Assessment of Corrosion Activity of Concrete Subjected to Chloride Attack

Graduate School of Science and Technology, Kumamoto University, Member of JSCE ○ Mohamed Ismail
Graduate School of Science and Technology, Kumamoto University, Member of JSCE Masayasu Ohtsu

1. Introduction

Corrosion of reinforcing steels in concrete costs significant capital in the United States and many other countries[1, 2]. A laboratory study was conducted to estimate the corrosion activity of a reinforcing steel rod embedded in Ordinary Portland Concrete (OPC) and High Performance Concrete (HPC) specimens, using the half-cell potentials and chloride contents.

2. Experiment

Two concrete mixtures, Ordinary Portland Cement Concrete (OPC) and High Performance Concrete (HPC) were used in this study. Mixtures proportion and properties of fresh and hardened concrete are shown in Table 1. Details of reinforced concrete cylinder used in this investigation are explained elsewhere[3]. These were cylindrical specimens of 15 cm diameter and 30 cm height with a rebar embedded at the center.

Table 1 Concrete mixtures proportioning and properties.

Materials and properties	(OPC)	(HPC)
Cement- Type 10 (kg/m^3)	300	495
Water (kg/m^3)	180	165
Fine aggregate (kg/m^3) – Fineness Modulus =2.8	675	612
Coarse aggregate (kg/m^3) - max. size 20-mm	1250	1151
Superplasticizer (ml/100 kg cement)	0	2424
Silica fume (kg/m^3)	0	55
Slump (mm)	125	150
Air content (%)	1	1
Compressive strength (MPa) at 28 days	32.5	95.2

3. Corrosion Activity Levels

Corrosion activity of reinforcing steel was estimated based on corrosion testing. Several researchers have suggested three corrosion levels for reinforcing steel in concrete: initiation, propagation, and damage. These corrosion activity levels are used widely to determine the repair time and to select an appropriate repair method for the bridge deck[4].To estimate corrosion-activity levels based on tested results, it is necessary to define a threshold values corresponding to different corrosion activity levels. So far, there is no consensus among researchers regarding these values. Based on a review of the literature, certain threshold values (for Half-cell potential (HCP) and percent of chloride in concrete) were selected to estimate the initiation, propagation, and damage states of corrosion. These were designated as A, B, and C. The threshold values selected for the HCP are suggested by the ASTM C 867. Chloride contents around 0.3% and more than 1% of the weight of cement at the surface of reinforcing steel are selected for initiation and damage stages of corrosion (A and C, respectively) and values between these could be related to the propagation stage (B). These threshold values and their corresponding corrosion-activity levels are summarized in Table 2.

Table 2. Corrosion activity ranking system.

Testing method	Criteria	Description	Corrosion levels
Half-cell potentials (HCP)	• $E \geq -200$ mV	• Very low probability of corrosion.	A
	• $-350 \leq E < -200$ mV	• Corrosion state is uncertain.	B
	• $E < -350$ mV	• Very high probability of corrosion.	C
Chloride contents	• $[Cl]^* < 0.3\%$	• low corrosion state	A
	• $0.3 \leq [Cl]^* < 1\%$	• Moderate corrosion state	B
	• $[Cl]^* \geq 1\%$	• High corrosion state	C

***** Cl^* % total chloride by weight of cement.

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Address: Kumamoto University; Kurokami 2-39-1, Kumamoto 860-8555, Japan; TEL 096-342-3542 FAX 096-342-3507

4. Results and Discussion

Figure 1 shows the relationship between chloride content and HCP values for OPC specimens. This relationship is reprersented as,

$$HCP = 120.48 Ln\,(Cl^{-}) + 478.34 \quad (1)$$

Where *HCP* is the potential reading in -mV and, Cl^{-} is the chloride contents as percent of weight of cement.

A high correlation between HCP and chloride content methods is found for OPC specimens (R^2=0.74). In Fig. 1, the data inside regions A, B, and C represent specimens in which both methods predict the same level of corrosion activity. A large number of data in region C indicates a high corrosion-activity level predicted by both methods for OPC specimens.

Fig. 2 shows the relationship between HCP and chloride contents for HPC specimens. Here, Eq. 2 summarises this relationship. A lower correlation is found for HPC specimens, comparing Eq. 2 with Eq. 1. Figure 2 shows a large number of specimens in region A. This implies lower corrosion activity for HPC specimens.

$$HCP = 101.79 Ln\,(Cl^{-}) + 454.27 \quad (2)$$

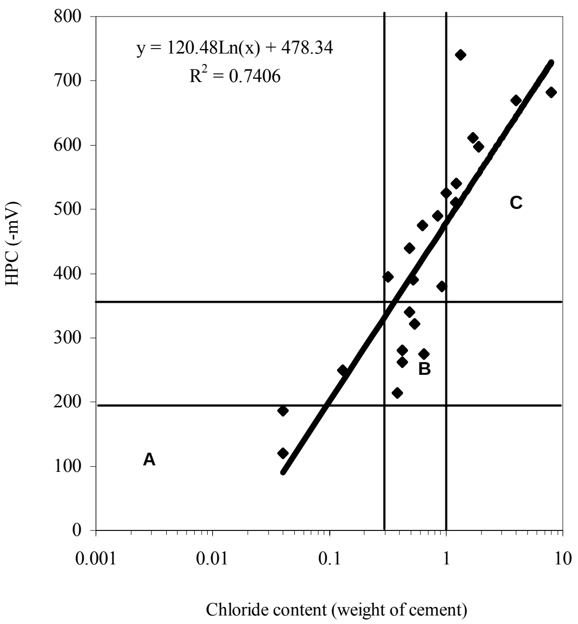

Fig.1 Chloride content and HCP relation for OPC specimens

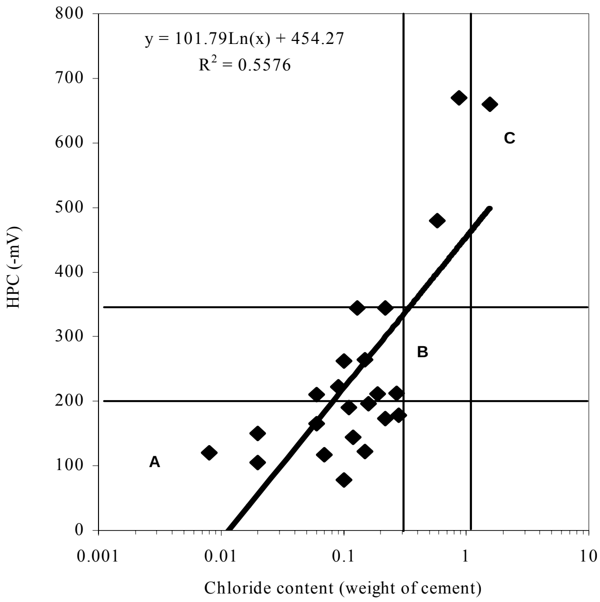

Fig.2 Chloride content and HCP relation for HPC specimens

5. Conclusion

A reasonable consistency (close to 65%) is observed between the HCP and chloride-contents for estimating the corrosion-activity levels of concrete specimens. In the remaining cases (35%), the HCP method tended to overestimate the corrosion activity, compared to chloride contents. HPC specimens showed lower corrosion, compared to OPC specimens with respect to both corrosion-testing procedures. The lower *w/c* ratio and the use of silica fume could be the main reasons for lower corrosion activity levels. Mathematical relationships are developed for chloride contents and HCP values. A higher correlation is found for OPC specimens compared to HPC specimens. To find a general relationship between HCP and chloride contents still needs more validation, based on the consideration of field variables.

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