Study on curing of concrete by the end time judgment of the DC specific resistance

T. Misaka[1] and T.Iyoda[2]

[1]*Sato kogyo Co, Ltd, Kanagawa, Japan*
[2]*Department of Civil Engineering, Shibaura Institute of Technology, Tokyo, Japan*
[1]*E-mail address: misaka@satokogyo.co.jp*
[2]*E-mail address: iyoda@shibaura-it.ac.jp*

ABSTRACT

It is very important for concrete structures to keep the compressive strength and durability. In order to demonstrate such performances, it is indispensable to curing of concrete. However these performances cannot be checked within the curing period. In this research, it is proposed the technique of predicting the strength and durability during curing period using electrical resistance. As a result, it has high correlation with the electrical resistance value at the demolding time and the compressive strength, carbonation depth.

Keywords. Electrical resistance, compressive strength at demolding time, durability, curing, Blast-Furnace slag cement

1. INTRODUCTION

Curing during construction is important for maintaining the required durability of concrete and, if proper curing is not carried out, there will be insufficient water for hydration. This phenomenon is observed to occur at the surface of concrete structures. In addition, degradation factors which cause steel corrosion, such as chloride ions and carbon dioxide, also penetrate from the concrete surface, so it is important to improve the quality of surface concrete in order to enhance the durability of concrete structures.

These days, the quality of surface concrete is verified using non-destructive tests such as the air permeability test (Torrent's Method) or the water permeability test However, it is necessary to conduct these tests on hardened concrete which has aged over a long period of time and, furthermore, it is known that these tests greatly depend on the amount of moisture in concrete.

In order to have concrete structures in service for a long period, it is necessary to keep good durability. Durability of concrete is affected by the material conditions factors, such as mix proportion and kind of cement, and the factor of setting conditions, such as curing condition, temperature and so on. In recent research, the relationship between concrete durability and curing method and periods has been clarified. In case of extended curing, such as a long time from casting of concrete to removal, concrete durability is improving. However, in the case of short curing period and not enough curing after removal, it is clear that the concrete durability does not improve and leads to early deterioration of concrete structures.

Furthermore, the compressive strength and durability of concrete are only known after concrete hardens, not in the fresh state. Presently, it is difficult to predict the strength and durability of concrete before hardening of concrete, or during the hardening process.

Curing is important for concrete durability after removal from the molds, and curing periods are different depending on the cement types and curing temperature. The time to removal is set to when concrete strength reaches 5 N/mm^2. This does not consider the durability of concrete. However, deterioration phenomena advance from the surface of concrete, such as carbonation, penetration of chloride ion and also penetrating water and oxygen for leading to steel corrosion. Increasing the life-span of concrete structures requires improving the durability of surface concrete. For that purpose, curing becomes indispensable.

This research aims at developing a system that can suggest the end timing of curing using a simple technique. At first, it will clarify the relationship between curing period and durability of concrete. Moreover, it focuses on water content in concrete at the curing period and will measure the decrease in water used for cement hydration and evaporated water from concrete by drying. If both can be separated, we can estimate the hardening process, developing strength and durability with time by this method. Therefore, it was decided to measure the electrical resistance for evaluating the water contents in concrete, by the four-probe electrode method. The electrical resistance is measured continuously from the fresh concrete into the casting. It will be compared with electrical resistance at early age and the durability of concrete after a long time from casting. Finally we will suggest the end timing of curing period from electrical resistance for meeting the durability requirements of concrete structures.

2. OUTLINE OF EXPERIMENT

In this research, the specific electrical resistance inside concrete was measured by the four-probe electrode method with direct current (DC). Generally, alternating current (AC) is used for this method. However, an AC power supply requires the large size machine and it is difficult for transporting to the construction site. The DC power supply is small and lightweight as compared to the AC power supply, and measurement on a construction site is possible. In addition, it is possible that the AC power machine is the power supply generating and measurement in one set. On the other hand, it is difficult to both electrify and measure using DC, as the value of specific electrical resistance is not stabilized. Therefore, the influence of electrification was made as small as possible by using a DC pulse wave.

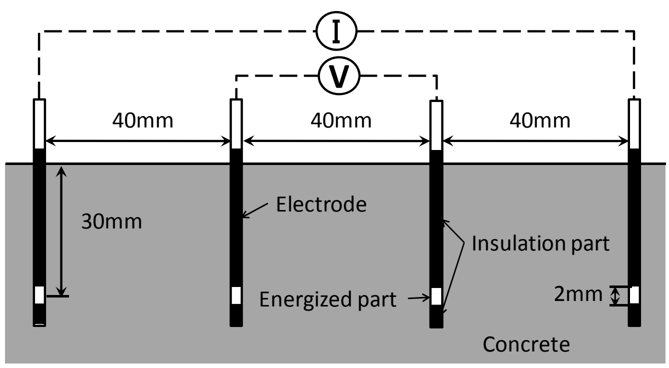

Figure 1 Outline for four-electrical method

Figure 1 shows the outline for four-probe electrical method and Figure 2 shows the outline of samples for measurement.

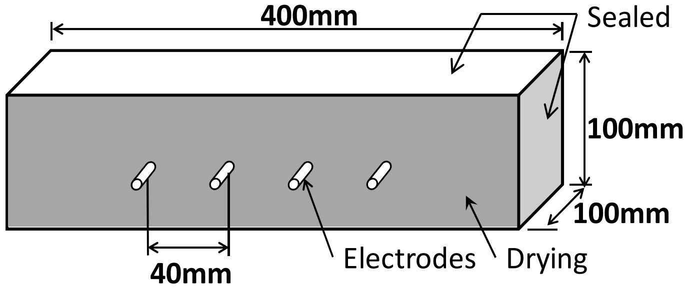

Figure 2 Outline of samples for measurement

The terminal used for measurement of specific resistance is an iron wire, and the distance between measurements was set at 40 mm. Measuring depth from the concrete surface is 30 mm constant, excepting the drying and curing affected. The sealing of the electrode was carried out so that only the necessary measurement depth position might turn on electricity.

The concrete mix proportion was in Table 1. It used some kinds of cement type, such as Normal, Blast Furnace slag cement type B (content BFS is 45% replacement as OPC) and type C (content BFS is 65% replacement as OPC), Fly ash cement type B (content Fly ash is 20% replacement as OPC). And water cement ratio is changed as 45, 55, 65 % on Normal cement. Unit water is constant as 172 kg/m^3.

Table 1 Mix proportions

Cement Type	W/C (%)	s/a (%)	W	C	BFS	FA	S	G	Add	AE
N	45	46	172	382	0	0	808	971	0.20×C	2.00A
	55	48		313	0	0	869	968	0.25×C	2.00A
	65	50		265	0	0	928	949	0.25×C	2.00A
BB	55	48		313	125	0	869	965	0.20×C	3.25A
BC		50		313	219	0	903	927	0.25×C	2.00A
FC		50		250	0	63	896	919	0.20×C	6.00A

The periods when drying began after the end of curing, were 1, 3, 5, 7, 28, 56days as shown in Figure 3. The molds were removed after 1 day of casting, then all surface put on the wrap for protecting the evaporating water from surface. Specific electrical resistance was continuously measured. And cylinder for compressive test and cubic specimen for carbonation test were demolded at the same time as measuring the electrical resistance. Compressive strength and carbonation test were done based on JIS.

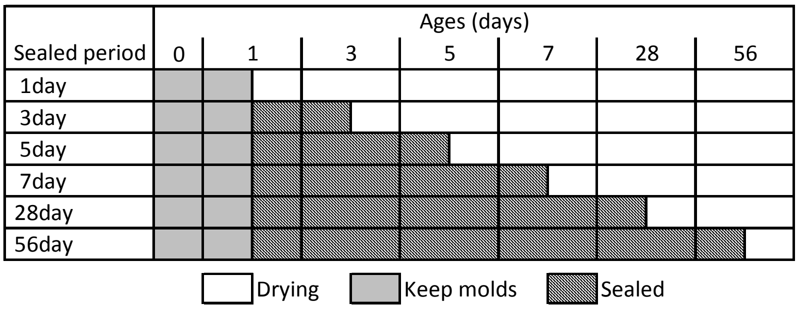

Figure 3 The periods when drying began after the end of curing

3. RESULT OF EXPERIMENTS

3.1 Compressive Strength on demolding age

Figure 4 shows the progress of compressive strength at demolding age on different water cement ratio and different cement type. Compressive strength becomes high, so that water cement ratio is small. The compressive strength at the early age becomes small so that the amount of admixture increases, but the growth of long age strength is large.

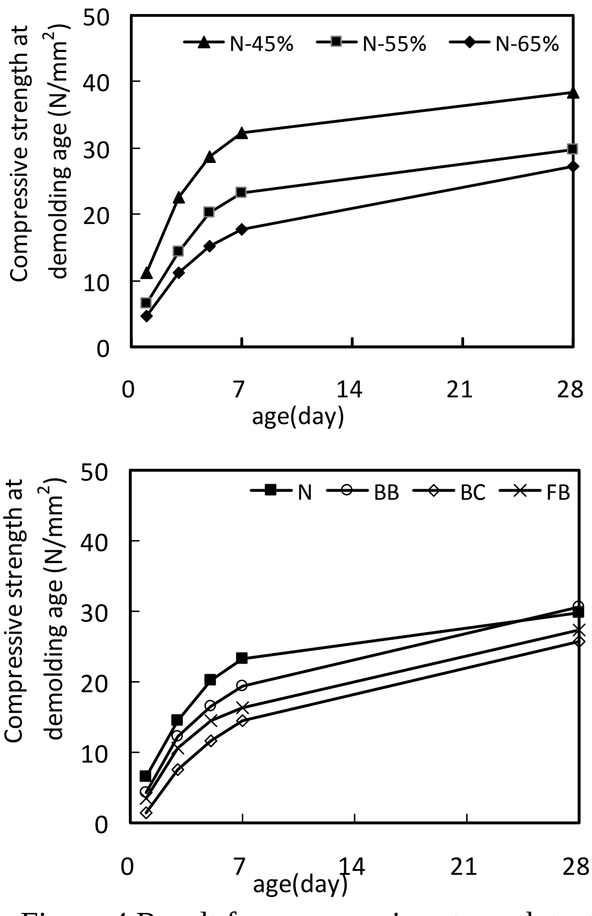

Figure 4 Result for compressive strength tests

3.2 Electrical resistance affected on mix proportions

Figure 5 shows the electrical resistance at the different water cement ratio. The values of electrical resistance on each water cement ratio are same at age of 3 days, however, the electrical resistance increases as the water cement ratio, with the passage of age. In the case of a constant of unit water, if the water cement ratio is small, the amount of cement increases. The water used for hydration increased in case of a large amount of cement. Therefore, it is considered that the amount of water except the used by hydration in the concrete is decreased.

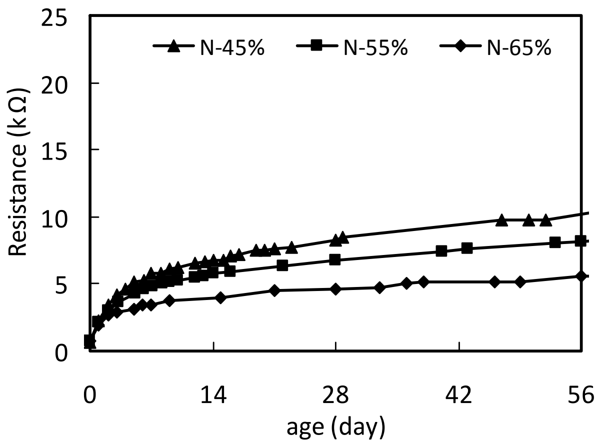

Figure 5 Electrical resistance at the different water cement ratio

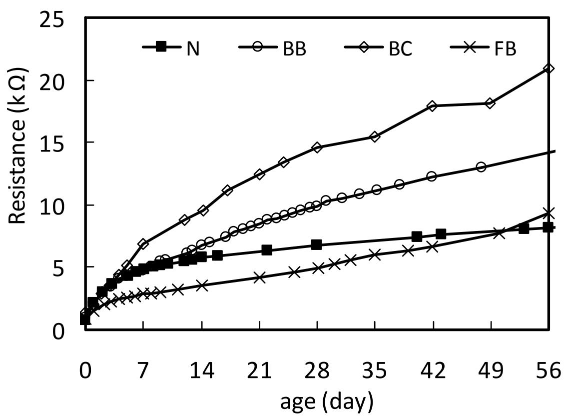

Figure 6 Replacement ratio of admixtures on binder affected the electrical resistance

Figure 6 shows that the replacement ratio of admixtures on binder affected the electrical resistance. Each specimen of water cement ratio is same as 55 %. At the early age from contacting water, all specimens using on ground granulated blast furnace slag had not difference on electrical resistance until age at 4 days. However with progress age, resistance on concrete of replacement on Blast Furnace slag are larger than normal concrete with progress age. And it is clear that resistance is large with high replacement ratio. On the other hand, the electrical resistance of concrete using fly ash is smaller than it of concrete using ordinary Portland cement. However the value is same at 56 days. It means the effective of cement into amount of admixtures. So it was cleared that the electrical resistance affected by the kind of mineral admixture. This reason is a subject for future work.

3.3 Relationship between compressive strength at demolding age and electrical resistance

Figure 7 shows the relationship between compressive strength at demolding age and electrical resistance on different water cement ratio. With the increase of the electrical resistance, the compressive strength at demolding age is increased. The relationship ratio were almost same at 45 and 55% of W/C, however it was increased in 65% of W/C.

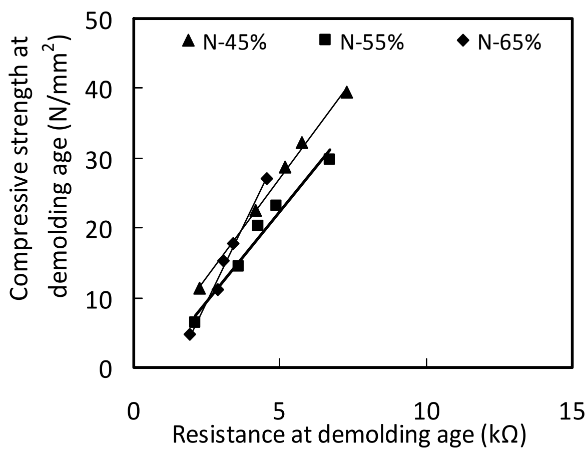

Figure 7 Relationship between compressive strength at demolding age and electrical resistance on different water cement ratio

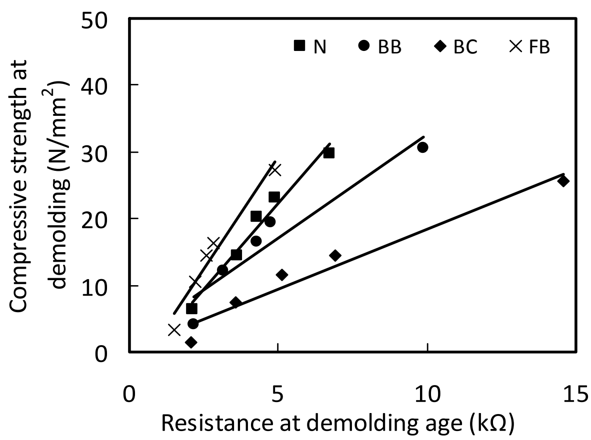

Figure 8 Relationship on the replacement ratio of mineral admixture

Thus, the compressive strength at the time can be predicted the electrical resistance value from immediate demolding. Figure 8 shows the relationship on the replacement ratio of ground granulated blast furnace slag. The higher the replacement ratio of BFS, it was observed that the slope of line was decreased. Since the rate of hydration is slower, is that the delayed strength progress is shown.

3.4 Relationship between carbonation depth and electrical resistance

Figure 9 shows the relationship between carbonation depth at 4 weeks on accelerated carbonation test and electrical resistance on different water cement ratio and used BB cement. With the increase in the electrical resistance value, the carbonation depth showed the tendency which becomes small. It had good relationship between the electrical resistance value at the demolding age and the carbonation depth on for 4 week as an accelerated age. Even if it was the case with same electrical resistance value at the demolding age, the difference with the large carbonation depth was seen by different water cement ratio and kind of cement.

By using the above results, it is possible that the compressive strength and durability can be guessed within a curing period or period of concrete in a mold by measuring the electrical resistance value before demolding age.

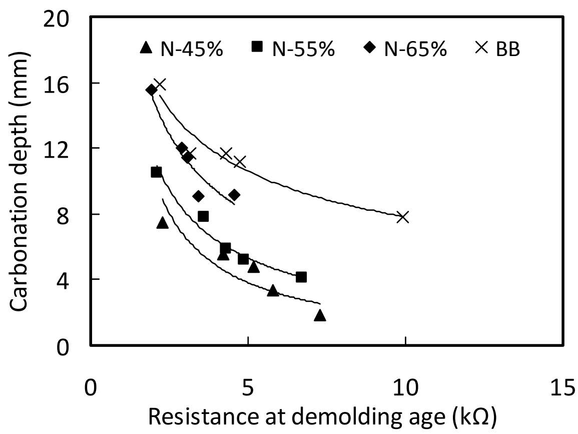

Figure 9 Relationship between carbonation depth and resistance at demolding age

4. CONCLUSION

1) An electrical resistance value is subject to the influence of the W/C, kind of cement and containing admixtures.

2) It is high correlation with an electrical resistance value at the just demolding age and the compressive strength at demolding or carbonation depth after passage ages.

3) It is possible that the prediction of compressive strength and durability at long term is measuring the electrical resistance in the concrete.

5. ACKNOWLEDGEMENT

The author wishes to thank Mr. Riku Hitotsuyanagi at Shibaura Institute of technology for supporting these experiments and anysis in this research.

I am deeply grateful to Riku Hitotsuyanagi who provided helpful comments and suggestions.

REFERENCES

Japan Society of Civil Engineers, (2007), Standard Specifications for Concrete Structures-2007 Materials and Construction, Japan.

R.Torrent. (2012). Non-destructive air-permeability measurement, from gass-flow modelling to improved testing, proceedings of the second international conference on microstructural-related durability of cementitious composites.

S.Okazaki and T.Yagi and T.Kishi and T.Yajima.(2007).Defference of sensitivety due to curing condition on strength and permeability (in japanese), JAC Proceedings of Cement & concrete, Japan,

T.Iyoda and E.Toyomura, (2012). Study on the prediction of curing period length for meetiog repuired concrete durability, The5th International Conference of Asian Concrete Federation, Pattaya, Thailand.

U.Akmal and A.Hosoda and K.Hayasi.(2011). Inspection of Cover Concrete of an Actual Structure by Surface Water Absorption Test, Proceedings of the 9th International Symposium on High Performance Concrete-Design, Verification and Utilization, Rotorua, New Zealand, C9-1

U.Akmal and A.Hosoda and K.Hayasi and K.Suhara.(2011). Evaluation of Covercrete of Expansive Concrete with External Restraint by Surface Water Absorption Test, Proceedings of the 13th International Summer Symposium, JSCE.