CHLORIDE-INDUCED CORROSION OF CRACKED RC MEMBERS

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1. INTRODUCTION

One of the most severe and widespread problems, however, is the internal damage caused by the corrosive action of external chlorides on embedded reinforcing steel in concrete. Cracks in concrete provide easy access of chloride ions, moisture and oxygen, and thus accelerates the onset of the corrosion process. The purpose of this work is to study the influence of crack width on chloride penetration into different concrete including a typical structural concrete and low water cement ratio (W/C=20%), and to investigate the chloride corrosion of two types of steel in cracked and uncracked concrete member.

2. TEST PROGRAM

The summary of test program is shown in Table 1. Test specimens were prepared from different concretes mixes. Normal steel (SD-30) and modified steel (Seibun Cho Tekkin) were used as reinforcing bars. After curing, the specimens were loaded in middle span by coupling two beams, and subjected to flexural cracking as shown in Fig. 1. Then, they were stored in laboratory and chloride solution (3% NaCl solution) was sprayed once a day. After 6 months, the beams were broken, and 0.1% fluorescein-sodium aqueous solution and 0.1 N silver nitrate aqueous solution were sprayed on. Those area which changed color to white were measured and regarded as chloride penetration areas. Also, reinforcing bars taken from the beams were observed and their weight loss were measured.

Table 1 Summary of test program

Size of specimen	Reinforcement	Parameter
10x10x40 cm	one bar of 25 mm in diameter	crack width (from 0.05 to 0.30 mm)
		cover-diameter ratio (0.5, 1.0, 1.5 & 2.0)
		concrete quality (W/C= 0.2, 0.4, 0.5 & 0.6)

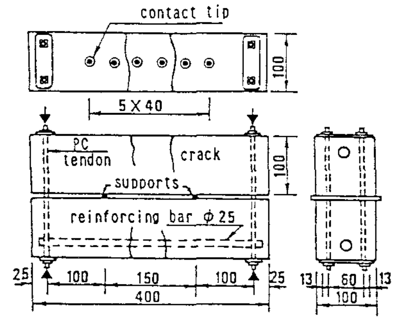

Fig. 1 Arrangement of test specimens

3. TEST RESULTS AND DISCUSSION

3.1 Chloride Penetration

By observing the longitudinal cross section of beams at cracked and uncracked positions, it was found that the presence of cracks was significantly increased the chloride penetration depths as shown in Fig.2. Also, this figure shows the shape of contaminated zone in front of cracking. It was noticed that chloride penetrates quickly along cracks but diffuses only a little in the concrete mass from fracture surfaces. Then, chloride ion progresses along steel bars from the intersection between cracks and reinforcement. The depth of cover, as well as, crack width had a remarkable effect on the shape of contaminated concrete zone. The relation between crack width and contaminated concrete zone around reinforcing bar (passive length of bar "L") is shown in Fig. 3. The passive length of bar was very small at narrow cracks and was increased with increasing crack width. Also, the passive length of bar was affected with concrete quality and thickness of cover as shown in Figs. 4 & 5 respectively. The penetration of chloride ion into low water-cement ratio concrete (W/C=20%) was very small compared with the penetration into high water-cement ratio concretes, especially for

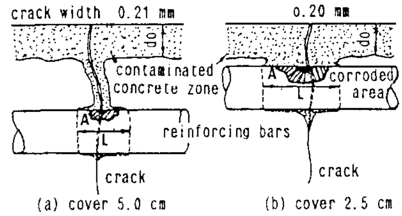

Fig. 2 Delimitation of shape of the contaminated concrete zone by chloride in front of crack

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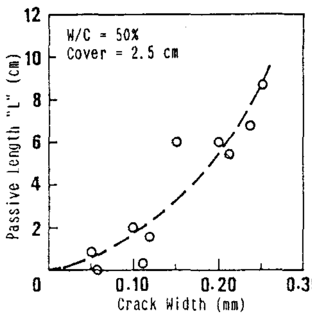

Fig. 3 The relation between crack width and passive length of the bar (L)

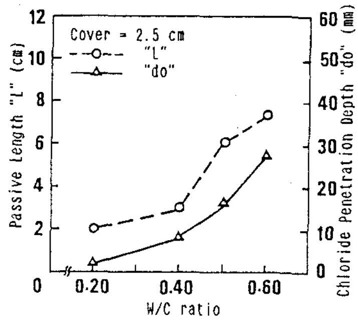

Fig. 4 Influence of water-cement ratio chloride penetration depth and passive length of the bar (L)

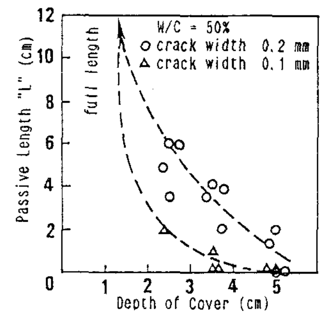

Fig. 5 The effect of depth of cover on passive length of the bar (L)

for uncracked concrete. The passive length of the bar was decreased with increasing depth of cover.

3.2 Corrosion of reinforcement

It was found that the exposed area of the bar at cracks was corroded, and also corrosion extended much further along the bars as shown in Fig. 2. The corroded area of the bars was proportioned with the crack width and their values were very small (approximate zero) for crack width less than 0.1 mm (Fig. 6). The reason would be that narrow cracks tend to retain water in them and do not dry out even at times when the concrete is not externally exposed to water, so that enough oxygen can not penetrate to the steel. The influence of concrete quality on corrosion of normal and modified steel in cracked and uncracked concrete is shown in Fig. 7. The influence of W/C ratio on weight loss was remarkable for uncracked concrete. In cracked concrete the corrosion at cracks is often more severe and weight loss is larger than those of uncracked members. Also, the percentage of weight loss of modified steel was less than that of normal steel (Figs. 7 & 8). The depth of cover had great effect on percentage of weight loss of bars embedded in cracked and uncracked concrete as shown in Fig. 8.

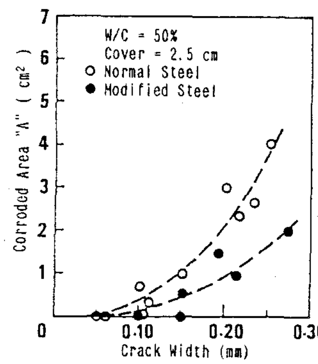

Fig. 6 Influence of type of steel on the relation between crack width and corroded area of the bar (A)

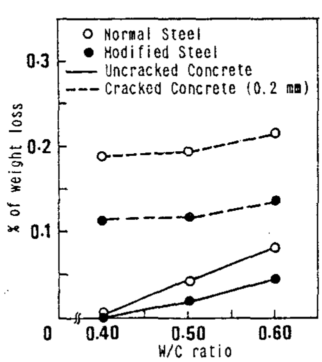

Fig. 7 Influence of water-cement ratio on % of weight loss of bars in cracked and uncraked concrete

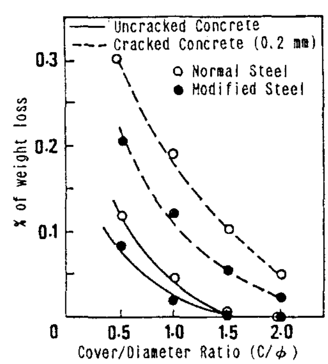

Fig. 8 Influence of cover-diameter ratio on % of weight loss of bars in cracked and uncracked concrete

4. CONCLUSION

The following conclusions are obtained from the present investigation;

1) The chloride penetration test which was used in this experiments can be used easily as a field test.

2) The contaminated concrete zone in the front of crack was dependent not only upon the crack width, but also upon the depth of cover and water-cement ratio.

3) Under conditions of chloride attack, e.g., in the splash zone of an offshore structure, there could be a critical lower limit to crack widths (less than 0.1 mm). Also, the cover-diameter ratio must be more than 2.0

4) The performance of modified reinforcing steel in severe environment (salt spray) is better than that of normal reinforcing steel, even in cracked concrete.