- Technical Paper -

AN EXPERIMENTAL STUDY ON ESTIMATION METHOD OF BLEEDING CAPACITY OF VIBRATION-PLACED FRESH CONCRETE

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ABSTRACT

The bleeding capacity of fresh concrete cast is difficult to measure in construction site. We first investigated the relationship between the final bleeding capacities of 8 series of concrete, occurring in the cylinder of JIS method and in the filling side of a U-shaped filling box with two types of obstacles. The measurement of bleeding capacity with JIS method needs a long time, we measured the bleeding capacity of fresh concrete after vibrated for 10 seconds and kept still for 20 minutes in a cylindrical container, and got relational formulas between three kinds of bleeding capacities.

Keywords: bleeding, fresh concrete, static state, vibration construction, evaluating method

1. INTRODUCTION

The bleeding is a rising phenomenon of mixing water of cementitious materials in fresh state. Bleed water may contibute to preventing concrete from drying out and plastic cracks. However, excessive bleeding gives many bad effects on mechanical properties and durability of concrete[1] [2], since excessive bleeding weakens the bond of the interfaces of cement matrix and aggregates, and induces a anisotropy of strength due to the formation of water channels. The importance of understanding concrete's bleeding have long been recognized, clarification of bleeding behavior and influencing factors has consequently been the research subject till now in the field of study of concrete [3].

Many studies have been performed on the influencing factors of concrete's bleeding [4], and to develope test method, including preasured evaporate method, and vacuum evaporate method, etc. [5]. Bleeding capacity and bleeding rate of fresh concrete are usually measured according to JIS A1123 in Japan. The test results may evaluate the segregation resistance of mixing water, but they don't represent the bleeding degree of concrete member because the placement method of concrete in construction site is very different from that of the JIS test method. The placement of concrete is genernally under a vibration except self-compacting concrete (SCC), and fresh concrete flows through steel bars. The vibration would lead to the settelement of aggregate particles, and increase the bleeding. It is shown that there is a close correlation between the final bleeding capaicties in the standard test and after vibrated for 5 miutes [6]. But for evaluating properly the properties of hardened concrete member, we need to know the bleed water amount of concrete placed in mould in the actual construction. However, the relationship between the bleeding capacities in construction and in laboratory has not yet been clarified. It is necessary to investigate the relationship between the bleeding capacities in static state and after placed by vibration, for predicting the bleeding capacity of vibration-placed concrete based on the test result in laboratory.

Density of steel bars, lasting time of vibration till filling up, and height and width of placement vary with concrete members. Actural bleeding capacity depends on these factors, and may be predicted by a numerical analysis. But constructing a proper bleeding behavior model of fresh concrete is now in progress [3]. Modelling the process of concrete placement in mould with steel bars is alternative of evaluating the bleeding capacity of cast concrete member, just as the opening-passing ability of SCC is generally evaluated by a U-shaped box rather than actual constrcution experiment.

Hence, in this study, in order to develope a method of evaluting the final bleeding capacity of cocnrete placed by vibration in construction site, we first investigate the final bleeding capacities of fresh concrete samples with different flowability in static state according to JIS A1123 (hereafter called as final bleeding capacity of JIS method), and occuring in the filling side of a U-shaped box after filling up under vibration (hereafter called briefly as final bleeding capacity in U-shaped box). There two kinds of obstacle to be used in the partition gate of the box for discussing the effect of the density of steel bars. We also measure the bleeding capacity in a cylindrical container with a size of 200mm in diameter and 200mm in depth, after vibrated for 10 seconds and kept still for 20 minutes (hereafter called briefly as bleeding capacity of vibrated concrete). The relational formulas of the final bleeding capacities of JIS method and in U-shaped box, the bleeding capacity of

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vibrated concrete and the final bleeding capacity in U-shaped box, are further obtained, based on these measuring results and a series of regression analyses. These relational formulas would be used to evaluate the final bleeding capacity of concrete placed by vibration through the standard bleeding test or the vibrated bleeding test.

2. EXPERIMENTAL PROGRAM

2.1 Raw Materials and Mix Proportions of Concrete

The concrete mixes used in this study were prepared with ordinary Portland cement, sea sand, and crushed stone. The physical properties of used sea sand and crushed stone are shown in Table 1. AE super-plasticizer (standard type) was also used in the concrete.The mix proportions of used concretes are shown in Table 2. For making the concretes to have different fluidities and viscosities, the water-cement ratio, water amount, sand-aggregate ratio, and S_p content, etc. were adjusted.

Table 1 Physical property of the used aggregates

Property	Sea sand	Crushed stone
Density in water-saturated state (g/cm^3)	2.60	2.73
Water absorption ratio (%)	1.04	0.47
Fineness modulus	2.61	6.56
Maximum size (mm)	5	25

The mixing procedure of the concretes is: firstly, the fine aggregate and cement were mixed for 60 seconds by a forced-mixing type mixer; then mixed the mortar for 60 seconds, following by adding the mixing water and AE super-plasticizer; finally, added the coarse aggregate and mixed for 60 seconds to get the concretes. Right after mixing the concretes, the slump, air content and unit mass of concrete were measured respectively, as shown in Table 2.

2.2 Experimental Method

Ther bleeding test in static state was performed following JIS A1123, using a standard cylindrical container with 250 mm in diameter and 285 mm deep, a balance with reciprocal sensibility of 10 g, and a graduated cup. The cylindrical container was filled with concrete in three layers, every layer was rodded 25 times with a steel rod that is used in slump test. The top surface of concrete was 3±0.3 cm lower than the edge of the container. The time was recorded after prepared the sample. The bleed water was sucked up with a pipette every 10 minutes in the first one hour, and then at an interval of 30 minutes one hour later, recording the volume of bleed water.

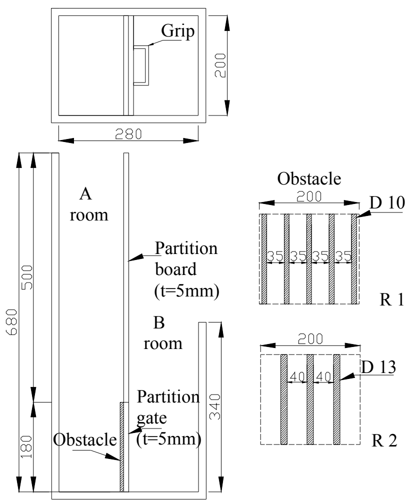

Fig.1 U-shaped box and obstacles used

The bleeding capacity is calculated by Eq. (1).

$$B = V_q / A \tag{1}$$

where B is bleeding capacity (cm^3/cm^2), V_q is quantity of bleed water (ml), A is surface area of concrete sample (cm^2).

In this study, the U-shaped box, as shown in Fig.1, which is usually used to evaluate the opening-passing ability of SCC, was used to simulate the flow process of fresh concrete placed into concrete member(column,

Table 2 Mix proportions of the used concretes

Series	Mix proportions		Unit mass (kg/m^3)					Properties of fresh concrete		
	W/*C* (%)	s/a	*W*	*C*	*S*	*G*	*Sp* (C×%, by mass)	*Sl* (cm)	Air content (%)	ρ (kg/m^3)
C1	0.40	0.38	180	450	611	1070	4.50	24.0	7.2	2282
C2	0.45	0.40	175	389	674	1070	2.92	21.0	5.8	2348
C3	0.60	0.43	173	288	761	1070	1.73	19.0	2.9	2354
C4	0.55	0.47	177	322	816	972	4.83	23.5	8.7	2266
C5	0.55	0.49	175	318	855	940	2.39	19.5	7.8	2299
C6	0.55	0.53	177	322	924	859	3.22	20.5	7.3	2195
C7	0.52	0.41	176	338	712	1070	1.02	19.0	2.6	2423
C8	0.53	0.42	172	325	734	1070	0.97	15.5	1.8	2406

[Notes] *W/C*: Water-cement ratio; *s/a*: Sand-aggregate volume ratio; *W, C, S,* and *G*: Mass of water, cement, sand, and crushed stone in 1m^3 concrete, respectively (kg); *Sp*: AE super-plasticizer; *Sl*: Slump; ρ; unit weight of concrete.

beam, slab, foundation, and wall, etc.)'s mould with reinforced steel bars. The final bleeding capacity in the filling side of the U-shaped box was measured. The used U-shaped box made of acrylic resin plates, has two rooms, the higher is room A (flowing side) and the lower is room B (filling side). The room A, B have the same width (140 mm) and depth(200 mm), but the heights of the room A, B are different, being 680 mm, and 340 mm, respectively. The U-shaped box equipped two types of obstacles R1 and R2, as shown in Fig.1. R2 has three steel bars with 13 mm diameter, and the interval of steel bars is 40 mm. R1 has five steel bars with 10 mm diameter, and the interval of steel bars is 35 mm. Right after mixed, the concrete was filled in the room A, the partition gate was opened. Then, a rod-shaped vibrator was inserted into the room A, and stared to vibrate. The concrete in the room A flowed to the room B though the steel bar obstacle, as shown in Fig.2. The vibration was stopped and the elasped time was recorded when the concrete filled up to 300mm high in the room B. Then, the U-shaped box was kept still, and the bleed water in the room B was sucked up every 60 minutes in the first one hour, and at an interval of 30 minutes one hour later till the bleeding was over. The power output of the rod-shaped vibrator used is 280 W, the frequency of vibration is 220~270Hz, and the vibrating section is 475mm in length and 28mm in diameter.

Fig.2 Fresh concrete in the room B of the U-shaped box before and after vibration

The final bleeding capacity in the U-shaped box may be predicted based on the final bleeding capacity of JIS method. But the measurement of the final bleeding capacity of JIS method needs a long time. For proposing a rapid predicting method, in this study, the relationship between the bleeding capacity of vibrated concrete and the final bleeding capacity in the U-shaped box was also examined. When measuring the bleeding capacity of vibrated concrete, a vinyl chloride cylindrical container was used, which was 200 mm in diameter and 300 mm deep. The amount of concrete, needed to fill 200 mm high in the container, was calculated by its unit weight. After filling concrete into the container without any kind of compacting, the concrete was vibrated for 10s with the rod-shaped vibrator, and was kept still for 20 minutes. Then, the bleed water was measured.

3. RESULTS AND DISCUSSION

The vibration times till the concretes filled up to 300 mm high in the room B of the U-shaped box are shown in Table 3 and Fig.3. Two types of obstacle R1, R2 were used in the box in this experiment. we can see from Fig.3 that the greater the slump of fresh concrete, the shorter the vibration time. That is to say, the concrete having a higher fluidity has a good filling ability accordingly. However, the correlation was not very close. This may be due to the effect of segregation resistance of fresh concrete. The segregation of coarse aggregate particles in front of the obstacle retards the concrete flow.

Fig.3 also shows that the vibration time when using the obstacle R2 was shorter than in the case of using R1 except the data of the concrete of 21cm slump. It is no doubt that the size of the interval of the steel bars of the obstacle produces a great influence on the flow speed of fresh concrete. The larger the interval of steel bars, the faster the concrete flow.

Table 3 Vibration time till the room B of the U-shaped box was filled up to 300 mm high

Series	*Sl* (cm)	Type of obstacle	
		R2	R1
C1	24.0	4.59	8.39
C2	21.0	37.80	17.07
C3	19.0	33.70	27.66
C4	23.5	7.11	12.26
C5	19.5	20.00	31.50
C6	20.5	5.60	10.20
C7	19.0	14.60	43.88
C8	15.5	41.20	41.83

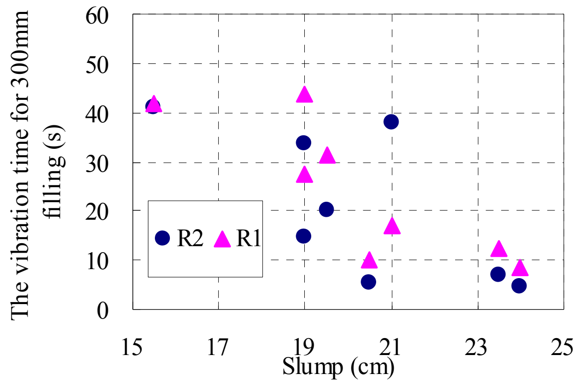

Fig.3 Relationship between the vibration time for 300mm filling and the slump of fresh concrete

The bleeding degree occurred in the room B of the U-shaped box is affected by the vibration time, which depends on the slump and segregation resistance of fresh concrete. The bleeding capacity of JIS method is also influenced by the slump and segregation resistance of tested concrete. Thus, it is considered that the vibration doesn't damage the correlation between bleeding capacities of JIS method and in U-shaped box. The bleeding behavior occurred in the room B of the

U-shaped box could express the bleeding behavior in actual concrete construction. The bleeding amount in concrete member cast in construction site would be predicted by using this U-shaped box experiment.

3.1 Relationships between Final Bleeding Capacities of JIS Method and in the U-Shaped Box

Fig.4 shows the relationship between the final bleeding capacities of JIS method and in the room B of the U-shaped box with the obstacle R2 for 8 series of concretes. As shown in Fig.4, the final bleeding capacity in the U-shaped box was greater than the final bleeding capacity of JIS method. This proves that the result of standard bleeding test can't express the bleeding degree of concrete constructed actually. But there is a close corelation between the two kinds of final bleeding capacities. The greater the final bleeding capacity of JIS method, the larger the final bleeding capacity in the U-shaped box. The relational expression was obtained by a regression analysis, as shown in Eq. (2).

$$B_{U1} = 0.214Ln(B_{JIS}) + 0.7565,\ R^2 = 0.9496 \qquad (2)$$

where B_{U1} is final bleeding capacity of fresh concrete in U-shaped box with the obstacle R2 (cm^3/cm^2), B_{JIS} is final bleeding capacity of JIS method (cm^3/cm^2).

Fig.5 shows the relationship between the final bleeding capacities of JIS method and in the room B of the U-shaped box with the obstacle R1 for 8 series of concretes. As shown in Fig.5, the greater the final bleeding capacity of JIS method, the larger the final bleeding capacity in the room B of the U-shaped box with the obstacle R1. By a regression analysis,the relational expression was obtained, as shown in Eq. (3).

$$B_{U2} = 0.1962Ln(B_{JIS}) + 0.729,\ R^2 = 0.9313 \qquad (3)$$

where B_{U2} is final bleeding capacity of fresh concrete in the room B of the U-shaped box with obtacle R1 (cm^3/cm^2).

Using Eq. (2) or Eq.(3) would evaluate the final bleeding capacity (B_{U1}, or B_{U2}) of fresh concrete placed in a member mould containing reinforced steel bars in constrcution site, based on the result (B_{JIS}) of standard bleeding test. Eq. (2) and Eq.(3) correspond respectively to the U-shaped box wiht the obstacle R2 and R1. No matter what kind of concrete, the selection of the obstacle used in the box should consider the aomunt and the minium interval of reinforced steel bars used in the actural concrete member. Hence, the selection of obstacle R2 and R1 may refer to the Guideline for Construction of High Fluidity Concrete published by Japan Society of Civil Engineer. In case that the amount of reinforced steel bars is between 100~350 kg/m^3 and the minium interval of steel bars is between 60~200 mm, the obstacle R2 is used. In this case, Eq.(2) is applied to the bleeding capacity evaluation. If the amount of reinforced steel bars is more than 350 kg/m^3 and the minium interval of steel bars is between 35~60 mm, the obstacle R1 should be selected, and the Eq.(3) is thus applicable.

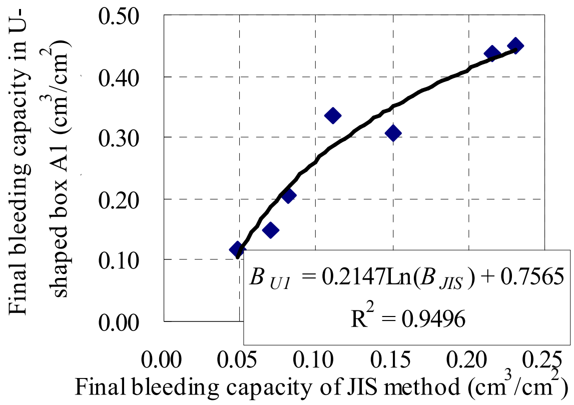

Fig.4 Relationship between final bleeding capacities of JIS method and in the U-shaped box with the obstacle A1

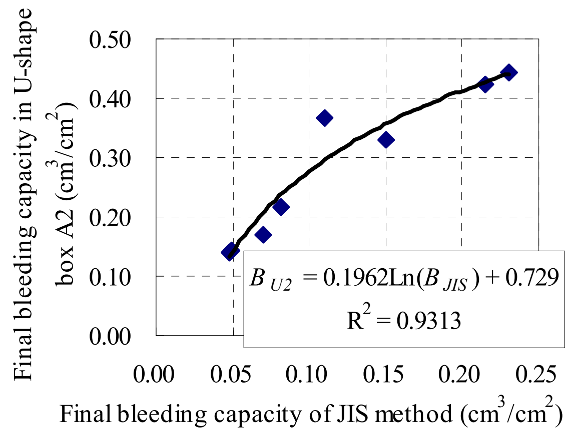

Fig.5 Relationship between final bleeding capacities of JIS method and in the U-shaped box with the obstacle A2

3.2 Relationship between Final Bleeding Capacity in the U-shaped Box and Bleeding Capacity of Vibrated Concrete

As mentioned above, the measurement of the final bleeding capacity of JIS method (B_{JIS}) needs a long time, in order to develope a rapid evaluating method of the bleeding of concrete placed in constrcution site, the relationship between the final bleeding capacity in U-shaped box and the bleeding capacity (B_v) of fresh concrete after it was vibrated for 10s and kept still for 20 minutes in a cylindrical container.

Fig.6 shows the relationship between the final bleeding capacity (B_{U1}) in the U-shaped box with the obstacle R2 and the bleeding capacity (B_v) of vibrated concrete. This figure indicates that the final bleeding capacity in the U-shaped box was greater than the bleeding capacity of vibrated concrete, but there is a good correlation between the two kinds of bleeding capacities, the greater the B_v, the smaller the B_{U1}.

The bleeding capacity B_v of vibrated concrete in the cylindrical container depends on the viscosity of concrete. The lower the viscosity, the B_v is greater.

However, the concrete with a lower viscosity requires shorter vibration time for filling concrete up to 300mm high in the room B of the U-shaped box because the flow speed of concrete is greater. During the vibration, the bleeding occurs due to excessive pore water pressure resulted from the vibration. It is considered that shorter vibration time would result in less bleeding water. Hence, for the concrete having lower viscosity, the B_v would be greater, but the B_{U2} is smaller.

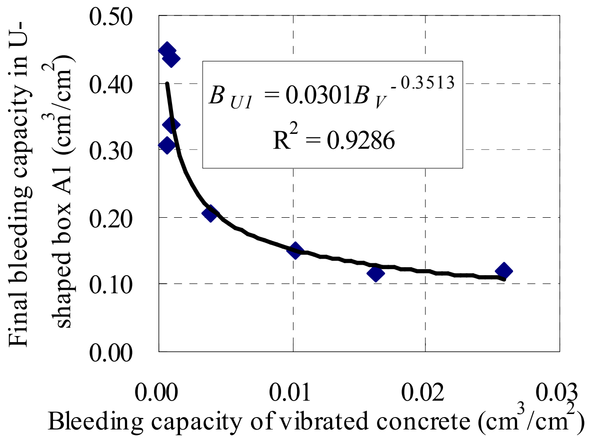

Fig.6 Relationship between the final bleeding capacity in the U-shaped box with the obstacle A1 and the bleeding capacity of vibrated concrete

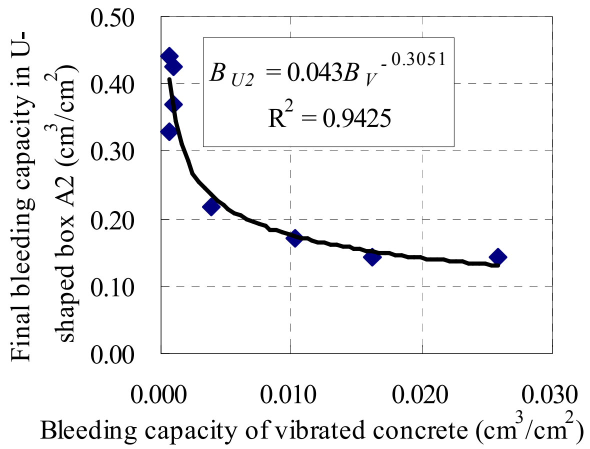

Fig.7 Relationship between the final bleeding capacity in the U-shaped box with the obstacle A2 and the bleeding capacity of vibrated concrete

Based on the regression analysis, the exponential function can be used to express this relationship, as shown in Eq. (4).

$$B_{U1} = 0.0301 B_V^{0.3513},\quad R^2 = 0.9286 \tag{4}$$

where B_v is bleeding capacity of vibrated concrete (cm^3/cm^2)

Fig.7 show the relationship between the final bleeding capacity (B_{U2}) in the U-shaped box with the obstacle R1 and the bleeding capacity (B_v) of vibrated concrete.We can see from this figure that there is also a good correlation between B_{U2} and B_v. A relational expression was obtained by the regression analysis, as shown in Eq. (5).

$$B_{U2} = 0.043 B_V^{-0.3051},\quad R^2 = 0.9425 \tag{5}$$

By using Eq. (4) and Eq. (5), we may predict early the fianl bleeding capacity (B_{U1}, or B_{U2}) of concrete member from the test result (B_v) of the bleeding capacity of vibrated concrete .

3.3 Relationship between the Bleeding Capacities of JIS Method and Vibrated Concrete

Fig.8 shows the relationship between the final bleeding capacity (B_{JIS}) of JIS method and bleeding capacity (B_v) of vibrated concrete. As shown in this figure, the bleeding capacity (B_v) was very smaller than the final bleeding capacity (B_{JIS}) of JIS method. This is not only because the measuring time of the B_v was short, but also because the concrete, filled into the cylindrical container, was not compacted and thus was loose before the vibration of 10s, the vibration didn't almost result in an excessive pore water pressure that is usually main cause of bleeding under vibrated state.

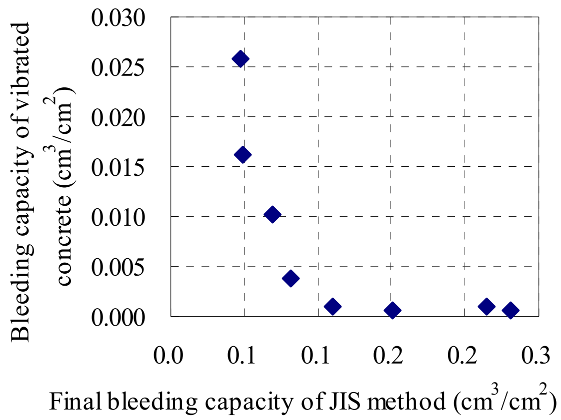

Fig.8 Relationship between B_v and B_{JIS}

The reference [7] states that some studies indicate that a 2~3s vibration period can slightly increase the bleeding capacity, however, the use of an internal vibratior in concretes from 20s~10 minutes tends to reduce bleeding capacity. This reference further pionts out that this reduction is partly due to the reduced volume of the matrix, the decreasing degree of dispersion of the aggregate particles, and the expulsion of some of the entrapped air.

Fig. 8 also shows that with the increase of the B_{JIS}, the B_v decreases. But when the B_{JIS} was more than 0.15 cm^3/cm^2, the B_v approached to zero. It is considered that the bleeding of fresh concrete is caused by the consolidation of solid particles [3]. The more the settlement of solid particles, the much the bleed water occurs. The concrete sample having a great final bleeding capacity (B_{JIS}) of JIS method implies that the solid particles in this concrete settle down easily. If the concrete is vibrated even only for 10s, many solid particles settle down during the vibration, and thus there are few solid particles to settle down after the vibration, less bleeding water rises up. Therefore, the greater the B_{JIS}, the smaller the B_v.

The relationship between the B_v and the B_{JIS} can be expressed by Eq.(6), based on the regression analysis of the data shown in Fig.8, of which the B_{JIS} are smaller than 0.15 cm^3/cm^2. Eq.(6) shown that there is a good correlation between the B_v and the B_{JIS}, when the B_{JIS} is not too large (smaller than 0.15cm^3/cm^2).

$$B_V = 1\times 10^{-6} B_{JIS}^{-3.2954},\ \ R^2 = 0.9568 \quad (B_{JIS}<0.15) \qquad (6)$$

Using the above equation, final bleeding capacity of JIS method would be predicted early from the bleeding capacity of vibrated concrete. It may be expected to further develop a rapid test method of bleeding from this experimental results.

In this study, the U-shaped box was used to simulate the filling process of fresh concrete in concrete member's mould. In the filling process, fresh concrete flows horizontally and then rises up when it reaches to lateral mould plates under a vibration. However, if the filling process of concrete is almost only a compacting process, not includes a horizontal flow process, e.g. column construction, it is not reasonable to use the U-shaped box. In this case, replacing the U-shaped box with a cylindrical container is practical, but it is necesary to discuss how to set steel bars in the container. However, the good correlation of the B_{JIS} with the B_v suggests that it is possible to predict the bleeding capacity of concrete, which is merely compacted by vibration, from the test result of the standard bleeding test.

4. CONCLUSIONS

In order to propose an evaluating method of bleeding capactiy of fresh concrete placed into member mould by vibration, a series of experiments were carried out to examine the relationships between the final bleeding capacity B_{JIS} of fresh cocnrete measured with JIS method, the final bleeding capacity B_{U1}, B_{U2} of fresh concrete filled in the room B of the U-shaped box by vibration, and the bleeding capacity B_v of fresh concrete after vibrated for 10s and kept still for 20 minutes in a cylindrical container, respectively. Main conclusions are as follows:

(1) The final bleeding capacity of fresh concrete placed by vibration is greater than the final bleeding capacity of JIS method. The test result of the standard bleeding test can't reflect the bleeding degree of vibration-placed concrete member.

(2) There is a close correlation between the final bleeding capacity (B_{U1} or B_{u2}) in the U-shaped box and the final bleeding capacity (B_{JIS}) of JIS method, no matter what kind of obstacle of steel bars is used. The greater the B_{JIS} , the greater the B_{U1} or the B_{u2}. Using the B_{JIS}, final bleeding capacity of concrere member placed by vibration can be evaluated.

(3) The B_{JIS} is larger than the bleeding capacity (B_v) of fresh concrete after vibrated for 10s and kept still for 20 minutes in a cylindrical container. When the B_{JIS} is more than 0.15cm^3/cm^2, the B_v is close to zero. There is a good correlation between the B_{JIS} and the B_v, it is possibe to rapidly predict method of the B_{JIS} base on the measurement of the B_v.

(4) There are close correlation between the B_v and the B_{U1}, B_{U2}. The greater the B_v, the smaller the B_{U1} or B_{U2}, The final bleeding capacity of concrere member cast by vibration can be evaluated early base on the measurement of the B_v.

Development a rapid test method of bleeding will be performed. The U-shaped box can't necessarily simulate the process of concrete member. Therefore, We will further propose a model of placement of concrete member, e.g. using L-shaped box with steel bar mesh, and investigate how to evalute the final bleeding capacity of fresh concrete after placed by vibration, based on the bleeding capacity measurement of JIS method or vbration method.

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