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EFFECT OF RHEOLOGICAL PROPERTY ON FLUIDITY OF FRESH MORTAR UNDER VIBRATION

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ABSTRACT

The rheological properties and workability of fresh mortar were investigated under both static condition and vibration. Also, in the case with various unit water of fresh mortar, the case with investigated in different flow value caused by changing quantity of additive and mixing of different materials. 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 larger plastic viscosity takes longer time to achieve appropriate consolidation. The case that fresh mortar with different material and mix proportions showed varied change amount of rheological property and performance of fluid under vibration.

Keywords: box test, fluidity, fresh mortar, plastic viscosity, rheological property, vibration, yield value.

INTRODUCTION

Using much amount of reinforcing bar, high workable concrete and precast concrete products are 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 is 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 proportions. If material and mix 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 ability of fresh concrete.

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

In this study, rheological property and workability and fluidity of fresh mortar were investigated under vibration by blades viscometer [11], box test and table vibrator. In addition, relationship between effect of the vibration to the fresh mortar and mixing conditions of mortar were investigated.

MATERIALS AND METHODS

Materials used and mix proportions of fresh mortar

Materials used are shown in Table 1. 4 kinds of cement as Ordinary Portland cement (here in after ”N”), Blast-furnace slag cement type B(here in after “BB”), Low heat Portland cement (here in after “L”), High early strength Portland cement (here in after “H”) and 2 kinds of fine aggregate as natural sand from Kimitsu Chiba (here in after “S1”), crushed sand from Ome Tokyo (here in after “S2”) were used. It is expected that the shape and size of particle of each cement and fine aggregate are different each other. It can effect to the variation of rheological property by vibration. Polycarboxylic acids-based high performance water reducing agent AE type was used for chemical admixture.

Table-1. Materials used.

Material		Properties
Cement	N	Ordinary portland cement: Density 3.16g/cm^3
	BB	Blast-furnace slug cement type B: 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	S1	Natural sand from Kimitsu Chiba: Density 2.61g/cm^3
	S2	Crushed sand from Ome Tokyo: Density 2.60g/cm^3
Chemical admixture	Ad	High-performance water reducing agent AE type: (Polycarboxylic acid base)

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Table-2 shows the mix proportions of fresh mortar. Values of unit water were set to 264kg/m³, 279 kg/m³ and 294 kg/m³ respectively which suppose the unit water in mix proportions of typical concrete (i.e. W=157kg/m³, 164 kg/m³, 175 kg/m³). The combination of 50% of water cement issue and S1 were mainly examined in this experiment. S2 and 40% of water cement ratio condition were tested when N 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 property.

Table-2. Mix proportions of fresh mortar.

Type of cement	Fine aggregate	W/C (%)	W (kg/m^3)	Ad
N,BB,H,L	S1	50	264	C× 0~2.0(%)
			279	
			294	
N		40	264	
			279	
			294	
	S2	50	264	
			279	
			294	

Method of experiment

Rheology test

Figure-1 shows schematic of a viscometer which was used in this experiment. A thin steel shaft which has 3 thin steel plates subsides into the fresh mortar by weight of itself and apparent plastic viscosity can be calculated from the relation of shearing rate and shearing stress which includes both of shaft and additional weight. The calibration lines for correction from apparent plastic viscosity to plastic viscosity have been gotten in previous study. Figure-2 shows behaviour of the Bingham fluid. Fresh mortar is being considered as a Bingham fluid. Measuring the shearing rate was supposed to be done 4 to 5 times with different levels of additional weight for accuracy. In addition, upper part of the blade was set to same level of surface of the fresh mortar before it starts sinking to get equivalent effect of surface area of blades and influence of buoyancy. A table vibrator (acceleration 42.0 m/s^2, frequency 45Hz) was used when the measurement under vibration. The total time of the vibration has to be as short as possible for the fresh mortar to get less undesirable influence from the vibration which changes the rheological property of fresh mortar negatively.

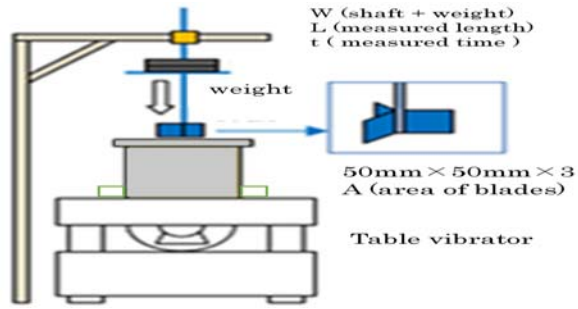

Figure-1. Schematic of the viscometer.

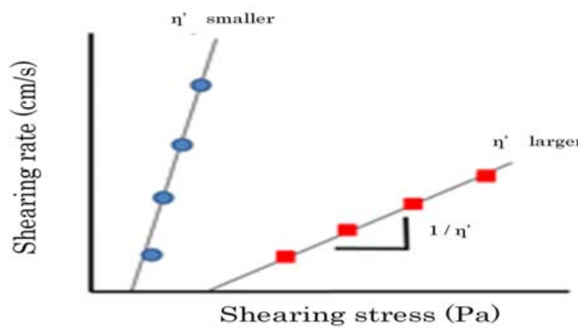

Figure-2. Behavior of Bingham fluid.

Box test

Figure-3 shows schematic of box test apparatus which was used to evaluate the fluidity of fresh mortar under vibration. This refers test apparatus for self compacting concrete (JSCE-F511) reduced in scale of 1/2. Photo-1 shows that the outline of equipment. Each device was fixed on the table vibrator stiffly.

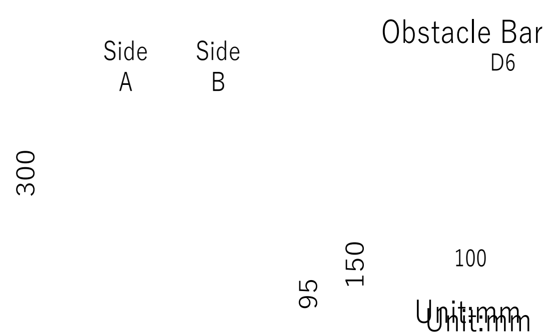

Figure-3. Schematic of box test apparatus.

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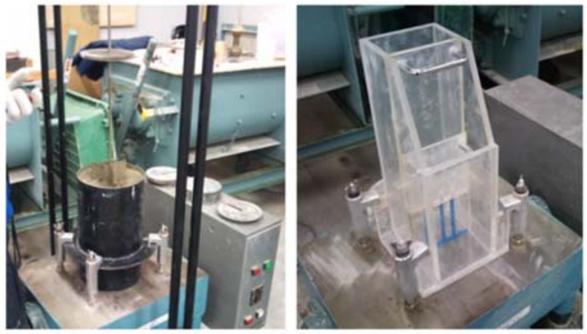

Photo-1. Outline of equipment.

There are three vertical obstacle bars which have 6mm of diameter between side A and side B at even intervals to prevent mortar flowing before it receives vibration.

Fresh mortar was poured into side A divided by 3 layers using tamping rod consequently and settled for a minute into side A. Then, shutter was opened fully and the table vibrator was actuated immediately. Time which surface level of mortar reaches to 95 mm and 150 mm from the bottom of device after the table vibrator was operated was measured. Time to reach 150mm was defined as 150mm filling time(s) and rising velocity of surface of mortar between 95 to 150mm was calculated and defined as V_{pass}(mm/s).

RESULTS AND DISCUSSIONS

3 different flow value was set by changing of additive in each mix proportions of fresh mortar. To evaluate rheological property and performance of workability and fluidity measured by box test when each mortar shows same flow value, approximation was obtained from relation between flow value of fresh mortar. Each test results as shown in Figure-4 to Figure-6 discussing about each test results when the flow value of fresh mortar was assumed as 180mm in this chapter.

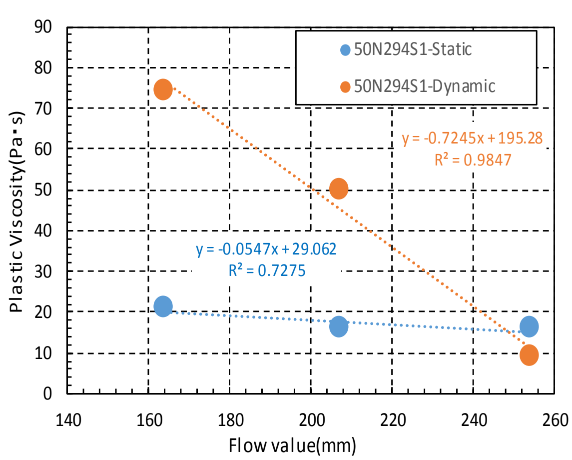

Figure-4. Relation between flow value and plastic viscosity.

Figure-4 shows the relation between flow value and plastic viscosity of fresh mortar under vibration and Figure-5 shows the relation of flow value and yield value of fresh mortar. The name of explanatory notes in Figure-4 to Figure-6 shows the mix proportions of fresh mortar. As an example, 50N294S1-Static means that W/C (50%), type of cement (N), unit water (294kg/m³), type of fine aggregate (S1), the letter at the end means the condition when it is being measured (Static or Dynamic).

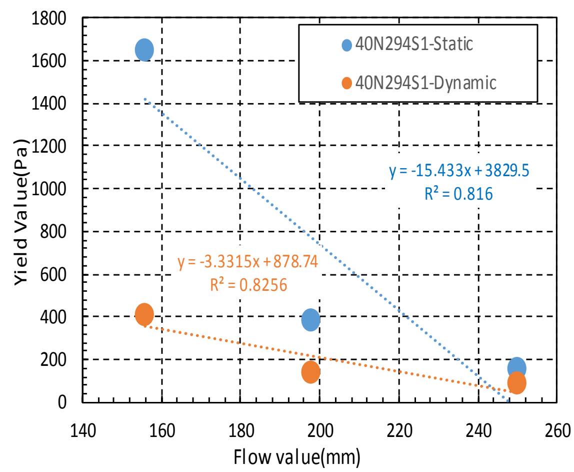

Figure-5. Relation between flow value and yield value.

Larger mortar flow value shows smaller plastic viscosity and yield value nearly linear and high coefficient of correlation can be obtained in each mix proportions. Plastic viscosity of mortar under vibration is greater than static condition in major case, but high flow mortar which flows more than 250mm shows lesser plastic viscosity when it is vibrated. Yield value normally get decrease largely by vibration. Figure-6 shows relation between flow value and results of box test. 150 mm filling time get shorter and V_{pass} got faster according to flow value increase. It is clear that the relation of flow value of mortar and test results of box test is nearly linear for each same mix proportions of fresh mortar.

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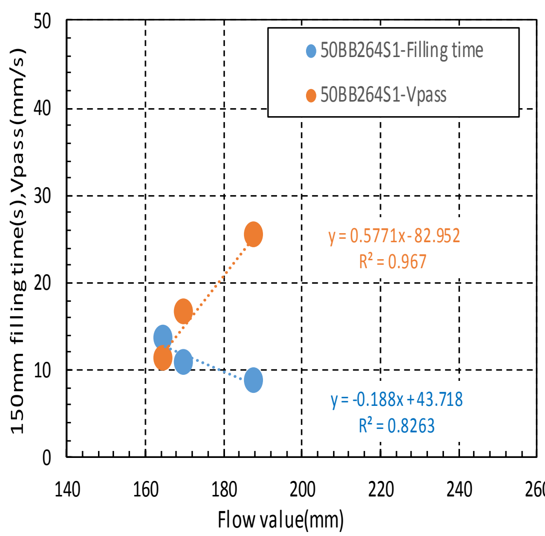

Figure-6. Relation between flow value and 150mm filling time, V_{pass}.

Secondly, rheological property and fluidity of fresh mortar when they have 180mm of flow value which was calculated in last chapter is discussed. Figure-7 shows relation between 150 mm filling time and plastic viscosity of fresh mortar in each type of cement and fine aggregate. Figure-8 shows the relation of 150mm filling time and yield value of mortar as similarly. The name of explanatory notes in Figure-7 to Figure-10 describe the condition of mix proportions and material of fresh mortar. As an example, 50NS1 means that W/C (50%), type of cement (N), type of sand (S1).

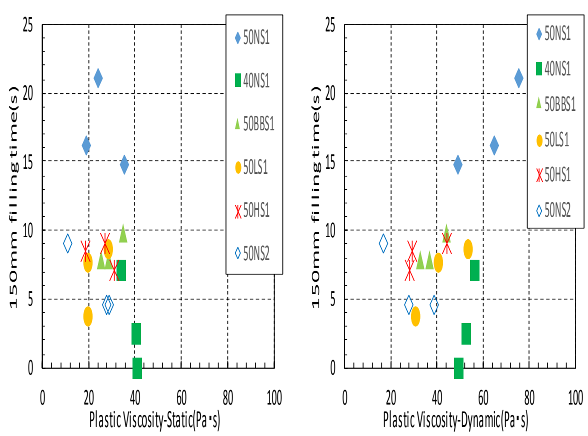

Figure-7. Relation between plastic viscosity and 150mm filling time (180mm of flow value).

From Figure-7, relation of plastic viscosity and 150mm filling time is not linear and unclear under static condition. However, in dynamic condition, relation of plastic viscosity and 150mm filling time is nearly linear inclination for each material condition and almost whole samples in this experiment. It is obtained the correlation of plastic viscosity of fresh mortar in dynamic condition and fluidity of fresh mortar is clearly good, that means it is possible to evaluate workability of fresh concrete by investigating plastic viscosity under dynamic condition.

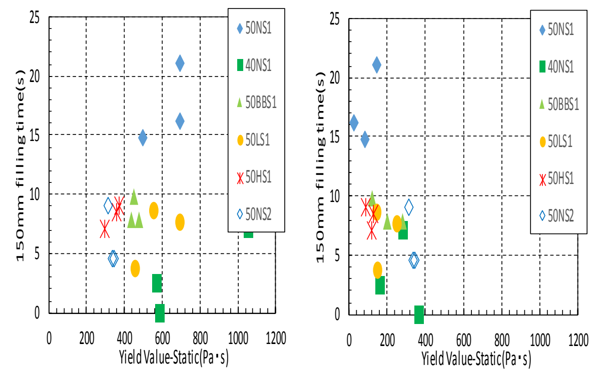

Figure-8. Relation between yield value and 150mm filling time (180mm of flow value).

In Figure-8, fresh mortar which have larger yield value take longer 150mm filling time but it is difficult to compare with different material condition. In addition, yield value under vibration does not show huge difference between maximum value and minimum value. The effect of yield value on fluidity under vibration might be smaller than effect of material condition to estimate the compaction performance of fresh mortar in this experiment.Figure-9 and Figure-10 show relation between plastic viscosity, yield value under both static, dynamic condition and V_{pass}. Basically, V_{pass} get smaller if the plastic viscosity got larger but there is big difference in each material condition, especially mortar which mixed of S2 shows totally different results from mixed of S1 mortar. Relation between yield value and V_{pass} shown in Figure-10, larger yield value lead smaller V_{pass} in many case and that inclination is more clear in dynamic condition.

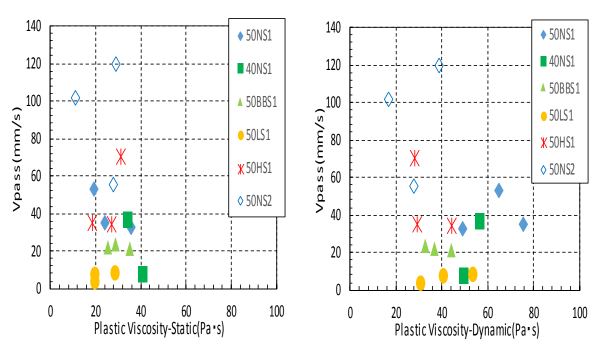

Figure-9. Relation between plastic viscosity and V_{pass} (180mm of flow value).

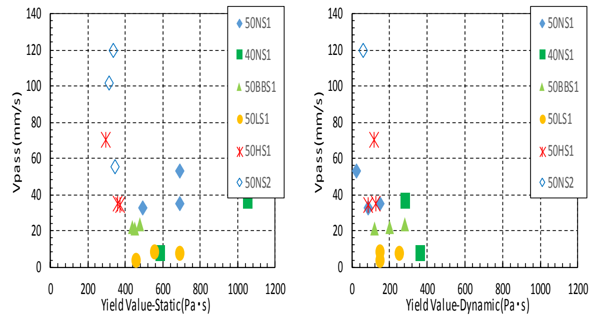

Figure-10. Relation between yield value and V_{pass} (180mm of flow value).

Material condition of fresh mortar can effect on the fluidity and workability under vibration such as V_{pass} more effectively than rheological property.

It is possible that other conditions of fine aggregate like solid content in aggregate effect to the rheological property and workability, and fluidity directly according to extra cement paste thickness theory.

Not only estimating the relation between rheological property and fluidity, it is necessary to evaluate mechanism how the rheological property of fresh mortar will be changed, how much they will be changed by vibration to estimate the workability and fluidity of fresh concrete at construction site.

CONCLUSIONS

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

(1) There was high correlation between plastic viscosity of fresh mortar, especially under vibration and fluidity to achieve quick consolidation. It might be possible to evaluate workability and fluidity of fresh concrete by evaluating plastic viscosity of mortar matrix and character of coarse aggregate.

(2) It is necessary to examine rheological property neither static nor dynamic condition and evaluate the change degree of plastic viscosity and yield value by vibration.

(3) In future study, it will be really necessary to evaluate the effect of other conditions such as temperature, time after mortar mixed and so on. However, character of fine aggregate and admixture can efficiently effect on rheological property and workability of fresh mortar under vibration.

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