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Study on Consolidation of Concrete with Vibration

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Abstract

Development of concrete with good productivity with vibration is required to manufacture concrete products by low cost and less energy. In order to determine the mix proportion of high-performance concrete, it is necessary to understand the relationship between the compactability with vibration and the fresh properties of concrete. Not only slump test but also table box shaped compaction test apparatus were used for the evaluation of the various sand percentages, mineral admixture and various mixing method for fresh concrete. It was confirmed that productivity of concrete with vibration increases as sand percentage and content of fly ash increase. Furthermore, two stage mixing method shows good performance on improvement of productivity of concrete as well.

Keywords: Compactability; Vibration; Sand percentage; Plastic viscosity; Two stage mixing method

1. Introduction

In Japan, as of recent, the situation surrounding concrete structures has undergone dramatic changes. Some of the changes were:

1. Increased steel content for earthquake resistance.
2. Environmental issues have affected the material properties of concrete and significant increase in the degree of difficultly for concrete construction.

By imposing some of these environmental changes, there is a greater risk of defects such as honeycomb or exfoliation will be detected in concrete structures, and thereby noticeable visual defects to public. Generally, using vibration for compaction is the standard practice both cast in place concrete and

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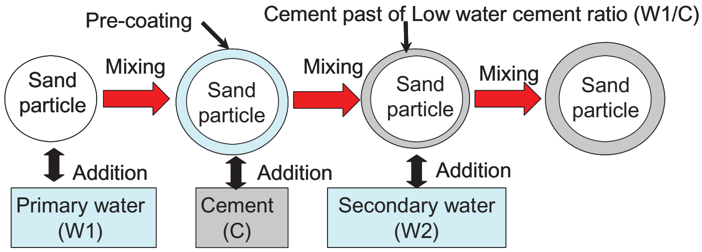

Fig.1 Image of the surroundings of sand with cement past (W_1/C) in double mixing

precast concrete. In order to satisfy the demand for the reduction of construction cost and the decrease the noise level which occurs at the construction site in concrete manufacturing factory, it is necessary to produce concrete which can fill into the form smoothly with minimal amount of energy for compacting. However relationship between compactability with vibration and the fresh properties of concrete has not clarified yet. Thus, in this study, influence of mix parameter and mixing method on productivity of concrete were investigated.

2. Two stage mixing method

Usually concrete ingredients are added simultaneously into the mixer. This method is called single or conventional mixing. However, it has been found that cement paste of remarkably different property can be manufactured by a new mixing method for the same mix proportion according to research work [1] by Dr. Higuchi. This mixing method is called two stage mixing method. In two stage mixing method, water is divided into two portions and each portion is added and mixed with cement at different times. A conception of two stage mixing method is shown in Fig.1. In this mixing, the surface of sand is kept in an appropriate moist state during the first mixing. In next process (second mixing), the surroundings sand is covered by cement paste of the low water-cement ratio. Therefore the interface of cement paste and sand shows good enough adhesion to reduce or prevent formation of a transition zone. As a result, the concrete with two stage mixing method enhances desirable properties such as less bleeding, higher strength and higher resistance to segregation. In other words, this method is effective for improvement of compressive strength, durability of hardening concrete and pumpability of fresh concrete.

In this study, this two stage mixing method was conducted as one of the experimental parameters.

3. Outline of experiment

3.1 Materials and mix proportions

The materials used and mix proportions are indicated in Table.1 and Table.2, respectively. In Japan, high early strength Portland cement is generally used as a raw material for manufacturing precast concrete products, and therefore, the same type of cement was used in the study. The maximum size of coarse aggregate was 25mm. A total eight mix proportions were selected in this study. The mix proportion of Mix.3 is the control parameter in this study. Except for Mix.7 & Mix.8, the other mixes had sand percentages (s/a) of from 53% to 39%. Fly ash was added to the remaining mixes 20% and 30% substituting the cement level in the control mix. In addition, the concrete of Mix.3 was mixing with not only the single mixing but also the two stage mixing method. The primary water-cement ratio (W_1/P) was constant as 31%, according to previous studies[2].

Table 1 Properties of materials used

Materials		Gravity	Rate of Absorption	Specific surface area	Fineness Modulus	Solid volume
		g/cm^3	%	cm^2/g		%
Cement	High early portland cement	3.14	―――	4520	―――	―――
Fly Ash	Class Ⅱ／Shikoku Electric Co. Ltd.	2.31	―――	3980	―――	―――
Fine Aggregate	Natural Ohoi-gawa river sand	2.61	1.31	―――	2.54	―――
Coarse Aggragate	Natural Ohoi-gawa river gravel	2.65	0.83	―――	7.35	62.8
Admixture	Polycarboxylic acid-type superplasticizer	1.04	―――	―――	―――	―――

Table 2 Mix proportions of concrete

Mixture Number	W/P*	s /a**	Slump	Air	Unit content (kg/m^3)					
	%	%	cm	%	W	C	FA	S	G	SP***
Mix. 1	40.8	53	21.0 ±1.5	1.5	155	380	0	985	877	2.66
Mix. 2		51						948	914	2.66
Mix. 3		49						912	952	2.66
Mix. 4		45						837	1027	2.66
Mix. 5		41						763	1102	2.85
Mix. 6		39						725	1138	2.28
Mix. 7		49				304	76	899	939	2.28
Mix. 8						260	114	894	934	1.71

W/P* means the ratio of water to sum of cement and Fly ash on weight
s/a** means the volumetric ratio of fine aggregate to sum of fine aggregate and coarse aggregate
SP*** means superplasicizer

3.2 Test procedure

The concrete was mixed by a two-axial forced mixer having 60 liters of capacity. After discharging from the mixer, slump, air content and temperature were measured promptly. Afterwards, the table vibrator for the box shape-compactability test and the plastic viscosity test of mortar screened by 5mm sieve from fresh concrete was examined as shown in 3.3 and 3.4 later. When the measurements at first time were finished, concrete was returned into the vessel. Until the slump of concrete came into a range as 15.0±2.0 cm, the concrete was kept in static state in the vessel. After second measurements, concrete was kept in static state in the vessel until the slump of concrete became to a range as 10.0±2.0 cm. Then the measurements at third time were conducted. These measurements were continued until slump was under 2.0cm. In addition, measurement frequency was seven times in Mix.3 with sand percentage (s/a) of 49 %, as the control of this study.

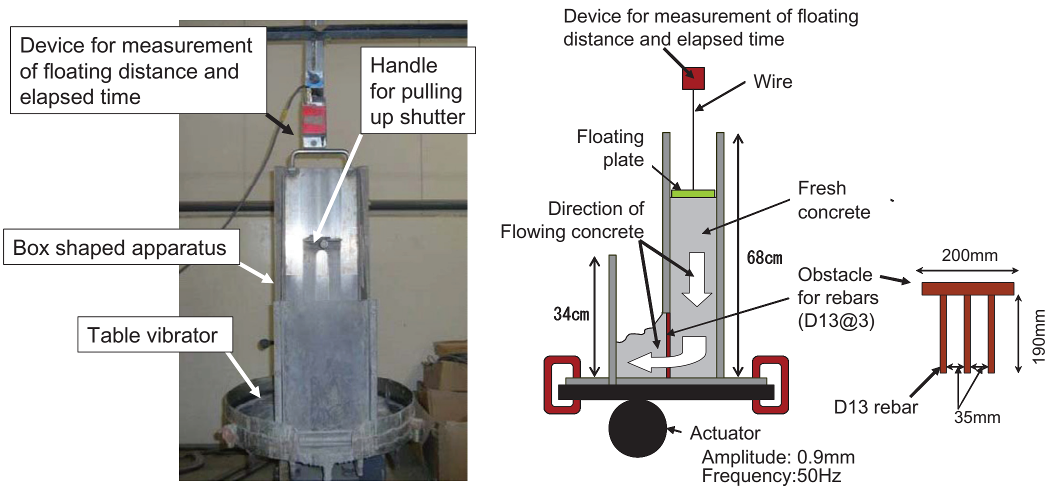

Fig.2 Overview of the box shaped compactivity test on table vibrator

3.3 Box shaped compactability test on table vibrator

A photograph and schematic diagram of the box shaped compactability test on table vibrator are shown in Fig.2. There is the obstacle with three re-bars at the center gate between right side box and left side box. Concrete will be moving through the center gate with the obstacle form right side box to left side box. The index of compactability with vibration was defined by measuring of the time which it took that the floating plate was falling for height of 20cm. First of all, concrete is molded in the right side box to the top.

Secondly, the handle of the shutter is pulled up at same time that the apparatus is given vibration by actuator. Concrete is falling and flowing through the connection into the left side in box as soon as the shutter is opening. The falling speed of concrete surface was measured using both a wire strain gauge and dynamic strain meter. Short compaction time indicates good compactability by vibration.

3.4 Plastic viscosity test using the blades sinking type viscometer for mortar

A photograph and schematic diagram of the blades sinking type viscometer for mortar [3] are shown in Fig.3. It would be quite difficult for the influence of collision of coarse aggregate to the blade and segregation of concrete to become an obstruction factor and to measure the plastic viscosity of concrete correctly. However, it might even be difficult to measure the plastic viscosity of mortar absolutely because mortar is suspension material composed of air, water, cement and fine aggregate. In this viscometer, plastic viscosity will be calibrated by comparing a fluidity whose viscosity is already-known.

The plastic viscosity measured and defined by this viscometer would be considered as relative value. Apparent plastic viscosity could be measured by this viscometer.

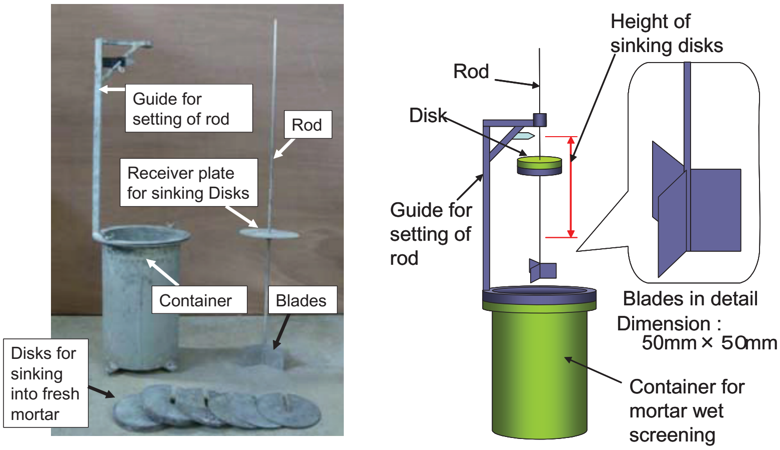

Fig.3 Overview of the blades sinking type viscometer for mortar

4. Results and Discussion

4.1 Influence of plastic viscosity and sand percentage

The relationship between the compaction time and the plastic viscosity is shown in Fig.4. Although sand percentage was higher, the plastic viscosity and the compaction time were almost constant. On the other hand, in low sand percentage mix, the compaction time was shortened so that the plastic viscosity was low. Then it can be considered that compaction ability by vibration was improved.

The relationship between the compaction time and the slump is shown in Fig.5. In the case each mix proportions, the compaction time showed the tendency to decrease inversely as the slump increased. In the case mix proportions with sand percentage of 39% and 41%; under the condition of around 10 cm or less in the slump, the compaction time tended to decrease inversely as the slump increased, as well as other mix proportions. However, in mixes with a slump value ≥ 13 cm, the compaction time showed the tendency to increase with an increase of the slump. In the case mix proportion with small s/a, the influence of the inter friction of the coarse aggregate is bigger. Therefore it is considered that the delay of the compaction time was caused by dynamic segregation and the arch action of aggregate when the coarse aggregate passes through the gap of the obstacle re-bar under vibration.

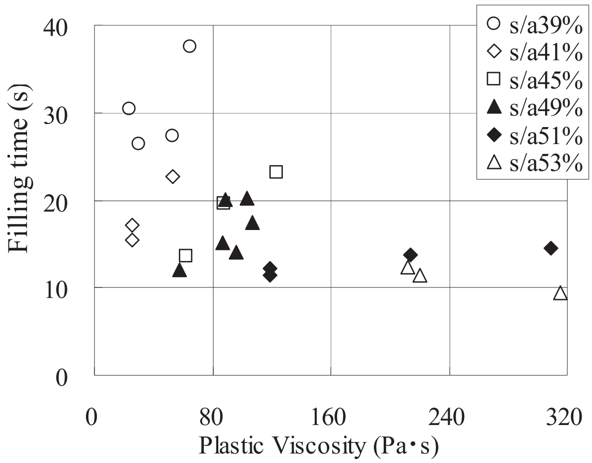

Fig.4 The relationship between compaction time and plastic viscosity

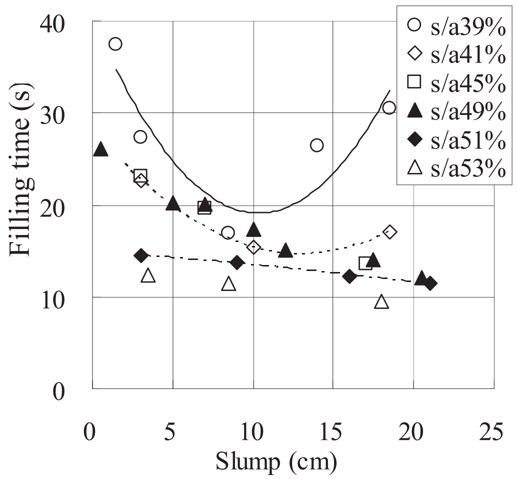

Fig.5 The relationship between compaction time and slump

4.2 Influence of fly ash and two stage mixing method

The relationship between the compaction time and the slump is shown in Fig.6. The compaction time with vibration tended to decrease by adding fly ash in all range of slump (0cm-21cm). The compaction time of mix proportion adding fly ash was clearly shorter as compared with the proportion without fly ash at same slump value. Therefore, it could be considered that adding fly ash to concrete contributes to improve the compaction ability by vibration. The relationship between the compaction time and the slump is shown in Fig.7. Compaction time of concrete manufactured by two stage mixing method was shorter than the compaction time of concrete by single mixing. This means the two stage mixing method is much more effective for compaction ability with vibration.

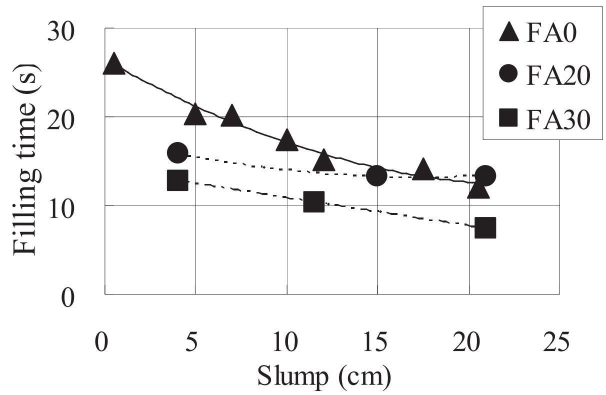

Fig.6 Effect of addition of fly ash on compaction time

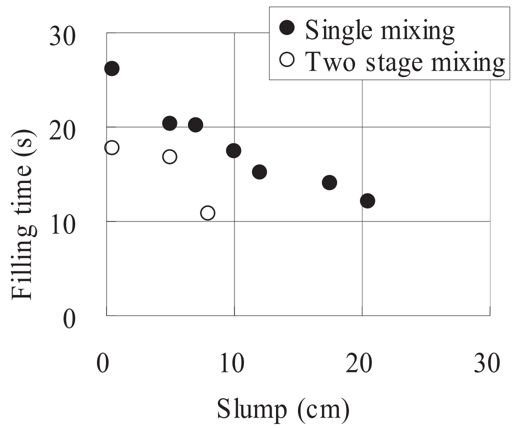

Fig.7 Effect of mixing method on compaction time

5. Conclusion

The results of this research on consolidation of concrete with vibration are summarized as follows;

- When sand percentage (s/a) was increased, plastic viscosity increased, and this prevented dynamic segregation caused by arching of the aggregate. Also the compactability by vibration was improved.
- The compactability of mixes with fly ash improved even if the sand percentage of concrete was increased.
- It was confirmed that two stage mixing method is excellent in the compactability by vibration compared with the conventional method.

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