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STUDY OF ELECTROCHEMICAL CHLORIDE EXTRACTION AS A NON-DESTRUCTIVE REPAIR METHOD: PART 2. STRUCTURAL ELEMENT TEST SAMPLE

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ABSTRACT

This paper is the second part of the paper that provides information on representative parameters in electro-chemical chloride extraction. In part one, results of discrete test samples were outlined. A structural element in the form of Reinforced Concrete (RC) slab was constructed and tested to evaluate the ECE performance in a simulated structure. The representative parameters of ECE were determined experimentally. The experimental program investigates chloride and alkali concentration, chloride removal efficiency, transference number and half-cell potential.

Test results on RC slab are compatible with those obtained in the Part one of the study on discrete test samples; thereby confirm the capability of applying the method to real structures.

Keywords: corrosion, electrochemical properties, durability, chloride

1. INTRODUCTION

The electro-chemical chloride extraction is a nondestructive repair method for enhancing the service life of RC structures, which suffer from chloride contamination. In part one of this series [1], a comprehensive test program was carried out to evaluate the representative parameters influencing ECE. Even though, there has been test reports on discrete (small) samples [1 to 7], however test on large-scale samples have not been reported. In this paper, experimental study on a structural element is performed to verify the compatibility of ECE performance in structure with those of discrete test samples.

2. TEST PROGRAM

A large-scale specimen in the form of slab with dimensions of 1000x1000x120 mm with a

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concrete mix containing 2 percent chloride by weight of cement was constructed. Concrete mix proportions is shown in table 1. The slab was reinforced with Φ12 bars spaced at 150 mm in two way with 60 mm cover (Figure 1).

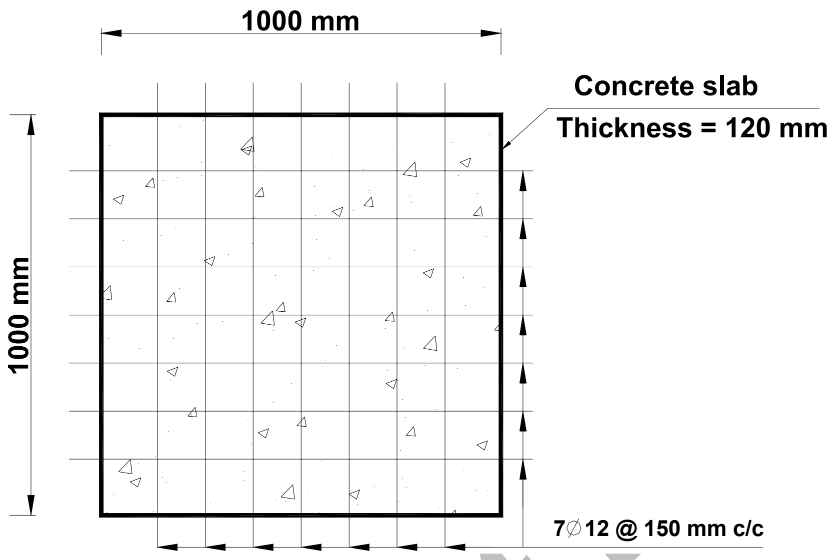

Figure 1. Slab dimensions and reinforcement

Table 1. Concrete mix proportions

Concrete mix	Ratio of total chloride to mass of cement (%)	Water (Kg/m^3)	Cement (Kg/m^3)	Sand (Kg/m^3)	Gravel (Kg/m^3)	Salt (Kg/m^3)	Slump (mm)	Density (Kg/m^3)	Compressive strength of cubes @ 28 day (MPa)
HC	2	210	350	807.7	911	11.34	100	2296	30

The following procedure was used to apply ECE repair method,

I) A layer of foam saturated with $Ca(OH)_2$ was placed on the top surface of slab.
II) A titanium electrode mesh was placed on the foam.
III) A second layer of foam saturated with Ca(OH)2 was placed on the electrode mesh.
IV) Slab rebar and titanium electrode mesh was connected to the negative and positive pole of an AC/DC rectifier, respectively.
V) The power supply was switched on and adjusted for a current density of 1A/m2 of concrete surface, which correspond to 1.6A/m2 current density of steel surface (Figure 2).

VI) Treatment was continued for 8 weeks. During and after this period, tests and measurements were carried out.

Figure 2. Equipment and application of electric field

Figure 3. Pattern of core drilling in slab

3. TEST RESULTS AND DISCUSSIONS

3.1 Chloride extraction

Nine 2" (50 mm) cores were taken from the slab at different times up to 8 weeks of treatment. The cores pattern was taken at rebar intersection (Figure 3). The drilled cores were sliced with a thickness of 1.5 cm from various depths. The slices were grinded and tested to obtain the average of total chloride. As shown in Figure 4, it is concluded that: 1) the efficiency of chloride extraction is higher near the reinforcement than that at the concrete surface and 2) after 6 to 8 weeks of treatment chloride content around rebar reduced to the constant value of about 0.4% of cement mass, known as threshold value for corrosion prevention [2]. Almost similar conclusion was obtained in discrete test samples for chloride concentration around steel bars [1].

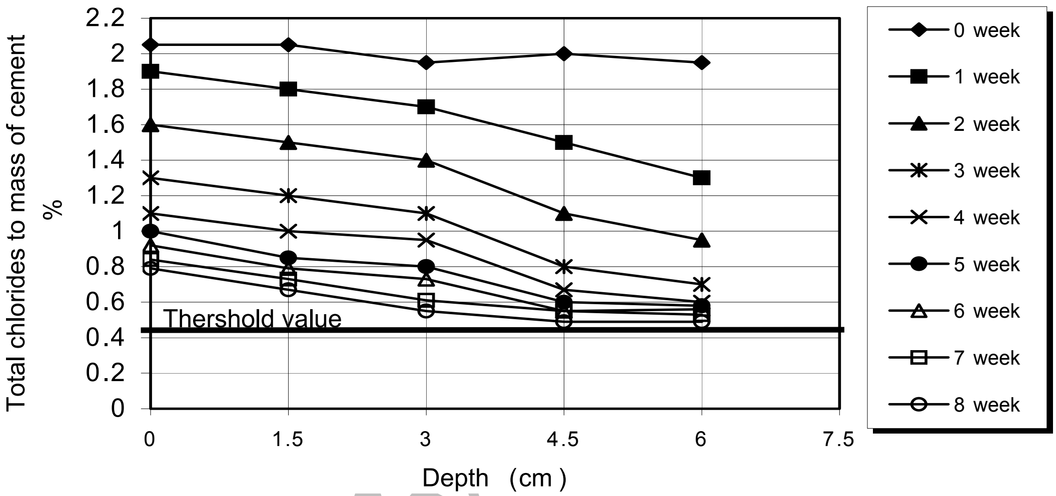

Figure 4. Chloride profile after various periods of ECE

3.2 Transference number of Cl^- and chloride removal efficiency

Transference number of Cl^- and chloride removal efficiency for the treated slab are calculated and shown in (Figures 5 and 6) As shown in (Figure 5) at the early stages of treatment, for the larger the amount of chlorides in concrete, the larger is the transference number of Cl^-. As shown in (Figure 6) chloride removal efficiency tends to reach a ceiling of about 70%. It is concluded that after 6 to 8 weeks of treatment the rate of Cl^- to OH^- ion (which contained in concrete and produced in results of cathodic reactions and competes with Cl^- to carrying electric charges) decreases and the electric charges carrying by Cl^- drops to a certain level. Therefore the transference number of Cl^- decreases and chloride removal efficiency tends to reach a ceiling. The results on transference number of Cl^- and chloride removal efficiency of RC slab are close to those obtained in part one of the study (Figures 5 and 6) [1].

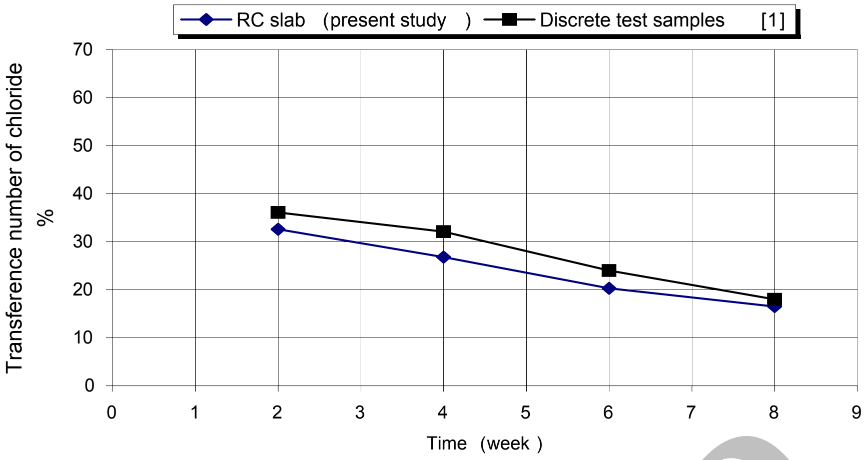

Figure 5. Transference number of chloride

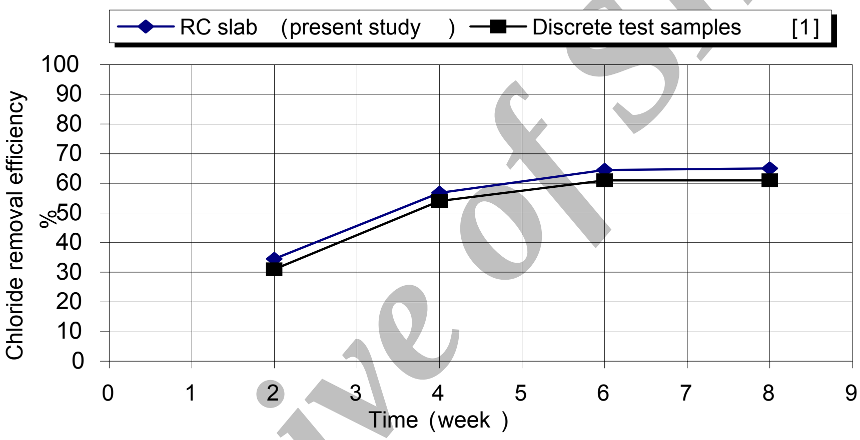

Figure 6. Chloride removal efficiency

3.3 Half – cell potential

Changes in half-cell potentials of steel bars in slab before, during, and after treatment were measured relative to Ag/Agcl reference electrode (Figures 7 and 8). All half-cell potentials of rebar were classified in the corrosion area (i.e., between –353 and –428 m.V based on Ag/AgCl reference electrode). Also, during and just at the end of treatment half-cell potentials were classified in the protection area before treatment (i.e., between –838 and -1022 m.V based on Ag/AgCl reference electrode). Furthermore, a new electro-chemical state was appeared in the slab reinforcement 8 weeks after the end of treatment in which the half-cell potentials were classified in the non corrosion area (i.e., between –33 and –97 m.V based on Ag/AgCl reference electrode).

Generally, the results of slab are in agreement with those of discrete test samples [1].

Figure 7. Half-cell potential instrument

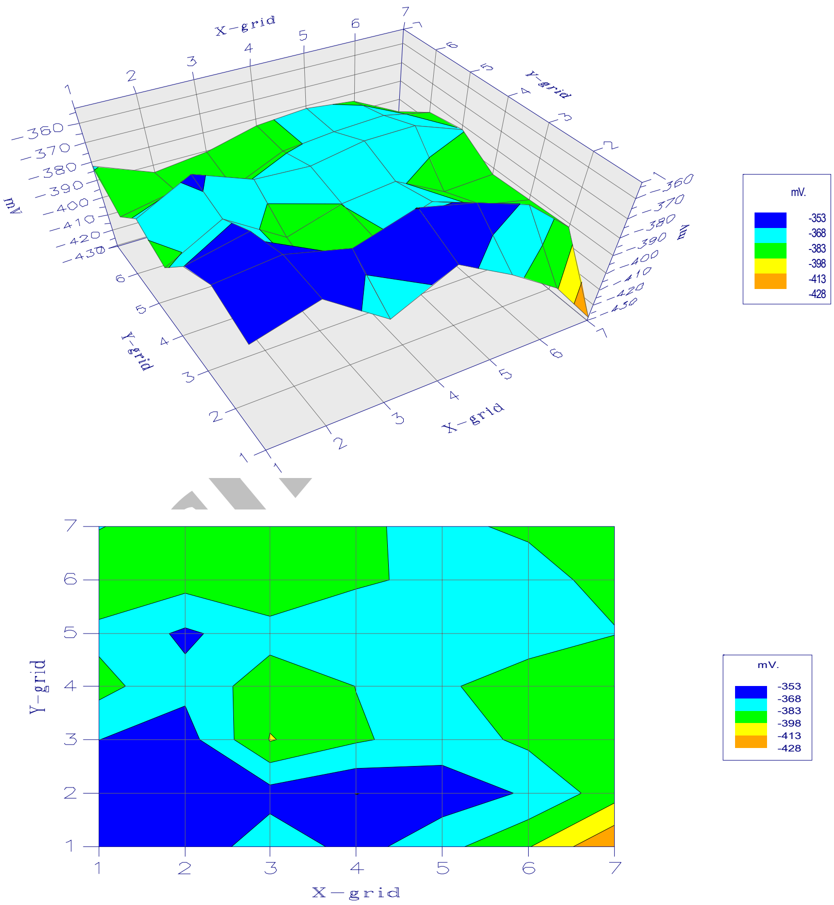

Figure 8(a). Half-cell potential of steel bars in slab before ECE

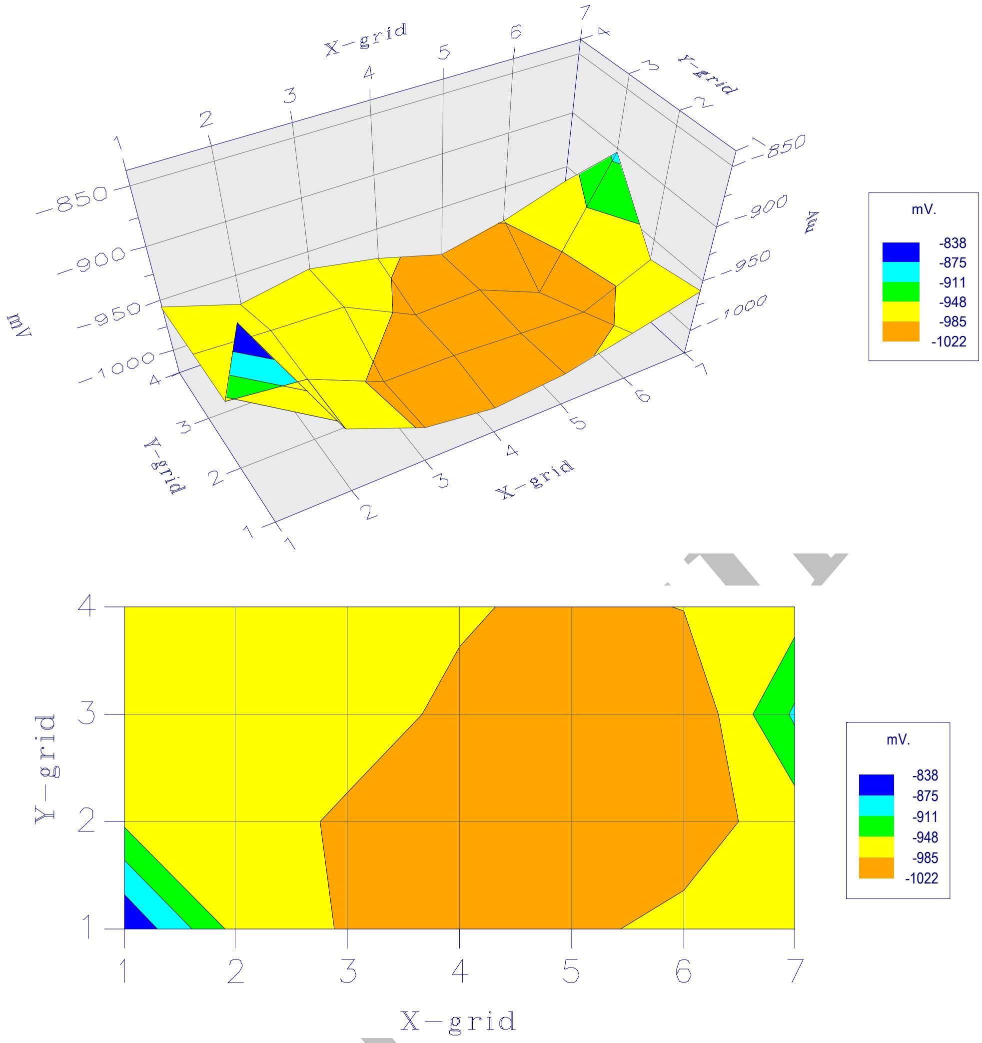

Figure 8(b). Half-cell potential of steel bars in slab during ECE

Test results on the RC slab as a structural element are in good agreement with those obtained for discrete test samples [1], which is indicative of efficiency of the ECE method to full size structures.

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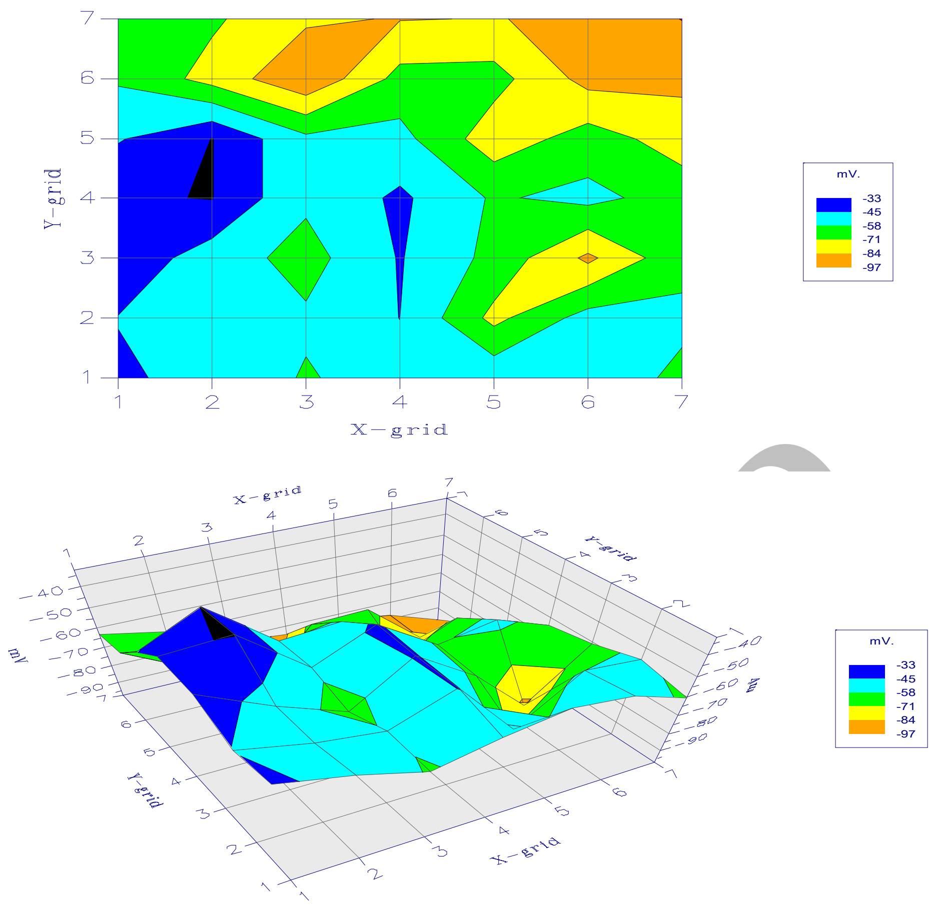

Figure 8(c). Half-cell potential of steel bars in slab 8 weeks after the end of ECE

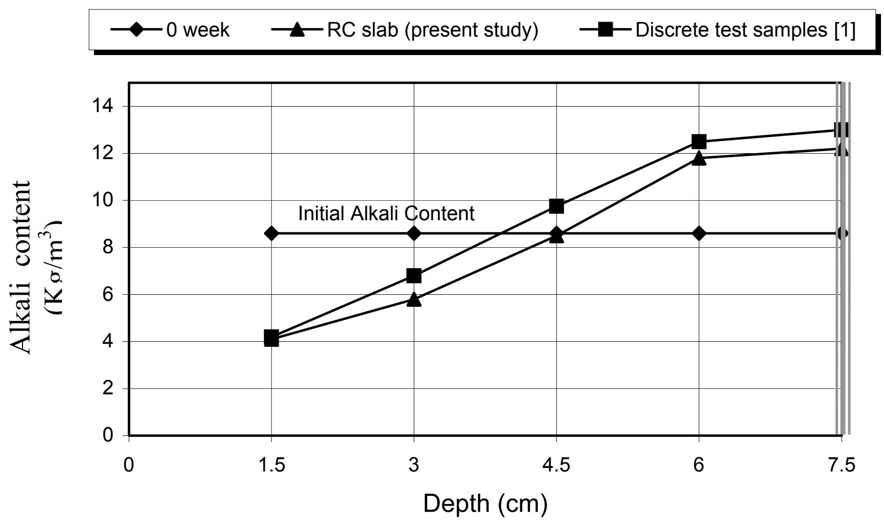

Figure 9. Distribution of alkali ions in concrete cover at various depth after 8 weeks of ECE

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