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Improve the Strength of Different Rate for Corroding Steel in Concrete Slabs

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ABSTRACT- The strength capacity of the structural elements affected by the rate of corrosion, which is one of the most expensive problems facing civil projects in all countries, which resulting in premature failure of structures exposed to harsh environments. Program of thirty six samples starts in 2002 was 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 was connected to the electronic circuit to accelerate corrosion process. In this paper, to refresh and growth the strength of the samples five 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 are usually used in structure maintenance. Some techniques results achieved a reasonable degree of efficiency in flexural capacity compared to that both (CSM) and (RM) systems with fibers and additional steel bars.

KEYWORDS: slab, efficiency, strength, corrosion, CSM, RM, CSM+HF, CSM+RS

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1. INTRODUCTION

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 cause special cracks due to the corrosion of steel. The application of the thick surface coating with materials has smaller properties of the concrete material or sealer is one repair method that is intended to create a barrier to the incoming contaminated water, thereby robbing corrosion of its reactants. [2].

The temperature dependence of corrosion in concrete will usually be quite different widths are directly related to the tensile stress in reinforcement, which implies that there must be a maximum permissible tensile stress if the steel is to be prevented from corroding [3]. The deformed bars showed an improvement of more than 10% in crack control with respect to the plain round bars at higher stresses than are typical for mild steel [4].

J. SIM and I. BAE had tested 24 specimens of rectangular reinforced concrete beams with cross section of 15x25 cm, and total length of 240 cm and clear span is 200 cm. Reinforcing bars are consisted of 2 ϕ10 mm in compression side, 2 ϕ 13 mm in tension side and ϕ10 mm stirrups in 10 cm spacing , the specimens are over designed in shear to avoid a brittle shear failure. Proper preparation of bonding surface between the existing concrete and repair materials is extremely important. Therefore, after 28 days of curing, the bonding surfaces of specimens were roughened using mechanical chipping. [5].

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].

2. EXPERIMENTAL WORK

16 slabs with low corrosion rate were tested at year 2004 and other slab were tested at the end of the program at 2009, the 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. All slabs were cast with the same manner; the slabs were 240×50×14cm. With steel reinforcements as shown in figure 1 and the same mix design. The slabs were

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prepared with the same steel and the slabs dimension were 50 cm 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.

3. 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. 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. then Repairing and strengthening systems applying. After applying the repairing systems and chloride attack for a period to state the corrosion situation after repair, a static loading test was done on these slabs, each slab was firstly located on the movable head of machine, then the dial gauge is fixed at the mid span. To record the initial reading of the dial gauge, the slab was loaded by small amount, there after the load is increased with increment each 0.2ton, the load was kept constant between two successive increments for five minutes. During this period, reading of dial gauge and cracks propagation's was recorded at the beginning and at end of each increment of loading till the failure load. The main program details and methods of repair and strengthening are shown in table 1and figure 1.

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

Expression	Description
CSM	Crushed stone mix.
CSM + RS	Crushed stone mix + Reinforcement steel; (2 # 10 mm) in group L and (3 # 10 mm) in group M&H
CSM + HF	Crushed stone mix + Hrex Fiber.
RM	Ready mix. (Cetorex Grout)
RM + RS	Ready mix. + Reinforcement steel; (2 # 10 mm) in group L and (3 # 10 mm) in group M&H

CSM : Crushed stone mix. (from Basalt) S5, S18 & S19
CSM+RS:Crushed stone mix+Reinforcement S6, S14 &S17
CSM+HF :Crushed stone mix + Hrex Fiber S20, S27& S33
RM : Ready mix. (Cetorex Grout) Slabs S1, S24 & S25
RM + RS : Ready mix. + Reinforcement abs S2, S15 & S23
Reference: without repair H :High corrosion 50%
L :Low corrosion 10% M:Med. corrosion 30%

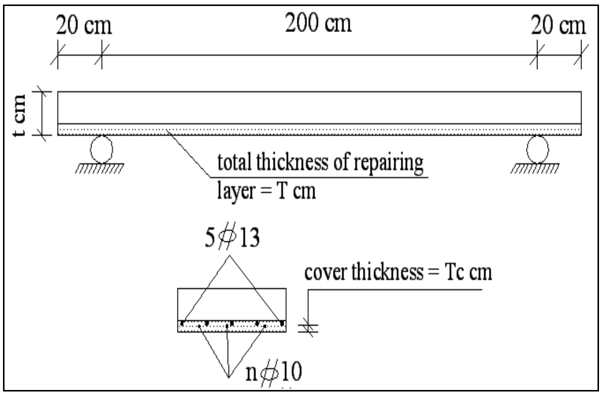

Fig. (1) Manner of loading and slabs details (M).

4. RESULTS

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

All Slabs, which were repaired and strengthened 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 applied load for repairing and strengthening systems of groups (L, M&H) , the slabs in each repairing system had the same behavior with a small difference and all of them had high load capacity than the slabs without repair for point of max deflection of all slabs as shown in fig. 2, fig.3 and fig.4.

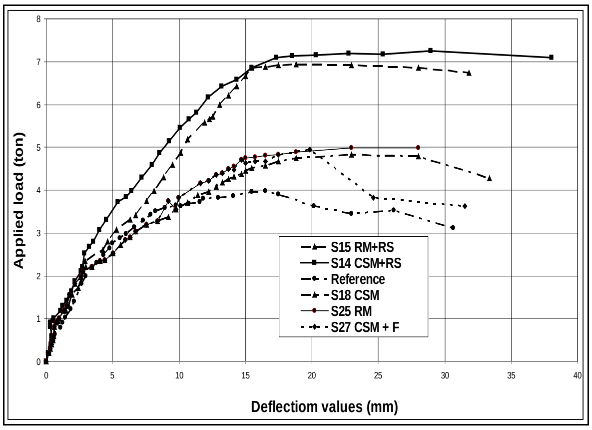

Fig. (2) Variation potential average values of steel with time for slabs (L).

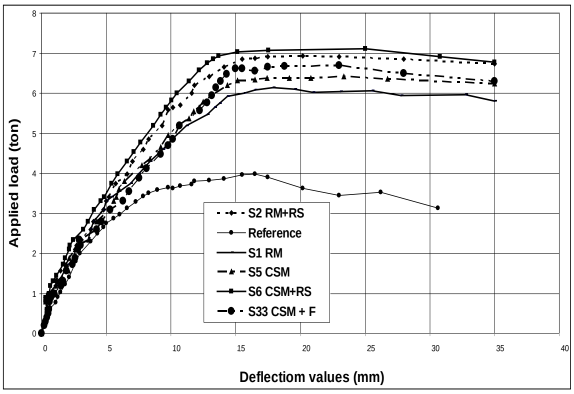

Fig. (3) Variation potential average values of steel with time for slabs (M).

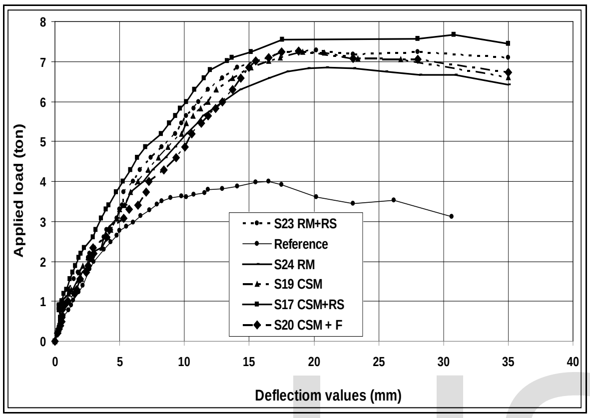

Fig. (4) Variation potential average values of steel with time for slabs (H).

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

The slabs S5, S18 and S19 were repaired with Basalt Crushed Stone Mix layers, while both slabs S6, S14 and S17 were repair and strengthened 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 CSM 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 corrosion.

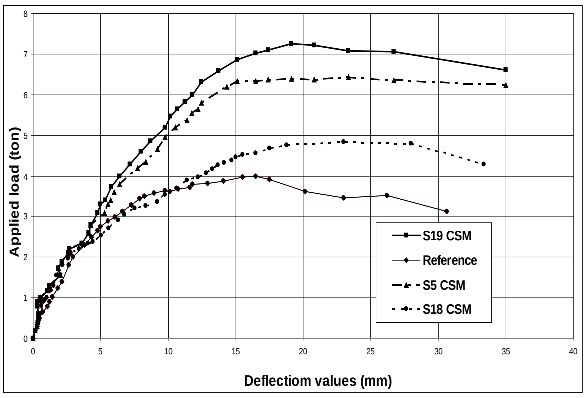

Fig. (5) Comparison potential values of steel with time for slabs repaired (CSM)..

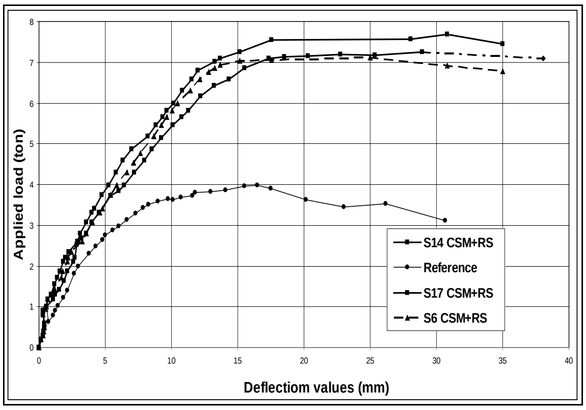

Fig.(6) Comparison potential values of steel with time for slabs repaired (CSM+RS).

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 the load and point of max deflection these slabs.

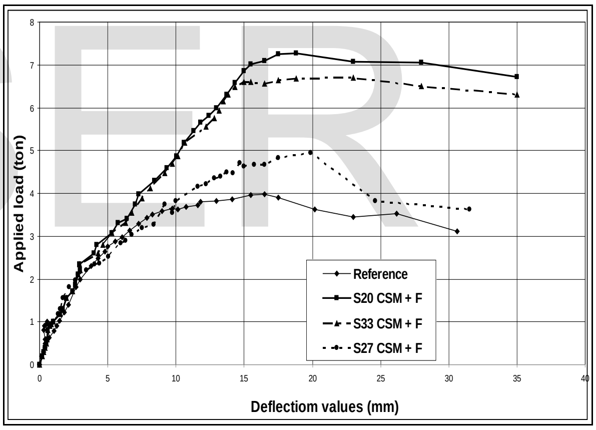

Fig.(7) Comparison potential values of steel with time for slabs repaired (CSM+F).

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

The slabs S1, S24 and S25 were repaired and strengthened with resdy mixing Mix layers, while both slabs S2, S15 and S23 were repair and strengthened 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 corrosion.

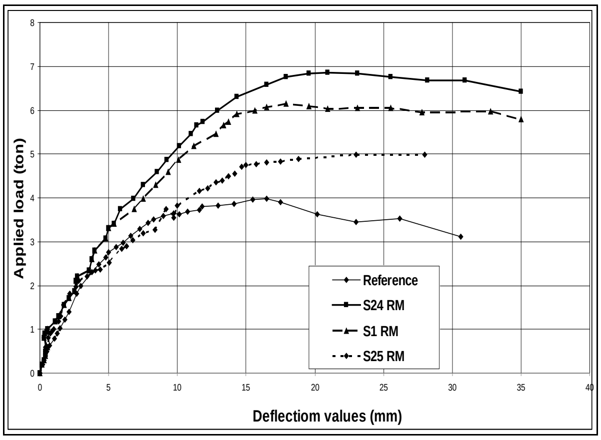

Fig.(8) Comparison potential values of steel with time for slabs repaired (RM).

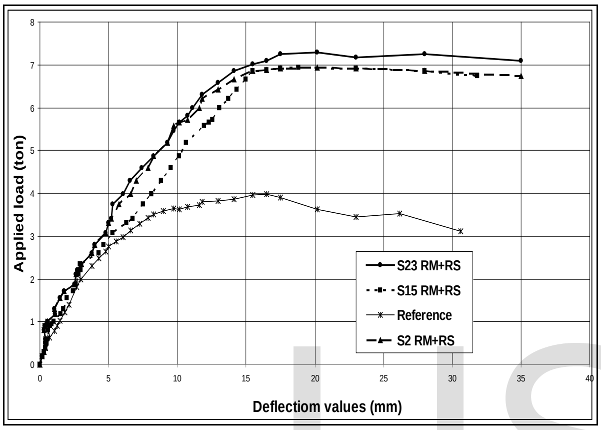

Fig.(9) Comparison potential values of steel with time for slabs repaired (RM+RS).

4.3. The general comparison for systems (L, M&H)

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, subsequently protect the steel reinforcements to keep the strength capacity.

I- The use of steel fibers in thick layers is feasible and effective for strengthening/repair of concrete structures and raises the efficiency of the repairing layer by amount of 10 percent.
II- The presence of fibers decreases the crack widths of CSM+F layers than the others, which were repaired with RM or CSM.
III- Using embedded reinforcement increases the ultimate capacity of the slab by 25 percent.
IV- Failure of both strengthened and unstrengthened slabs was due to crushing of concrete at the extreme compression fibers.
V- Introducing fibers did not change the mode of failure.

4.2 Flexural behavior dissolution

The efficiency of the different repairing and strengthening systems can be evaluated directly by comparing the repaired and strengthened slabs with respect to the original slab S0. The analysis shows the difference in the efficiency of these repairing systems under flexural behavior under the three main items:

- Deformation capacity (maximum Deflection)
- The maximum measured values of deflection corresponding to the point of maximum deflection along the slab span at cracking load (δcr.) and at 0.85 of ultimate load (δu) and the values of ratios of cracking and ultimate deflections of tested slabs (δcr / δu) are given in table 2 for all the tested slabs.

Slab No.	Repair system	P_{cr} (ton)	P_u (ton)	δ_{cr} (mm)	δ_u (mm)	$\delta_{Failure}$ (mm)	δ_u/δ_{cr}	P_{cr}/P_u
S0 Ref.	-	1.3	4.0	2.0	17.0	32.22	8.5	0.325
S5 - M	CSM	2.3	6.3	2.2	27.0	35.00	12.2	0.365
S18 - L	CSM	2.3	4.9	2.7	25.0	32.52	9.25	0.469
S19 - H	CSM	2.5	7.5	2.8	18.0	35.00	6.42	0.333
S6 - M	CSM+RS	2.5	7.2	2.5	25.0	35.00	10.0	0.347
S14 - L	CSM+RS	3.7	7.2	5.1	28.0	38.54	5.49	0.514
S17 - H	CSM+RS	2.5	7.9	2.5	33.0	35.00	13.2	0.316
S20 - H	CSM+F	2.5	7.5	2.7	20.0	35.00	7.4	0.333
S27 - L	CSM+F	2.2	5.0	2.5	23.0	32.00	9.2	0.440
S33 - M	CSM+F	2.6	6.5	2.7	27.0	35.00	10.0	0.400
S1 - M	RM	2.0	6.2	2.1	18.0	35.00	8.6	0.523
S24 - H	RM	3.0	6.8	2.8	20.0	35.00	7.14	0.4410
S25 - L	RM	2.1	5.0	2.5	23.0	28.60	9.2	0.42
S2 - M	RM+RS	2.4	6.95	2.4	20.0	35.00	8.33	0.345
S15 - L	RM RS	3.0	6.9	4.8	24.0	33.54	5.0	0.438
S23 - H	RM+RS	2.5	7.6	2.9	18.0	35.00	6.2	0.329

L :Low corrosion 10% M :Med. corrosion 30%
H :High corrosion 50%

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Table (2) shows in tabled data the comparison at different load stages.

5. CONCLUSIONS

From the previous comparisons and analysis we can conclude the following:

I- System slabs repaired with RM, CSM and CSM+F

Due to the big contact between the old concrete and both the RM, CSM and CSM+F and decrease of the included shear stress in the contact layer between old concrete and RM, CSM and CSM+F are no more significant difference in the behavior under static load test, except a slight decrease in ultimate strength that is due to the small thickness of this layer and the reduction in the cross section area of main steel due static load test, except a slight decrease in ultimate strength that is due to the corrosion rate, that leads to both the two systems CSM and RM restore its strength by range 50% to 60% depending on reduction in the cross section area of main steel and also the main distinct difference that it can be observed here is the higher value of (Pcr/Pu) for the CSM+F layer with low corrosion rate as shown in table 2 and its narrow crack widths than the other slabs, which were repaired with RM or CSM.

II- System Slabs Strengthened with Reinforcing Steel

Due to the reduction in the cross section area of main steel, the slabs have less ultimate strength and more ductility of the steel reinforcement, which results in wide cracks than the other slabs strengthened with steel reinforcement. The results show that the slabs strengthened by Reinforcing Steel in both CSM and RM layers undergo a higher load until cracks appear, that leads restoration its efficiency of 70% to 95% depending on the degree of the corrosion rates.

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