time of the vibration

has to be as short as possible for the fresh mortar to get less harmful influence from the vibration, which change the rheological property of fresh mortar negatively.

III. Results and Discussion

Fig. 4 shows results of the rheological experiment. The name of explanatory notes in Fig. 4 shows the mixing proportion of fresh mortar. As an example, 50N264y1.5S means that W/C (50%), type of cement (N), unit water (264kg/m^3), type of sand (y), quantity of additive (C×1.5%), the letter at the end means the condition when it is being measured (Static or Dynamic). Fig. 4 shows the comparison both under static condition and vibration each sample has the flow value which is around 185mm. The yield value of fresh mortar got decreased and the plasticity viscosity got increased under vibration compared with non-vibrated condition. Relation between the mortar flow and the plasticity viscosity of the fresh mortar under static condition is shown in Fig. 5 and about plasticity viscosity under vibration is shown in Fig. 6. Small mortar flow shows the large change amount of plasticity viscosity after it got vibrated [8]. Fig. 7 shows the change amount of plasticity viscosity in dynamic condition. The value of mortar flow which is from 150 to 180mm show the large degree of change compared with mortar flow which is more than 200mm. Then Fig.8 shows relation between mortar flow and yield value under static condition. Fig. 9 shows relation of mortar flow and yield value under vibration. Fig. 10 shows the relation of change amount of yield value by vibration and mortar flow. As similarly as change amount of plasticity viscosity of fresh mortar under vibration, small mortar flow has large change amount of yield value under vibration shown in Fig. 10. From these results, the rheological character of fresh mortar as Bingham fluid is related to flexibility and flow value of fresh mortar. Fig. 11 shows the relation of plasticity viscosity and yield value at the time which is under static condition and Fig. 12 shows the relation of the plasticity viscosity and yield value which is under vibration.

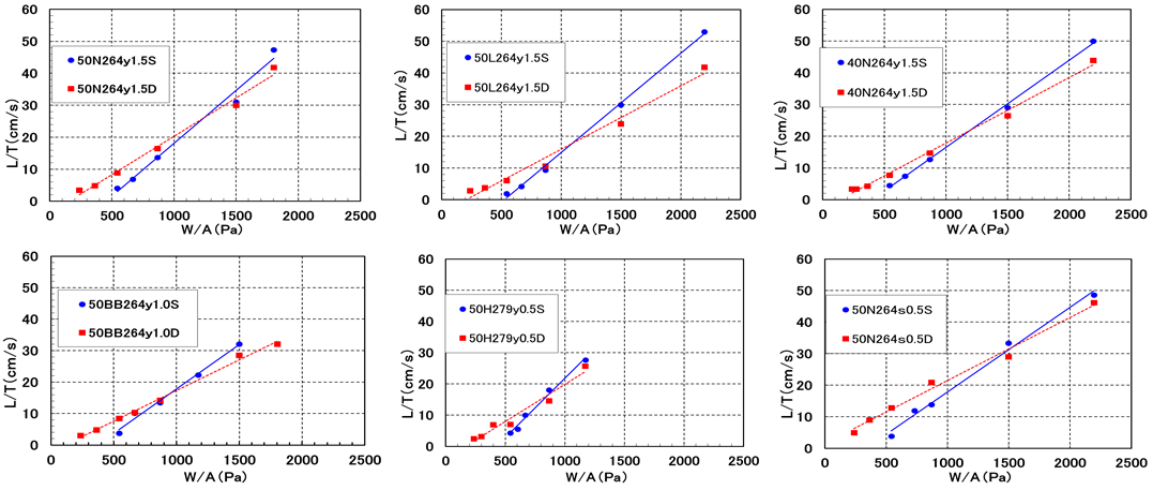

Figure 4. Examples of results of rheology test

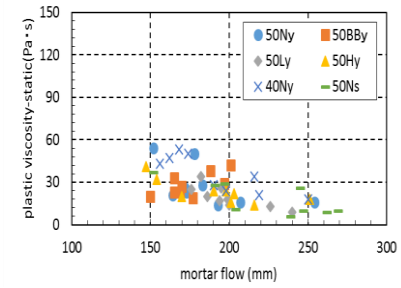

Figure 5. Flow vs viscosity-static.

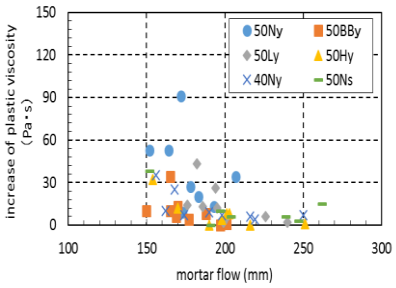

Figure 7. Flow vs increase of viscosity.

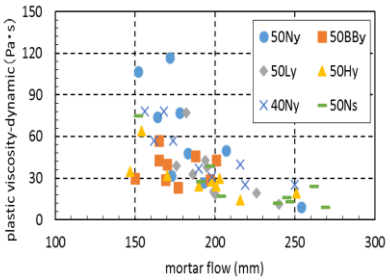

Figure 6. Flow vs viscosity-dynamic.

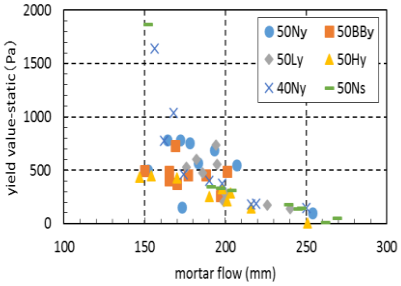

Figure 8. Flow vs yield value-static.

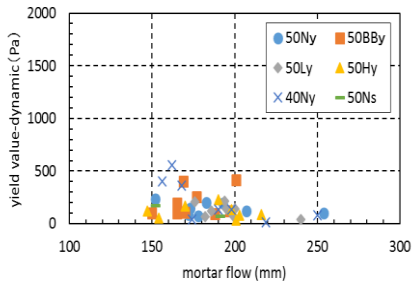

Figure 9. Flow vs yield value-dynamic

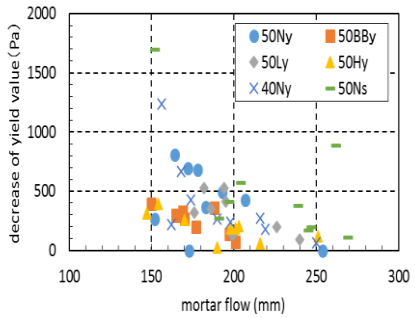

Figure 10. Flow vs decrease of yield value

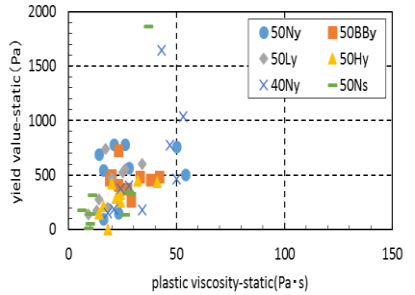

Figure 11. Viscosity vs yield value-static

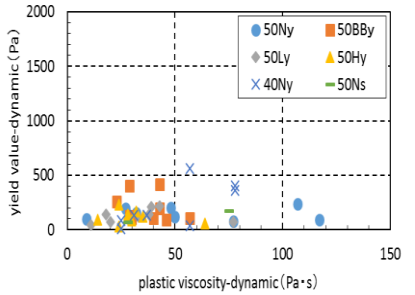

Figure 12. Viscosity vs yield value-dynamic

It is expectable that the yield value became bigger if the plastic viscosity was large under non-vibrated condition shown in Fig. 11. Phenomena which the increase of viscosity and the reduction of yield value were seen also from Fig. 11 and Fig. 12. In addition, Fig. 13 shows the relation of change amount of both plasticity viscosity and yield value by vibration. Large increase of viscosity show large amount of change of yield value by vibration. On the other hand, compared with the fresh mortar which mixed of mountain sand and crushed sand, these shows each varied degree of their rheological character [11]. The fresh mortar with crushed sand showed less increase of plasticity viscosity under vibration.

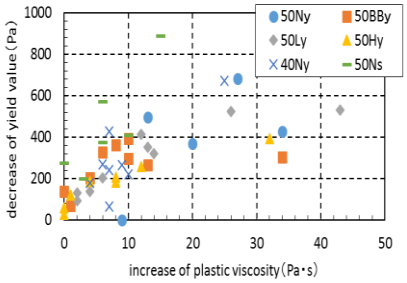

Figure 13. Change amount of viscosity vs yield value

IV. Conclusion

Based on the results and laboratory experiences of this progress, following conclusions can be drawn:

1) The rheological properties of the fresh mortar have been changed in under the vibrated condition. The plastic viscosity has increased and yield value has decreased by vibration. The mechanism which increases of viscosity should be discussed.
2) The change amount of rheological properties by vibration can be each different caused by type of material and difference of mixing proportion. In this study, flow value was related to the change amount of rheological properties of fresh mortar. It means the rheology of small flow mortar has been changed largely by vibration.
3) If the change amount of plastic viscosity was large, the degree of yield value of mortar becomes large. On the other hand, fresh mortar with crushed sand show the less increase of viscosity compared with the mortar with mountain sand.

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