Estimation of Early Aged Compressive Strength of Concrete by Electric Conductivity

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ABSTRACT

Concrete in a formwork must be demolded after reaching the required strength. However, it is difficult to estimate compressive strength of concrete in the formwork. Because the strength of concrete depends on ambient temperature, type of cement etc. If it is possible to estimate the strength of the concrete in real time, demolding time can be estimated. Then the period of the concrete in the formwork will be shorted. we focused on the electrical conductivity of concrete in this research. It has been reported that compressive strength and electrical conductivity are related. However, early aged compressive strength has not been estimated. So in this research concrete with different early aged compressive strength is made by different cement and ambient temperature. Then, the relationship between the electrical conductivity and early aged compressive strength of concrete was investigated. As a result, The electrical conductivity of concrete was related on compressive strength. Therefore, it is possible to estimate the early aged compressive strength of concrete by using electric conductivity.

KEYWORDS: *Compressive strength, Electric conductivity, Hydration reaction, Hydration heating rate, Temperature*

1. Introduction

Concrete in a formwork must be demolded after reaching the required strength. However, it is difficult to measure compressive strength in real time. Therefore, We focused on the conductivity of concrete as a method to estimate the strength of concrete. Conductivity is a value representing easiness of electricity. The conductivity meter is shown in Figure 1. Conductivity is mainly used to measure water quality and salt concentration. It has been reported that compressive strength and electrical conductivity are related in the past research. However, early aged compressive strength has not been estimated. Therefore, we examined the relationship between compressive strength and conductivity of early aged concrete.

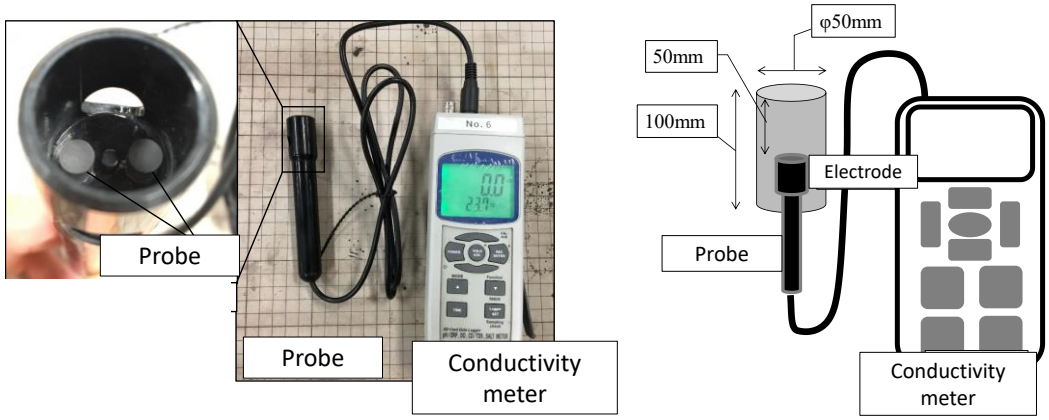


Figure 1 Conductivity mater

2. Experiment

2.1 Conductivity and Compressive strength.

The concrete mix proportion is shown in Table 1. Concrete using ordinary Portland cement (OPC) and blast furnace slug cement (BB) was made. Concrete with different types of cement and atmosphere temperature was made. In order to confirm the relationship between strength and conductivity at early aged. Then conductivity and compressive strength were measured. Compressive test specimen sealed curing. In addition, the atmosphere temperature of the specimen was changed to 5,20 and 35 degrees Celsius. In order to change the strength development of the concrete. Conductivity was measured with mortar screened with concrete at 5 mm. A probe was embedded in the specimen. In order to prevent water from entering the inside of the probe by bleeding, the electrode part faced upward. Measurement intervals of conductivity were set to 5-minute intervals up to 24 hours of age and 1 hour intervals until 28 days of age after 24 hours of age.

Table 1 Concrete mix proportion

Symbol	W/C(%)	s/a(%)	Unit amount(kg/m^3)				Temprature (℃)
			W	C	S	G	
OPC-5℃	50	48	175	349	840	938	5
OPC-20℃							20
OPC-35℃							35
BB-5℃	50	48	175	349	837	931	5
BB-20℃							20
BB-35℃							35

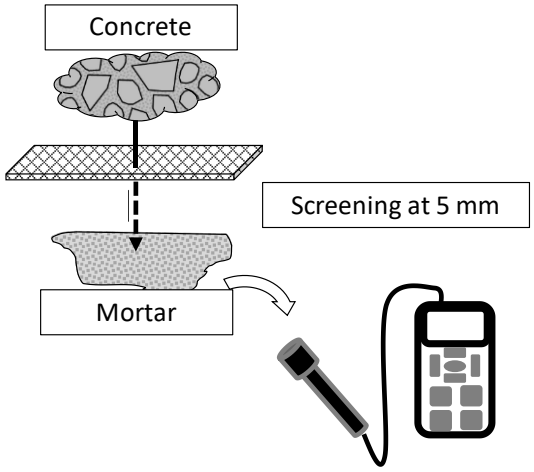


Figure 2 Measuring method of conductivity

2.2 Results of Conductivity and Compressive strength.

The results of conductivity of OPC and BB are shown in Figure 3. When the ambient temperature was high, the maximum value of the conductivity became large. The decrease in conductivity after peak also increased. The results of the compressive strength test are shown in Figure 4. Compressive strength increased as temperature increased. Strength development was different depending on ambient temperature. The results of conductivity and compressive strength are shown in Figure 5. There was a relation between conductivity and compressive strength.

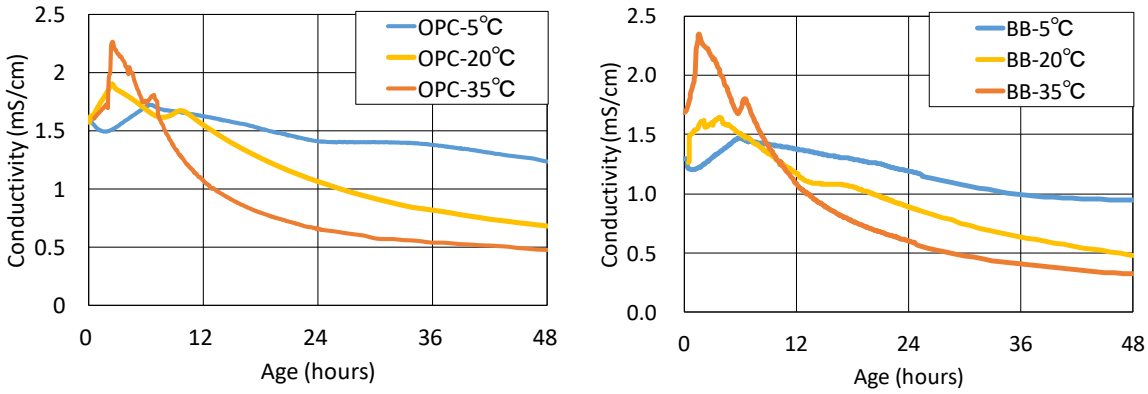


Figure 3 Conductivity (OPC and BB)

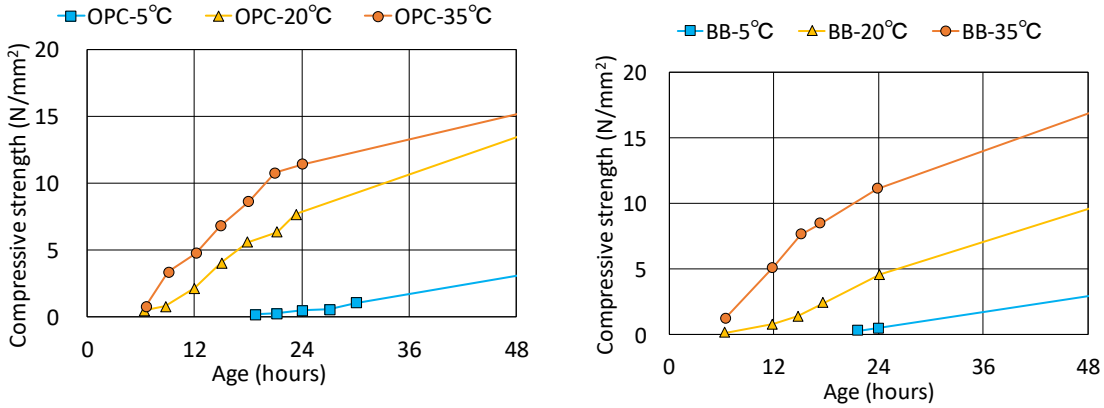
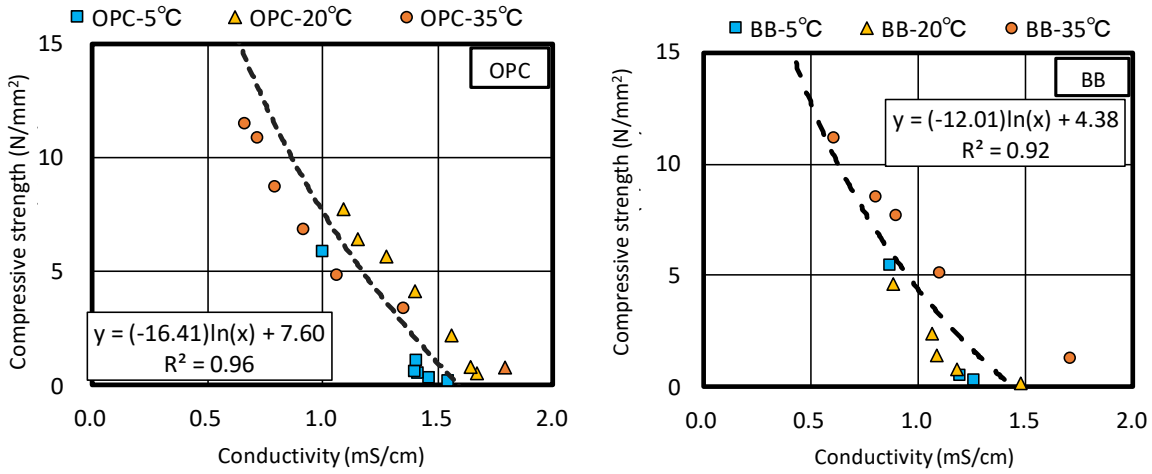


Figure 4 Compressive strength (OPC and BB)



Figurer 5 Conductivity and Compressive strength (OPC and BB)

2.3 Conductivity and hydration heat

Compressive strength increases with hydration reaction. In other words, it is conceivable that the conductivity measures the hydration reaction of concrete. Therefore, conductivity and hydration reaction were measured. Conductivity of concrete was the same as that of Table 1. Hydration heat was measured by a conduction calorimeter. Measured with mortar of 50% of water cement ratio.

2.4 Results of Conductivity and hydration heat.

The results of conductivity and hydration heat are shown in Figure 6. When the temperature is high, the maximum value of conductivity is large, and the decrease after peak is large. In addition, 35 ° C reached the maximum of conductivity earlier than 20 ° C. The result of hydration heat also reached a

maximum value at 35 ° C. earlier than 20 ° C.

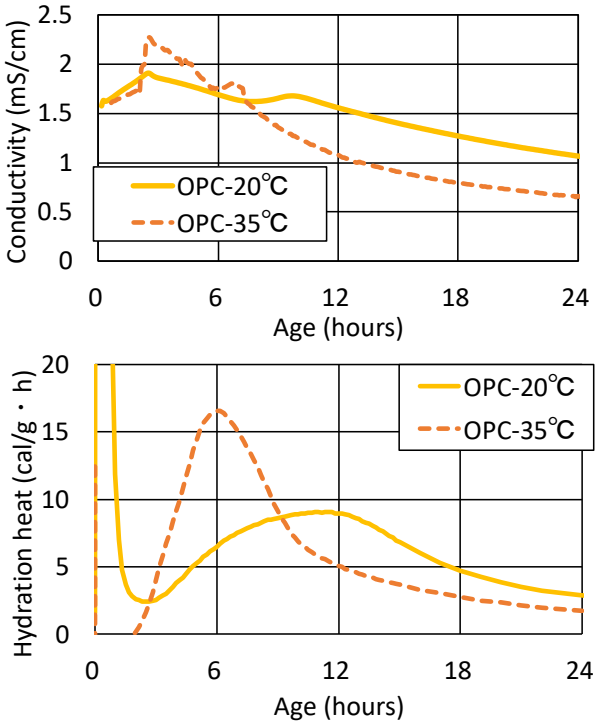


Figure 6 Conductivity and hydration heat

3.2 Estimation of early aged compressive strength.

Calculation formula of early aged concrete strength was calculated. The estimation equation is shown in (1). The strength was estimated with concrete of OPC in Table 1.
The results of the estimated strength are shown in Figure 7 The actual strength was higher than the estimated strength. In this study, the compressive strength was calculated by the average of specimens. However, the compressive strength of early age was about 1.5N/mm^2 different. This is considered to be the cause of the difference between the estimated strength and the experimental result. It is necessary to improve the estimation accuracy of intensity.

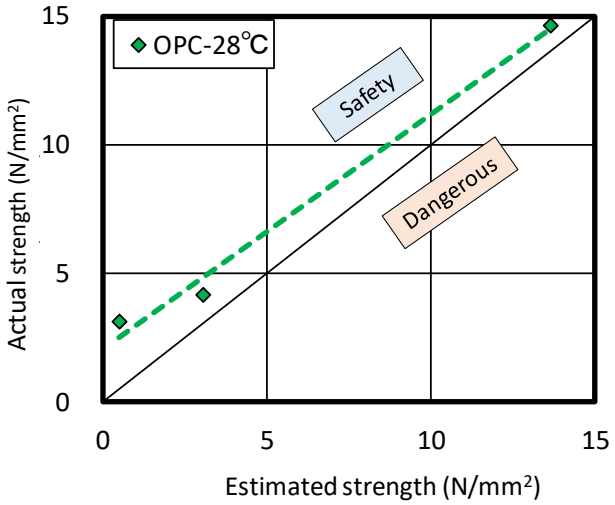


Figure 7 Compressive strength estimation

$$y = (-16.41)\ln(x) + 7.60 \quad (1)$$

y:Compressive strength (N/mm^2)
x:Conductivity (mS/cm)

4. Proposal of estimation method of demolding time

The estimation method of this study can calculate compressive strength from the conductivity of concrete. If it is possible to estimate the strength of the concrete in real time, demolding time can be estimated. Then, the period of the concrete in the formwork will be shorted. Figure 8 shows a model of strength estimation. Embed the conductivity meter inside the concrete formwork. Compressive strength is calculated from the measured conductivity. Then estimate demolding time. In the future, it is necessary to estimate the strength considering the construction conditions and environmental conditions

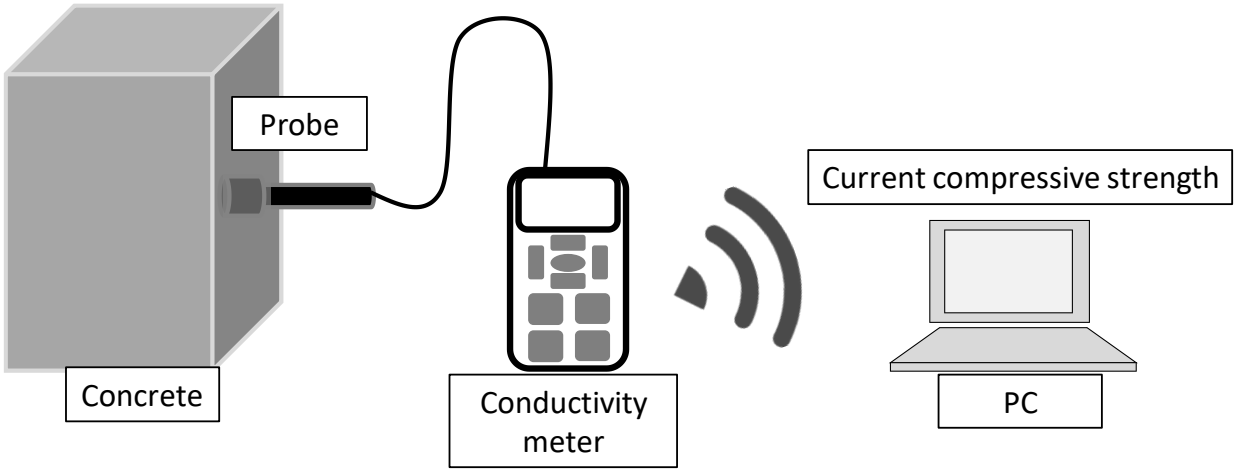


Figure 8 Strength estimation model

5. Conclusion

1. Conductivity of concrete is evaluating the progress of hydration reaction.
2. When the ambient temperature is high, the maximum value of conductivity becomes large, and thereafter, the decrease in conductivity is large.
3. Conductivity and compressive strength were related.
4. Compressive strength was estimated from conductivity. The actual strength was higher than the estimated strength.

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