Limitation of Corrosion Action for Concrete and Steel Corrosion action in aggressive conditions with time

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ABSTRACT- In this paper, the corrosion for both concrete and steel studied, program of thirty five samples start at year 2002 were prepared with the same steel and the slabs dimension were 50cm width 14 cm thickness and 240 cm span length, bottom steel five bars with diameter 13 mm and top steel with 10 mm width. The percentage of water to cement was 0.56 and the mixing water was with the chloride concentration 3% percent of the cement weight. All slabs were exposure in the laboratory temperature and spread daily with water concentration 3% of chloride, the steel on slabs were connected to the electronic circuit to accelerate corrosion process. The slabs were divided to three groups Group (L) with the calculated rate of corrosion of 10% were tested at year 2004, both Group (M) with 30% and Group (R) with 50% repairing were started at year 2004 and the rate Corrosion situation of steel before the repairing were measured after the slabs cover removed before the repairing process. The corrosion potentials were measured. Trying to limit the corrosion process in each rate of it, five repairing and strengthening techniques were suggested, crushed stone mix (CSM), ready mixing (RM), crushed stone mixing with steel fibers (CSM+HF), crushed stone mixing steel (CSM+RS) and ready mixing with additional new reinforcing (RM+RS), which they are usually used in structure maintenance. The obtained results show that the corrosion for concrete and steel effected in on maintenance process and all techniques didn't stop it totally.

KEYWORDS: corrosion, potential, scaling, CSM, RM, CSM+HF, CSM+RS

1. INTRODUCTION

In general, good quality concrete of appropriate mix proportions, compacting, and curing provides an excellent protective environment for steel. The physical protection is afforded by the cover concrete acting as a physical barrier to the access of aggressive species. Chemical protection is provided by concrete's high alkalinity solution within the pore structure of cement paste matrix due to the presence of sodium and potassium oxides in the cement, as well as calcium hydroxide produced in the hydration reactions of cement components

Quality control, maintenance and planning of the restoration work on reinforced concrete structures need rapid, non destructive inspection techniques to asses corrosion of rebars and provide a quantitative measure of instantaneous found that numerous reinforced concrete structures were not as durable as had been assumed. Deterioration of concrete structures due to corrosion of reinforcing steel is a major problem and has also caused extensive damage in various countries. The content of chloride ions (not total chloride content, only soluble one) at steel surface has a great effect on the corrosively of steel in concrete. The quality of cover concrete (permeability) and cover depth are the key to determine the ease of chloride ions reaching the steel surface. Whereas, when a pore volume of the concrete is completely filled with water, then oxygen can reach the steel surface only by diffusion through the pore water, and the diffusivity of oxygen in water is about four powers lower than that in air [2].

The corrosion rate, however, is very low-or lower than in passive state- and if shifting conditions make oxygen more available, the steel will repassivate. In this state of corrosion, pitting is impossible, because the potential is lower than that of the pitting anode, and in fully immersed marine structure, where this state is normally reached after a few months, it can be argued, that corrosion will not be possible at the bottom of cracks, because the steel is catholically protection by the embedded reinforcement. [3].

Cathodic protection, if applied from the start, will desecrate the concrete around the steel and shorten the time for reaching the active, low potential state. It is likely, but has not yet been proven by measurements that pre-stressing steel in grouted steel ducts also has this low potential after a while. If true, this will contribute very significantly to the corrosion protection of pre-stressing steels [1].

In local where the climate provides a relative humidity of between 55 and 75 % the range of temperature has no direct effect on corrosion. In hot wet climates with a relative humidity of more than 75% and temperatures over 20°C, the likelihood of the reinforcement corroding considerable. It thus follows that steam curing is a special example, although of short duration only. However,

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autoclaving introduces permanent chemical changes in the hydrated mortar which leaves it less able to protect the reinforcement subsequently [4].

2. EXPERIMENTAL WORK

35 slabs were tested slabs divided into stages with respect to percentage of corrosion; the reduction in the cross sectional area of main steel was taken as a main factor. The slabs were divided to three groups Group (L) with the calculated rate of corrosion of 10%, Group (M) with 30% and Group (R) with 50%.. The corrosion potentials were measured. Trying to limit the corrosion process in each rate of it, five repairing and strengthening techniques were suggested, crushed stone mix (CSM), ready mixing (RM), crushed stone mixing with steel fibers (CSM+HF), crushed stone mixing steel (CSM+RS) and ready mixing with additional new reinforcing (RM+RS), which they are usually used in structure maintenance.

2.1 Repairing Materials

The two main used materials were crushed stone basalt size 2 and Cetorex Grout ready-mix, the other used materials were Harex Steel Fibers, Epoxies (Kemapoxy 131, Kemapoxy 104), Addibond (Add Bond 65), and Superplasticizer (Add Crete DM2) purchased from C.M.B. Corporation. the slabs were placed vertically and sheltered. Then each six slabs were connected together in parallel to an adapter turnout 12volts/150mA to an AC Power supply. The main program details and methods of repair and strengthening are shown in table 1.

Table (1) Repair and Test Program for Slabs of Group (L&M&H).

Repair and Strengtheni g systems		Slab thickness t (cm)	Cover thicknes of repairing laye Tc (cm)	Added Reinf. n Ø 10
CSM	L	14	2.5	—
	M	14	2.5	—
	H	14	2.5	—
CSM+RS	L	14	2.5	2 Ø 10
	M	14	2.5	3 Ø 10
	H	14	2.5	3 Ø 10
CSM+HF	L	14	2.5	—
	M	14	2.5	—
	H	14	2.5	—
RM	L	14	2.5	—
	M	14	2.5	—
	H	14	2.5	—
RM+RS	L	14	2.5	2 Ø 10
	M	14	2.5	3 Ø 10
	H	14	2.5	3 Ø 10

CSM : Crushed stone mix. (from Basalt) Slabs S5, S6, S16, S18, S19 & S21
CSM+HF :Crushed stone mix + Hrex Fiber Slabs S20, S27& S33
RM : Ready mix. (Cetorex Grout) Slabs S1, S24, S25,S28, S30 & S31
RM + RS : Ready mix+ Reinforcement steel Slabs S2, S15, S23, S26, S32 & S35
L :Low corrosion 10% H :High corrosion 50%
M :Med. corrosion 30%

An electricity-conducting medium was made of 3% sodium chloride solution to complete this cell as like as stray current, and sprayed them daily with this solution each morning at destined time. The spraying process was stopped at the repairing process applying. This cell was continuously switched on except potential reading time. Any way the purpose of this cell is to achieve an accelerated corrosion process, then Repairing and strengthening systems applying.

3. CORROSION SITUATION OF STEEL BEFORE THE REPAIR

After the application of dynamic corrosion process, all slabs had developed cracks along the line of bars and some hairline cracks perpendicular to them with some corrosion stained in evidence on the surface. The slabs then were opened carefully by using the hammer and nail to remove the concrete cover to a depth at the center of the reinforcement. The corrosion degree was estimated by area reduction percentage for the entire reinforcement net of each slab, Then the average value was calculated for each slab, Hence the slabs was divided into three groups low 10% corrosion were repaired year 2003, medium corrosion 30% were repaired year 2004 and high corrosion 50%. General visual results of corrosion and opening different types of slabs are shown in fig. 1.

Fig. (1 a) Removing of contaminated concrete covered layer of slab27 (M).

Fig. (1 b) Removing of contaminated concrete covered layer of slab27 (H).

4 RESULTS

4.1 Rest results of groups (L, M and H)

All Slabs, which were repaired and strengthening with Crushed Stone Basalt Mix 2.5cm, Ready Mix 2.5cm and Crushed Stone Basalt Mix +Fibers 2.5cm didn't show any scaling, nor rust stain; they had a good appearance after repair. The results show some differences in the two main performances of the anodic potentials of the repairing systems of group M; the slabs in each repairing and strengthening system had the same behavior with a small difference of not more 40 mv, and all of them had low anodic potentials than the slabs without repair. The following figures describe the variation of the potentials with the time for the average values of the all measurements for each repairing systems (CSM, RM, CSM+F) and slab without repairing as shown in fig. 2, fig.3 and fig.4.

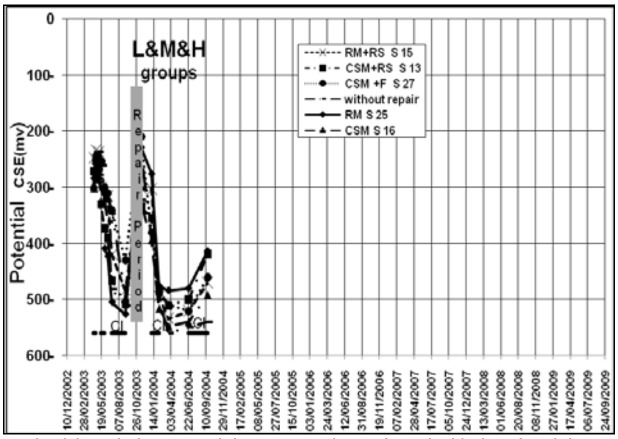

Fig. (2) Variation potential average values of steel with time for slabs group (L)

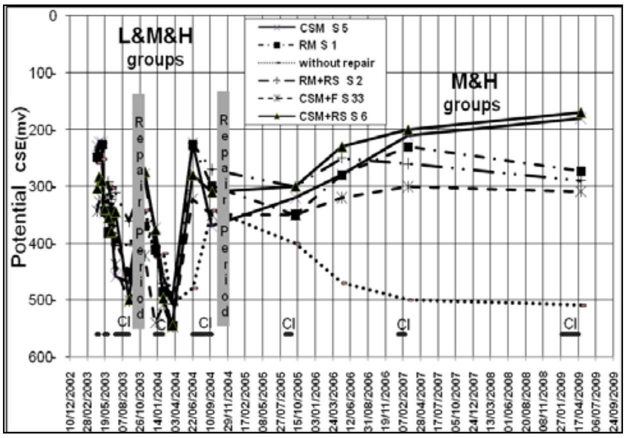

Fig. (3) Variation potential average values of steel with time for slabs group (M)

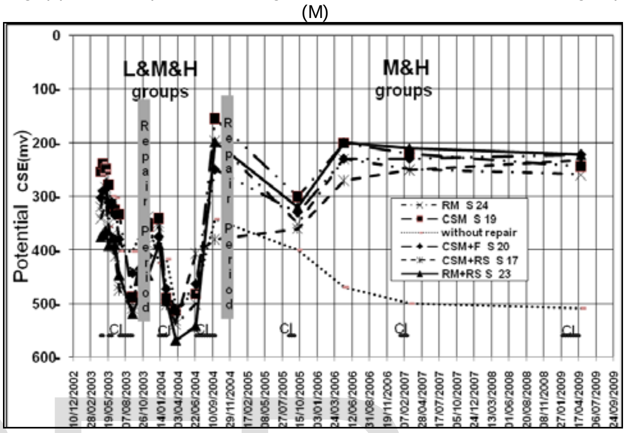

Fig. (4) Variation potential average values of steel with time for slabs group (H).

4.1.1 Comparison for slabs repaired with (CSM, CSM+RS)

The slabs S5, S16 and S19 were repaired and strengthened with Basalt Crushed Stone Mix layers, while both slabs S6, S13 and S17 were Strengthened with three bars of diameter 10 mm as mentioned before, these layers had full contact to the old concrete slabs and there weren't any cracks in the contact area between the CSM layer and the old concrete. Fig. 5 and fig. 6 show the comparison between these slabs.

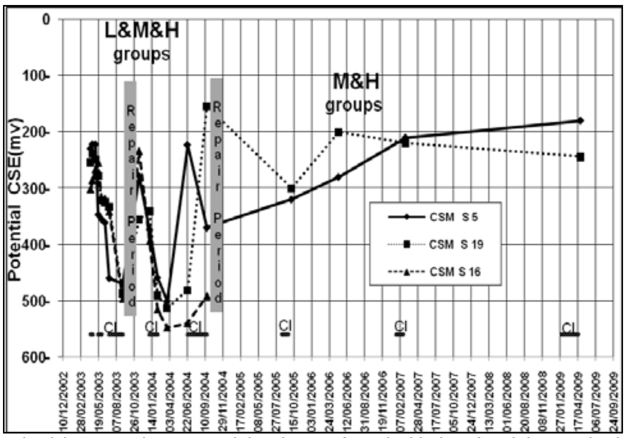

Fig. (5) Comparison potential values of steel with time for slabs repaired (CSM)

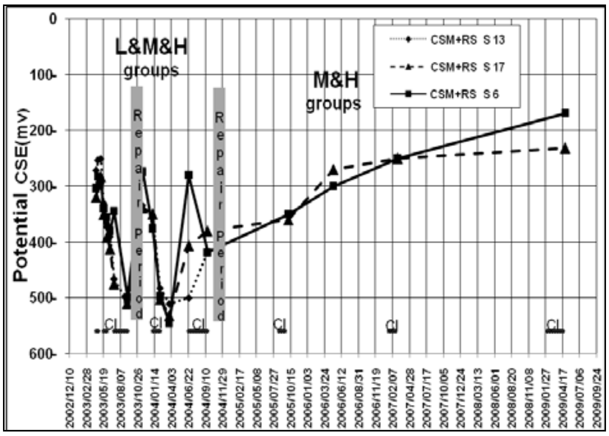

Fig. (6) Comparison potential values of steel with time for slabs repaired (CSM+RS).

4.1.2 Comparison for slabs repaired with (CSM+F)

The slabs S20, S27 and S33 were repaired and strengthened with Basalt Crushed Stone Mix Harex Steel Fibers layers, these layers had full contact to the old concrete slabs and there weren't any cracks in the contact area between the CSM layer and the old concrete. Fig. 7 shows the comparison between these slabs.with 2 or 3 bars of diameter 10 mm as mentioned before, these layers had full contact to the old concrete slabs and there weren't any cracks in the contact area between the RM layer and the old concrete. Fig. 5 and fig. 6 show the comparison between the load and point of max deflection these slabs for different rate of f corrosion.

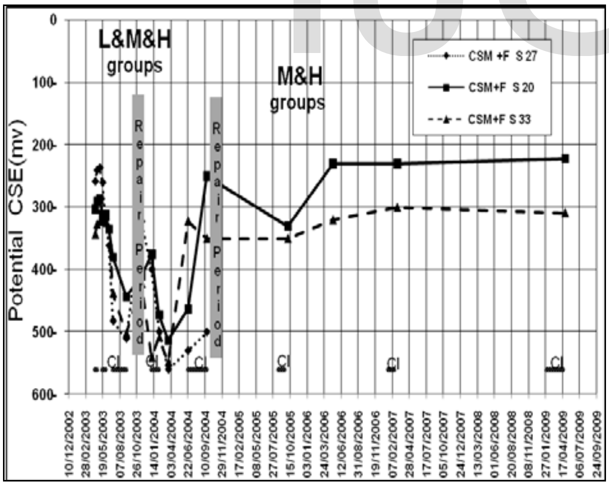

Fig.(7) Comparison potential values of steel with time for slabs repaired (CSM+F)

4.1.3 Comparison for slabs repaired with (RM, RM+RS)

The slabs S1, S24 and S25 were repaired and strengthened with resdy mixing layers, while both slabs S2, S15 and S23 were repaired and strengthened with 3 bars of diameter 10 mm as mentioned before, these layers had full contact to the old concrete slabs and there weren't any cracks in the contact area between the CSM layer and the old concrete. Fig. 8 and fig. 9 show the comparison between these slabs.

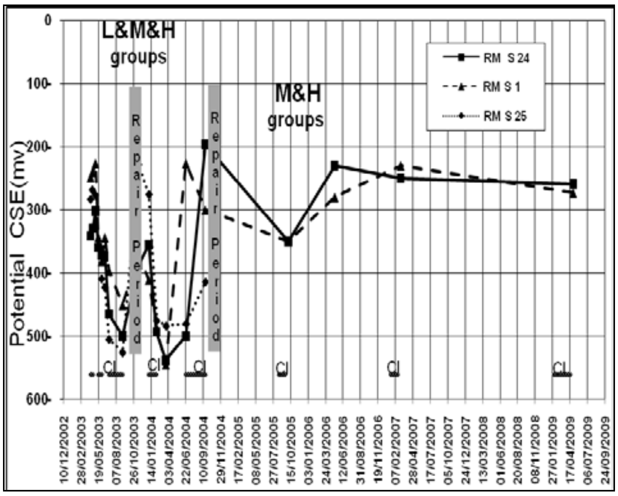

Fig.(8) Comparison potential values of steel with time for slabs repaired (RM).

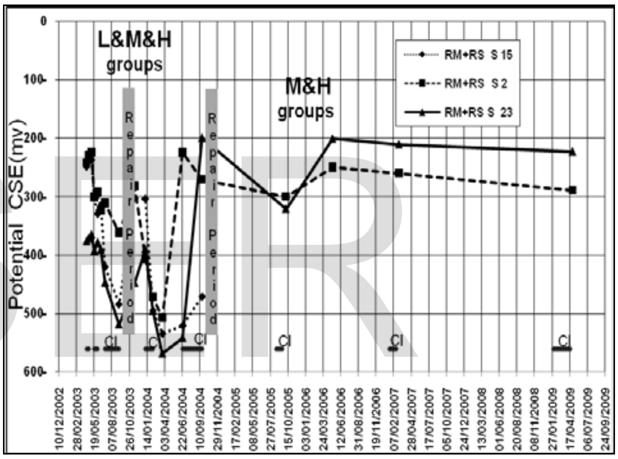

Fig.(9) Comparison potential values of steel with time for slabs repaired (RM+RS)

Then we can find that the mortars (CSM, CSM+F, RM) re-alkalized the old concrete and consequently re-passivated the steel surface, which corroded with common corrosion. Contrary to that, it stopped common corrosion and prevented further chloride penetration through the surface of repairing layers to the old concrete; this was due to high impermeable and 2.5cm thickness layers. The results obtained within the first few months of exposure after repair indicated a 90 percent probability of no corrosion activity in the specimens.

- The Crushed Stone Mix past showed less reaction with only slight effectiveness to prevent further chloride penetration through the Crushed Stone Mix layers to the old concrete, while the repair system Crushed Stone Mix with Steel Fibers is lesser in growth of cracks.

- The Ready Mix showed the least amount of corrosion and a moderate effectiveness to prevent further corrosion penetration with respect to the Crushed Stone Mix layers.

With the high chloride content in old concrete, all repair systems decrease the rate of corrosion, however the best one was the Ready Mix. The Crushed Stone Mix with Steel Fibers could reach a reasonable degree of preservation with increasing the corrosion potentials (Ecorr.) were measured periodically to examine the corrosion situation of the steel directly after the slabs were cast and stored. The most anodic potentials of the steel were plotted comparatively with time after the repair. However, the most anodic potential wasn't always found by the same amount; this amount often changed. The (-350mv) CSE was taken as a limit of corrosion presence. Before repair the most anodic potentials of the steel were some -ve this due to the high amount of admixed chloride, and the +ve potential reading, which responsible for forming the passive film didn't take reasonable time.

A long time after preparation of the slabs and applying the chloride attack with dynamic corrosion cell the anodic potentials continue to fall at an increasing rate. The potentials of the steel are measured at different times in this program within the chloride attack.

5. CONCLUSIONS

5.1 Repair Efficiency of Group L under Corrosion Process

1. The mortars (CSM, CSM+F, RM) re-alkalized the areas where the contaminated concrete was removing and protect the steel against further corrosion for the small period.

2. The RM repair system showed the least amount of corrosion and a moderate effectiveness to prevent further corrosion than the other systems with more than 90 percent efficiency.

3. The CSM repair system showed sensible effectiveness to prevent further corrosion with efficiency of about 40 percent.

4. The repair system CSM+F is lesser in growth of cracks with efficiency of 40 percent.

5.2 Repair Efficiency of Group M&H under Corrosion Process

1. The mortars (CSM, CSM+F, RM) re-alkalized the areas where the contaminated concrete was removing and re-passivated the steel surface.

2. The results obtained within the first few months of exposure after repair indicated more than a 95 percent efficiency of no corrosion activity for all specimens of group M.

3. With the high chloride content in old concrete, all repair systems decrease the rate of corrosion, however the best one was the RM.
4. The CSM+F could reach a reasonable degree of preservation with increasing the thickness of its repairing layer.
5. These results are changing significantly as the exposure time increases. A highly permeable concrete mix, numerous flexural cracks, low cover, and cast-in chlorides increase the rate of oxidation.

Also, the crushed Stone Mix past showed less reacation with only slight effectiveness to prevent futher chloride penetraton throughbthe Crushed Stone Mix layers to the old concrete, while the repair system Crushed Stone Mix with Steel Fibers is lesser in growth of cracks.

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