THE INFLUENCE OF VIBRATORS WITH DIFFERENT FREQUENCIES ON DURABILITY OF HARDENED CONCRETE

Koki Tagomori[1], Takeshi Iyoda [2]

[1] *Graduate school of Engineering, Shibaura Institute of Technology, Japan*

[2] *Department of Civil Engineering, Shibaura Institute of Technology, Japan*

ABSTRACT

Concrete compaction using vibrator suppress the decline of strength and durability of concrete. Giving appropriate vibration to concrete plays a role in removing unnecessary mixed air such as entrapped air. Also, the aggregate in the concrete is evenly positioned because there is no deviation in the material. However, if the vibration time is short, concrete can't be filled the formwork. On the other hand, if the vibration time is long, aggregate and paste separate in concrete. It is due to the large density of the aggregate. Compaction at the time of construction, vibration time is important for concrete. According to the Japanese standard, the vibration time per point is set to 5 to 15 seconds. In the field of civil engineering, there are two types frequency low and high. Also self-compacted concrete has been developed. Therefore, it is necessary to check whether the current standard is appropriate. Vibrators with different frequencies checked the influence on the durability with different properties of concrete. As a condition, the energy of the vibrator is constant. Accordingly, a vibrator different only in frequency was used. As a result of this research, it was confirmed that durability of concrete is improved high frequency vibrator than low frequency vibrator. A high frequency vibrator is considered to densify concrete. However, a high frequency vibrator greatly influences the moisture movement on the concrete surface. Therefore, the denseness differs between the top and the bottom of the concrete surface.

Keywords: vibration compaction, frequency, durability, middle fluidity concrete

1. INTRODUCTION

Vibrators are used for concrete structures. There are two advantages of using a vibrator. First, the aggregate in the concrete is evenly dispersed. Secondly, entrapped mixed air in the concrete can be removed. The compaction controls deterioration of strength and durability of concrete. However, if the vibration time is short, the concrete can't be sufficiently filled in the formwork. On the other side, if the vibration time is long, concrete causes separation. Therefore, compaction of the vibrator at construction is important for concrete. Vibrators are roughly divided into two types, low frequency and high frequency. A low frequency vibrator affects coarse aggregates with high density. Therefore, the low frequency vibrator is used at the dam. This is because large coarse aggregates are used. On the other hand, the high frequency vibrator affects low density cement paste and aggregate.

Therefore, high frequency vibrators are used in many construction sites. It is assembled in high density of rebar for safety in Japan. For that reason, construction that uses high-flowability concrete is increasing. Therefore, various slump concrete is currently used. According to the Japanese standard, the vibration time of a vibrator in one place is set to 5 to 15 seconds. However, the subject of this standard is low slump concrete. It is unknown whether it can be applied to various slump concrete. In this study, two kinds of vibrators, such as high frequency (240 Hz) and low frequency (170 Hz) were used. Also, the vibration energies of the two kinds of vibrators were set to be the same. The purpose of this research is to dear the influence of differenced frequency of vibrator on the durability of concrete.

2. OUTLINE OF EXPERIMENT

2.1. Concrete mix proportion

Table 1 shows the concrete mix proportions in this experiment. Two kinds of concrete were prepared. One is normal concrete and the other is middle fluidity concrete. The water cement ratio of the two concrete was 50%. The slump of normal concrete was adjusted to 18 ±2 cm. The slump flow of middle fluidity concrete was adjusted to be 50 ±10 cm. The air volume was adjusted to be 4.5±0.5%.

Table 1 : Mix proportion

Concrete type	W/C (%)	s/a (%)	Unit weight (kg/m³)				Water reducing agent (%)	Thickener (%)	AE agent (%)	Amount of air (%)	slump (cm)	Slump flow (cm)
			W	C	S	G						
Normal concrete	50	48	170	340	858	951	0.4	—	1.5A	4.5±0.5	18±2	—
Middle fluidity concrete		60	180	360	1047	714	—	1.6	2A		—	50±10

2.2. Compaction test

Figure 1 shows the outline of the concrete formwork. The size of the formwork was 600 × 300 × 200 mm. Two types of vibrators with different frequencies were prepared. The frequency were 170 Hz and 240 Hz. Table 2 shows compaction time and energy of the vibrator. The energy of the two vibrators as to be the same was calculated from the equation (1). No. 1 and 2 were vibrated within the allowed compaction time (5 to 15 seconds) determined by Japanese standards. The vibration time of No. 3 is longer than the specified time.

$$E = \frac{\rho_0 \times \alpha^2_{max}}{4\pi^2 f} \times t \quad (1)$$

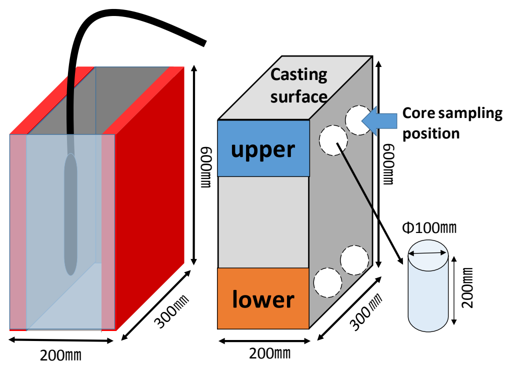
E : Compaction energy (J/l), ρ_0 : Unit volumetric mass (kg/l), α^2max : acceleration (m/s^2), f : Frequency (s^{-1}), t : Vibration time (s)

2.3. Simple water permeability test

Figure 2 shows the outline of the simple water permeability test. Concrete specimens were air curing. It was confirmed that the moisture content inside the concrete became constant using a moisture meter. The simple permeability test was installed at the upper part and the lower part of the side of the concrete specimen. The simple permeability test sealed so as not to leak water. We measured every hour until 12 hours. The amount of water absorption was calculated.

Table 2 : Vibration time and compaction energy

No.	Concrete type	low [170Hz]	high [240Hz]	Compaction energy (J/L)
①	Normal concrete	15	10	1.20
②	Middle fluidity concrete	10	7	0.79
③		30	25	2.38



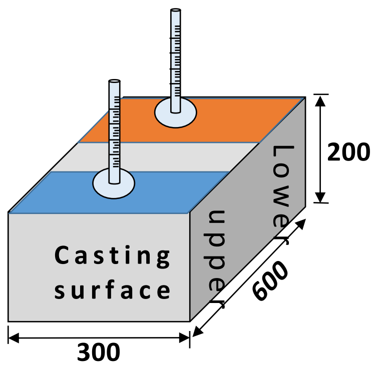


Figure 1 : Outline of specimen **Figure 2 : Simple water permeability test**

2.4. Air permeability test

The core (φ100 × 40 mm) was taken from the upper part and the lower part of the concrete specimen. The collected cores were dried in a drying oven until the weight loss became constant. Measurement was carried out using an air permeability test. The air permeability coefficient was calculated using Equation (2).

$$K = \frac{2LP_2}{P_1^2 - P_2^2} \times \frac{Q}{A} \tag{2}$$

K： Air permeability coefficient (cm^4/Ns), L： Specimen thickness (cm), P_1 ：Loading pressure (N/cm^2), P_2 ：Outflow side pressure (N/cm^2), Q： Amount of air permeability (cm^3/s), A：permeable area (cm^2)

3. RESULTS AND DISCUSSION

3.1. Simple water permeability test

Figure 3 shows the results of the simple water permeability test. Focus on the upper and lower parts of concrete. Water permeability is higher at the upper part than at the lower part. This tendency is not related to concrete mix proportion and frequency. It is thought that the bleeding effect reduced the durability of the surface layer at the upper part of the concrete. In the bleeding phenomenon, low density water rises in concrete. Next, focus on the vibrator frequency. The amount of water permeability is higher at low frequency than at high frequency. The high frequency of vibration has an effect on the durability of the concrete surface layer than the low frequency. Figure 4 shows difference in water permeability between the upper part and the lower part on different frequency. Focus on the frequency of the vibrator, the difference in water permeability is higher at high frequency than at low frequency. As the frequency increases, the durability of the surface layer improves but the uniformity of the upper part and the lower part disappears. Focus on the type of concrete, The difference in water permeability is smaller for middle fluidity concrete than normal concrete. Because middle fluidity concrete is viscous. The rise of water due to bleeding is prevented by viscosity. Focus on giving longer vibration time than the standard. When it is vibrated for a long time, the durability of the surface layer is low. Also, uniformity is greatly lost.

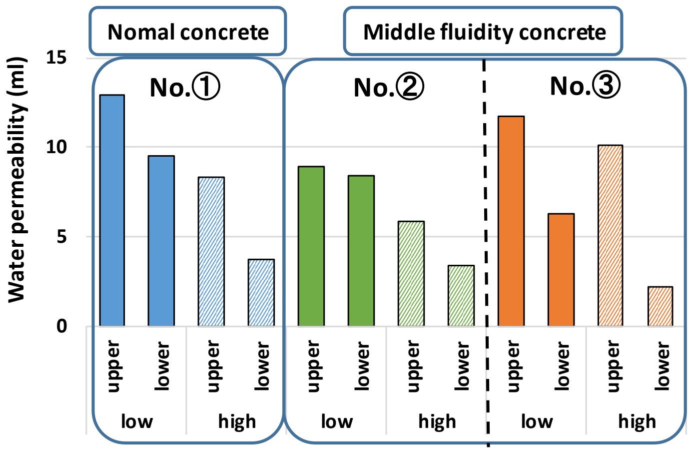


Figure 3 : Simple water permeability test

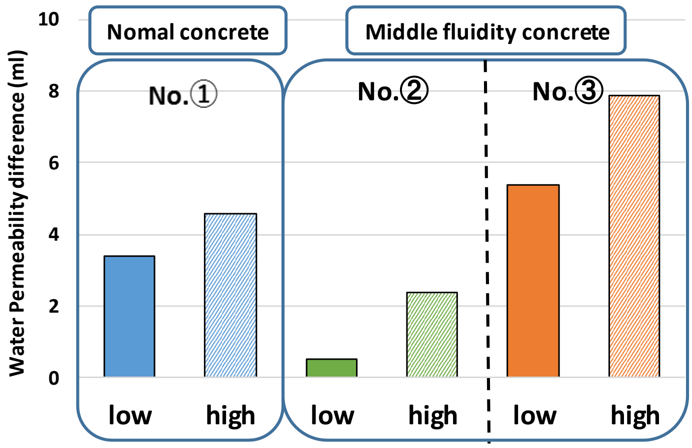


Figure 4 : water permeability difference

3.2. Air permeability test

Figure 5 shows the results of the air permeation test. Focus on the upper and lower parts of concrete, air permeability coefficient has smaller the lower part than the upper part. Next, focus on the frequency of the vibrator, the air permeability coefficient for high frequency is smaller than for low frequency. This tendency is the same as the simple water permeability test. Figure 6 shows the difference between the upper and lower permeability coefficients. Focus on the frequency of the vibrator, the difference of the air permeability coefficient is smaller in the high frequency than the low frequency. The low frequency has no homogeneity inside the concrete than the high frequency. Focus on the type of concrete, there is no difference in permeability coefficient for middle fluidity concrete. The influence of the difference in frequency on the inside of the middle fluidity concrete is small.

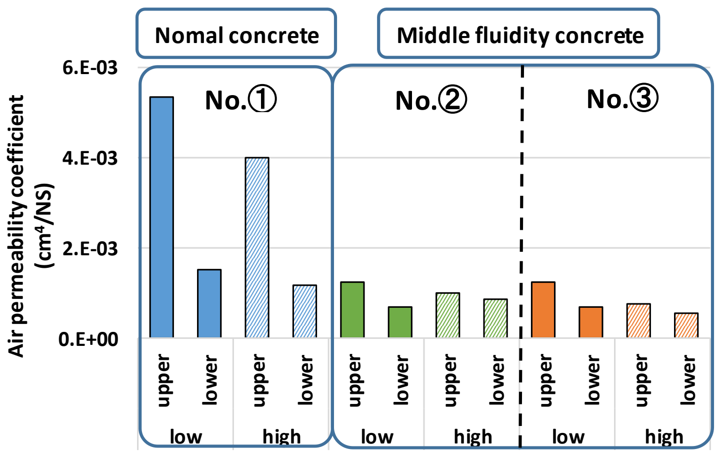


Figure 5 : Air permeability coefficient

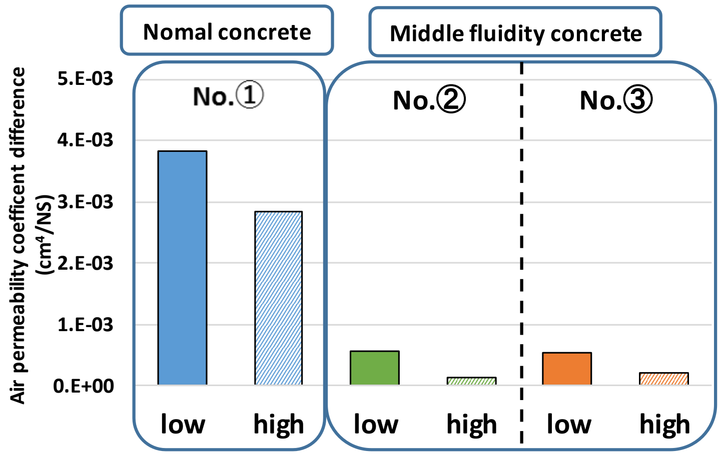


Figure 6 : Air permeability difference

4. CONCLUSION

The results of research are summarized as follows:

(1) When the vibrator is used, there is a difference in durability between the upper side and the lower side of the concrete. This is thought to be an effect of bleeding.

(2) The durability of the concrete surface layer and the inside of the concrete was improved the high frequency than the low frequency.

(3) Middle fluidity concrete is hardly influenced by frequency than normal concrete because it is viscous.

(4) The high frequency influences the durability of the surface layer more than inside the concrete.

5. REFERENCES

M.Hirata, N.Sasakura; Examination of Estimation Method of Vibration Propagation by Stick Vibrator - Induction of Acceleration Distribution Formula - Summary of JSCE annual academic lecture presentation, V-356, 2014

N.Yoshimitsu, H.Masashi; Estimation method of vibration propagation by bar vibrator - Comparison with experiment results - Summary of JSEE annual academic lecture presentation, V - 357 , 2014