Study of monitoring technique of hardening process concrete using electrical conductivity

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ABSTRACT: Strength and durability of concrete structure is greatly affected by demolding time. However, a technique for monitoring the state of concrete in the mold is not established now. Therefore, the authors proposed monitoring method on non-destructive using an electric conductivity meter. That is can be estimated compressive strength development in the mold. In this study, we analysis of the mechanism it is possible to estimate the compressive strength by electrical conductivity. As a result, there is a relationship between electrical conductivity and liquid water content in the pore. In other words, the conductivity meter is measured indirectly pore. So, it is possible to estimate the compressive strength.

1 INTORODUCTION

When construction of the concrete structure, management of demolding time and curing period are very important. Demolding at the time when strength is not enough state will cause the risk of cracking. Therefore, it is very important to monitoring the strength during the period from placing of concrete to demolding for the quality control of concrete. Currently, decision of demolding time and curing period is compressed tested using specimens for quality management. However, concrete structure is susceptible to environmental factors around the temperature and humidity as a specimen for quality control. Therefore, different comparing the strength of the specimens for quality control and concrete structure. Hence, the specimens for quality control, which may not be measured correctly compressive strength of concrete structure. Recently, authors have carried out research focused on the electrical characteristics as a concrete method of estimating the strength of concrete, and that by using the conductivity to estimates the strength of the concrete structure. We have reported that there is a relationship concrete strength and electrical conductivity. However, this mechanism is unresolved. Therefore, we the aimed at analyzing of the mechanism which the relationship between the compressive strength and electrical conductivity. In this study, we were a consideration first time. And we assumed, conductivity measures the ions of water present in pore inside the concrete as a medium. So, we measured that inside the concrete moisture and the pore. Then, we grasped those results and conductivity relationship. In addition, it was carried out to confirm the relationship between the compressive strength and electrical conductivity.

2 EXPERIMENTAL OUTLINE

2.1 The materials used and concrete mix proportions

The mix proportions shown in Table 1. Binder was used ordinary Portland cement (OPC) and ground granulated blast furnace slag (BFS). BB was replaced blast furnace slag 50%, BC was replaced it 70%. W/B30% was used a high-range AE water reducing admixture in order to prevent segregation.

Table 1. The specified mix proportions

Cement Type	W/B(%)	s/a(%)	Unit weight(kg/m^3)				
			W	OPC	BFS	S	G
N	30	48	170	567	-	768	850
	50			340	-	830	955
	65			262	-	890	986
BB	50			170	170	833	948
BC	50		165	102	238	831	945

2.2 Test method

2.2.1 Compressive strength test

The sealed curing of the specimen was constant temperature and relative humidity (60%). Sealed curing 1, 3, 7, 28, 91 days, BC 1.8, 3, 7, 28 days. The compressive strength was carried out according to the "concrete compressive strength test (JIS A 1108-2006)." Strength was calculated from the average of three data because in consideration of the error.

2.2.2 Conductivity measurement test

The conductivity represents the ease flow of electricity. High conductivity indicates that electricity easily flows, in other words small conductivity indicates that it is difficult to flow of electricity. It shows an outline of the measurement of conductivity in Figure 1. Use cylindrical specimens of ϕ100 × 200mm, it was placed a conductivity meter at the position of 50mm from the surface to prevent the effects of drying. Conductivity was automatically measured every 5 minutes.Specimens were sealed curing in a constant temperature and relative humidity (60%). Measuring section dimension conductivity is as small as 20 mm. Therefore, considered that an error is caused by the measuring devices, it is difficult evaluation of the absolute value. Hence, to calculate the conductivity ratios as shown to Equation (1), it was decided to evaluate this value.

$$Conductivity\,ratio = \frac{Conductivity\,at\,the\,time\,of\,measurement}{Conductivity\,at\,the\,time\,of\,peak} \quad (1)$$

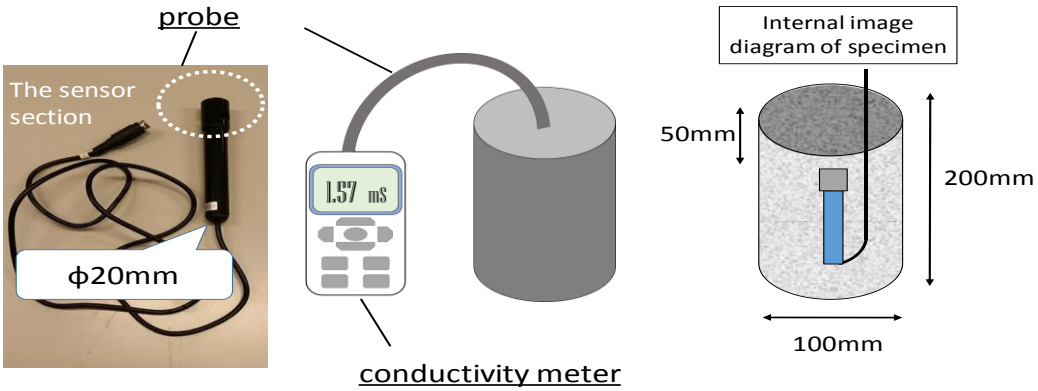


Figure 1. The measurement of conductivity

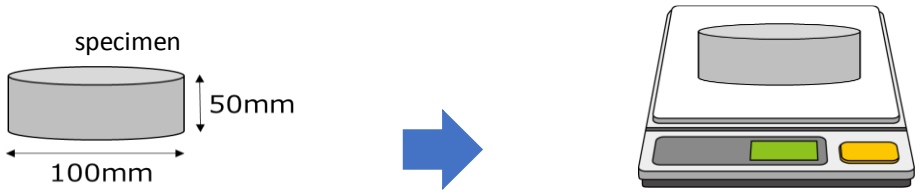
2.2.3 Measurement of the pore ratio

Specimens for measurement of pore was obtained from the compressive strength specimens. The specimens were immediately stopped to hydrate with acetone. And then, after it was dried in a drying oven at 40 degree Celsius. Then, it specimen measuring the pore by using the principle of Archimedes.

2.2.4 Measurement of the amount of water

In order to grasp the moisture of internal concrete, to calculate the evaporation amount of concrete inside of moisture by measuring the specimen weight. The measurement method is shown in Figure 2. Using specimens of ϕ100 × 50mm, it was the same curing as the specimen of compressive strength. Specimen of weight was measured in a constant temperature and relative humidity (60%) after demolding to constant weight. The reduced weight in RH 60% environment was set to liquid water that is not used in hydration. To compare the liquid water at each mix proportions, it was calculated water content per unit volume. It was regarded as the liquid amount of water which internal concrete. It shown the calculation method in the equation (2).

$$Amount\ of\ liquid\ water = \frac{Liquid\ water}{Volume\ of\ the\ specimen} \qquad (2)$$



①Demolding at the time of an age ② Measurement until a constant weight

Figure 2. Weight measurement method

3 EXPERIMENTAL RESULT

3.1 Test results and discussions

3.1.1 Conductivity ratio

The results of the conductivity measurement test of each mix proportions in Figure 3. The measurement of conductivity showed a behavior, conductivity increases after placing, thereafter decreasing. Peak of conductivity ratio was found at about 100 to 200 minutes regardless of mix proportion. Speed at which peak appears is different by mix proportions. Time when the peak of conductivity came has been reported that captures the ion elution in the initial stage of hydration.

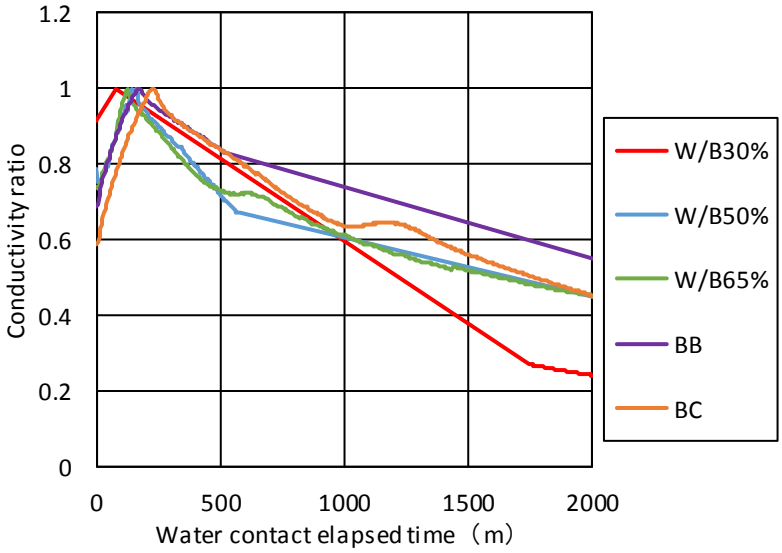


Figure 3. Conductivity ratio

3.1.2 Compressive strength

It shows the results of the compressive strength test of each mix proportions in Figure 4. W/B30% as compared to the other mix proportions, it is found that the strength development from an age of the early stage. Furthermore, BC was replaced 70% BFS it can be seen that the initial strength development is delayed compared to other the mix proportions.

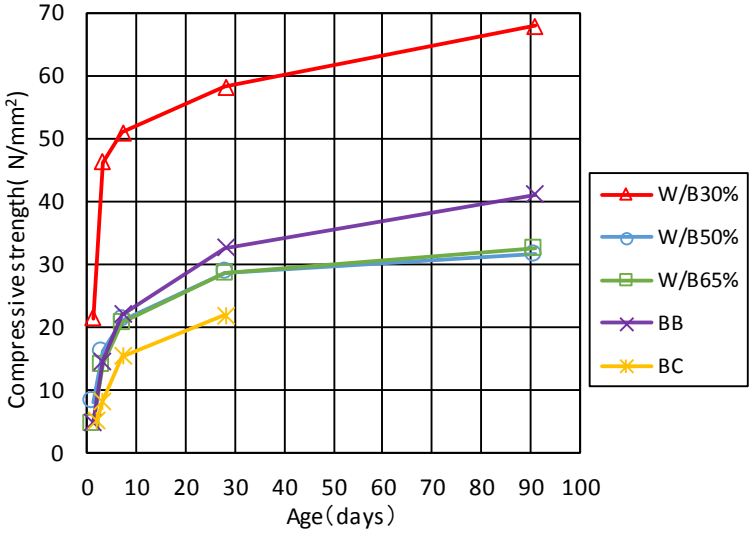


Figure 4. Compressive strength

3.1.3 Pore ratio

It shows the results of the pore ratio in Figure 5. Also shows the relationship between compressive strength and the pore ratio in Figure 6. Compressive strength is increased with decreasing the pore ratio.

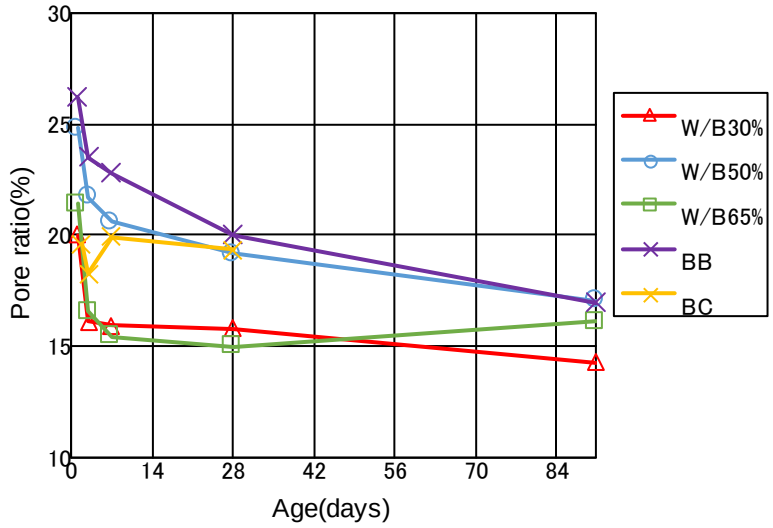


Figure 5. Pore ratio

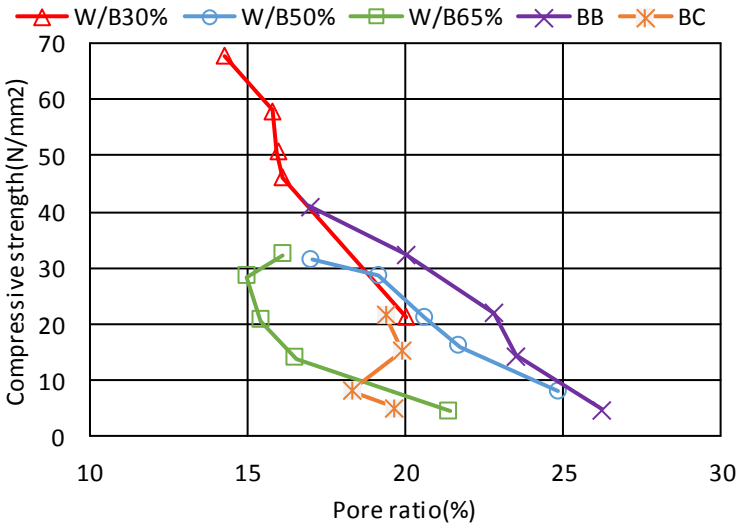


Figure 6. Relationship between compressive strength and pore ratio

3.1.4 Amount of liquid water

Figure 7 shows the weight loss of the W/B50% as an example. Weight reduction rate of curing period long specimen is small, the gradient of the weight loss was also slowed. Along with the passage of age, the water in the specimen is to use hydration. Therefore, we consider the amount of water that long-term curing the specimen was little. Figure 8 shows the liquid amount of water. It is found that liquid amount of water is reduced as well age has passed in any of mix proportions. Further, from the initial stage W/B30% it can be confirmed liquid amount of water is less than the other mix proportions. On the other hand, it can be confirmed that reduction rate of the liquid amount of water is comparable in each mix proportion. This is

in other words, it is found that the decrease in the proportion of liquid amount of water does not depend on such as W/B and admixtures.

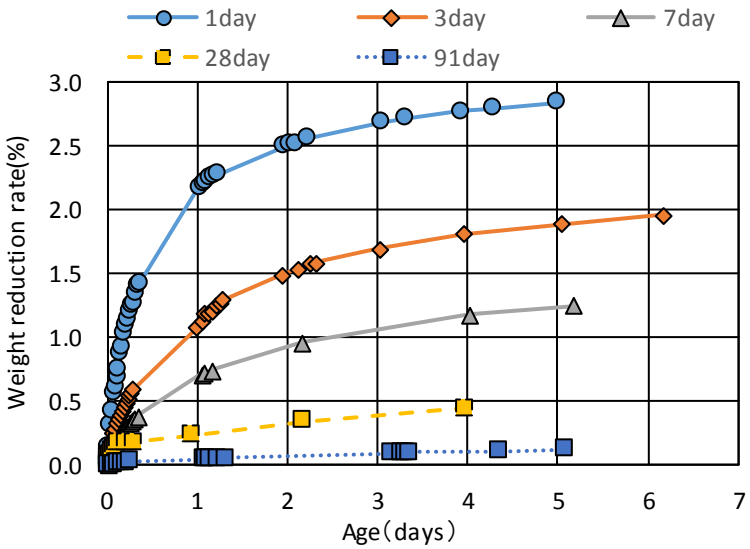


Figure 7. Weight reduction rate (W/C50%)

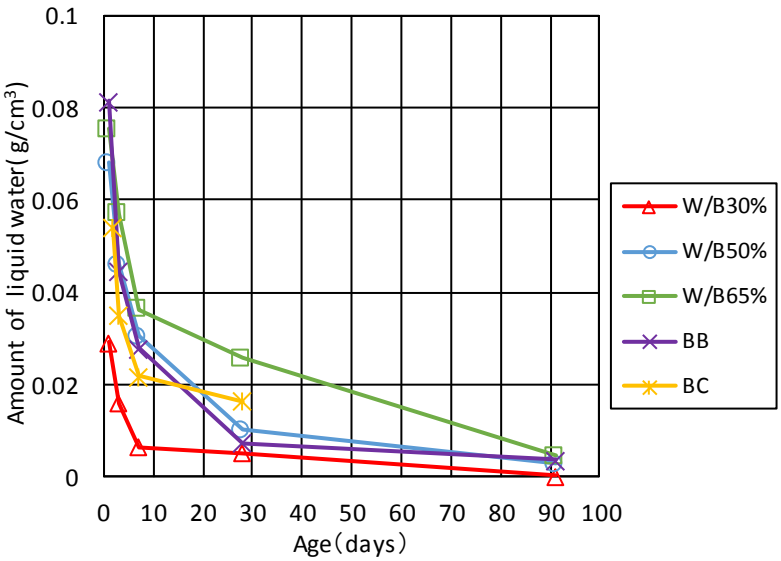


Figure 8. Amount of liquid water

3.1.5 Conductivity ratio and compressive strength

It shows a relationship between the compressive strength and conductivity ratio in Figure 9. W/B30% and BC can be confirmed that there is another relationship as compared to the other three mix proportions. As this causes depends on the ion concentration of water in the concrete. Because cement is known to elute calcium ions free water. BC, which replaces the blast furnace slag fine powder 70% is less the amount of calcium ions than other cement. Therefore considered conductivity ratio becomes smaller. W/B30%, compared with other mix proportions, holding water content is less, considered that allowed to increasing the conductivity ratio.

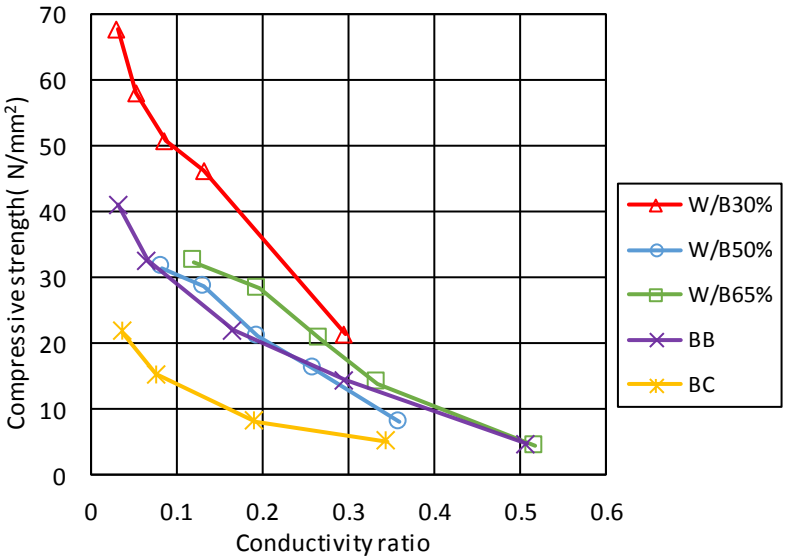


Figure 9. Relationship between the compressive strength and conductivity ratio

3.1.6 Conductivity ratio and concrete inside of liquid water

There is a relationship between conductivity ratio and the compressive strength. Therefore in order to clarify that mechanism, we decided to confirm assumptions initially that conductivity measures the ions of water present in pore inside the concrete as a medium. It shows a relationship between the conductive ratio and concrete inside of liquid water in Figure 10.With the passage of age, liquid water is reduced along with the electrical conductivity, it can be confirmed that decreases linearly. Also, this tendency is regardless of mix proportions. Therefore, conductivity is to capture the concrete inside of moisture. In particular, it considered that the measures the water not used for hydration.

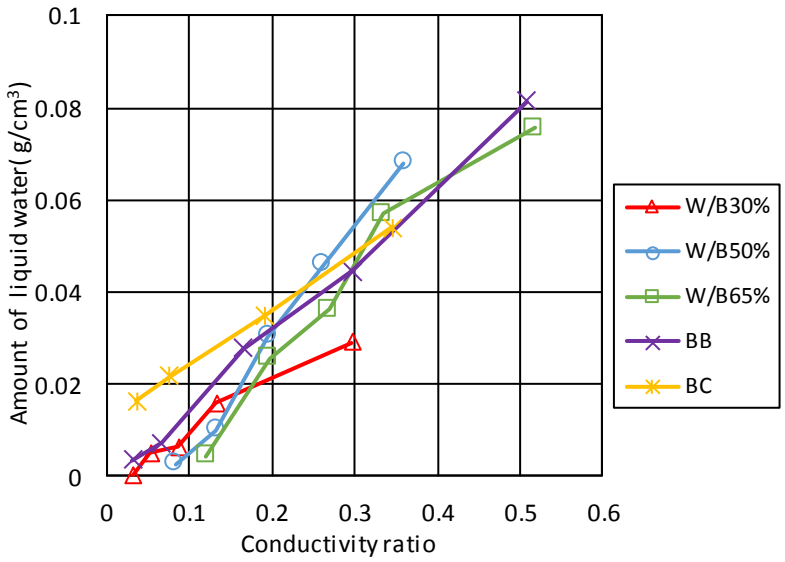


Figure 10. Relationship between the conductive ratio and concrete inside of liquid water

3.1.7 Conductivity ratio and liquid water in the pore

From the results of 3.1.6, conductivity meter is to measure the moisture in the concrete. Further it was confirmed that in particular measures the liquid water that is not used in hydration. However, the relationship of the liquid water and the compressive strength is not elucidated. Therefore, pore ratio having a relationship with the compressive strength, we focusing on the relationship between liquid water in the pore and the conductivity ratio. It shows a relationship between conductivity ratio and liquid water in the pore in Figure 11. Similar to Figure 10, Liquid water in the pore decreases along with the conductivity. It can confirm that decreases linearly. Conductivity is to measure the liquid water in the pore, In other words it measures indirectly pore. So conductivity ratio is considered to be measuring the compressive strength.

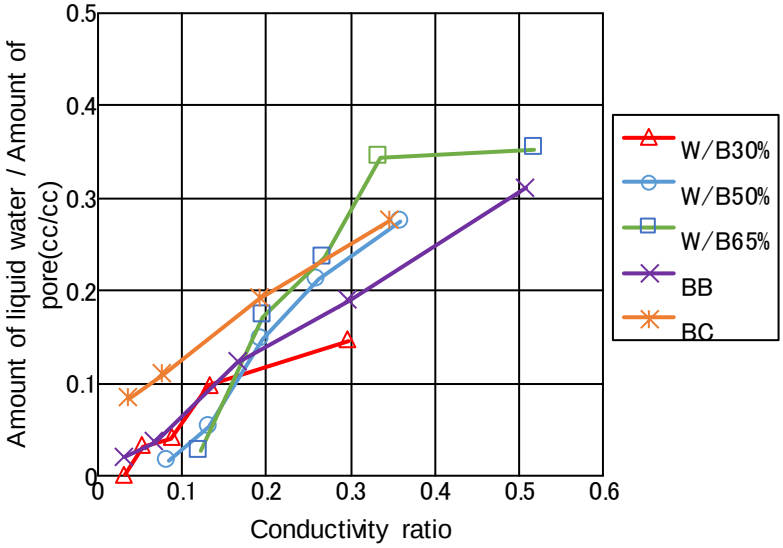


Figure 11. Relationship between Conductivity ratio and liquid water in the pore

4 CONCLUSION

1) Regardless of the mix proportions, conductivity ratio shows a behavior of increase to decreasing

2) Correlation to the conductivity ratio and compression strength was observed, but the relationship is different in each mix proportions.

3) Conductivity meter is to measure the water that is not used for hydrating in the pore, in other words it is measured indirectly pore. So, it is possible to estimate the compressive strength with electrical conductivity.

5 REFERENCES

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