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Effect of Plastering Layer on Corrosion Resistances of Reinforced Concrete Beams

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Abstract: ***Reinforced concrete structures are subjected to deterioration due to many factors such as corrosion of reinforcing steel. Ultimate strengths of structural elements can be greatly affected by these deteriorating factors. There are numerous methods and techniques used to protect these structural elements. The mortar layer (Plastering) is considered the first defense line against all the deteriorating factors. The main goal of this research is to investigate to what extent the plastering layer can protect reinforced concrete beams against corrosion. The aim of the experimental program is to study the effect of plastering layer on corrosion resistance of reinforced concrete beams. Four reinforced concrete beams (100×200×1100 mms) and four Lollypop specimens (cylinders 100×200 mms) were tested and described as follows:***

- ***A beam and a lollypop specimen without any plastering layer (control).***
- ***A beam and a lollypop specimen with traditional plastering layer (cement + sand + water).***
- ***A beam and a lollypop specimen with modified plastering (traditional plastering + waterproof admixtures).***
- ***A beam and a lollypop specimen with painted and modified plastering layer (traditional plastering + waterproof admixtures + external waterproof paint).***

These eight specimens were subjected to corrosion using accelerated corrosion technique, after that the four beams were tested in flexure under three point load arrangement while the four lollypops were used to calculate the total mass loss due to accelerated corrosion. The test results were used to figure out the effect of plastering layer on corrosion resistance of RC beams.

Keywords: RC beams; Corrosion resistance; plastering layer; Waterproof admixture; Waterproof paint.

I. INTRODUCTION

Corrosion of steel reinforcement is considered as one of the major causes of reinforced concrete deterioration [1], [3] & [13]. Corrosion can be defined in many ways but the most commonly one is the loss of steel weight due to chemical or electrochemical reactions [5], [7] & [14]. Causes of corrosion are related to the reinforcing steel itself, concrete strength, concrete materials and the surrounding environment.

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Steel surface can have adjacent areas with different potentials due to presence of impurities, non-uniform cooling during the manufacturing process and different concentrations of ions surrounding the steel surface [4], [6], & [16]. Concrete may contains some ions such as chloride ions either intentionally, as a concrete admixture, or unintentionally like those present in concrete materials. Surrounding environment may be corrosive such as the case of industrial buildings, marine structures, foundations…etc. [11]. The mechanism of corrosion process is known as an electro-chemical reaction occurs at the surface of the steel due to presence of a potential difference between two adjacent points on the steel surface. This potential difference occurs because of any of the aforementioned causes. At anode point the electrochemical oxidation takes place and at cathode point the electrochemical reduction occurs where the steel bar acts as an electric conductor and concrete acts as an aqueous medium. Different techniques with variable effectiveness are used to protect the steel reinforcement from corrosion. Choice of the most suitable protection method depends on many factors as cost, nature of the structure, and the required level of protection [8], [9], & [15].

II. OBJECTIVES

The main objective of this research work is to evaluate to what extent the plastering layer can provide a protection to RC beams subjected to corrosion.

III. MATERIALS & TEST SPECIMENS

A. Concrete Mix

The cement used was Portland cement of grade R 42.5. The coarse aggregate was crushed stone. The used sand was natural sand with fineness modulus of 2.30. Table-I gives the sieve analysis test results for the used sand and crushed stone. Table-II gives physical properties of the used sand, crushed stone. The concrete mix was designed to achieve cube compressive strength after 28 days of 250 Kg/cm^2 as given in Table-III. The steel reinforcement used was high tensile steel with oblique ribs of grade 36/52 and nominal diameters 10 and 13 mm. The average measured 7 and 28 days cube compressive strength were 248 and 300 Kg/cm^2 respectively. All the test specimens were cast and cured by wet burlap until the test date.

B. Test Specimens

The four RC beams are of dimensions 100×200 mms in cross section and 1000 mms span. The upper reinforcing bars were 2 high tensile steel deformed bars of diameter 10 mm and the bottom reinforcing bars were 2 high tensile steel de-formed bars of diameter 13 mm as shown in Fig. 1. After 28 days from the casting date, the plastering layers were carried out for three beams (note that the beam without any plastering layer was used as a control specimen). Beams and lollypop specimens were as follows:

- Group A:
  a beam & a lollypop specimen without any plastering.
- Group B:
  a beam & a lollypop specimen were with traditional plastering (cement : sand = 1 : 3 & w/c ratio = 0.3).
- Group C:
  a beam & a lollypop specimen with modified plastering (traditional mortar + waterproof admixtures RHEOMIX 141M ®).
- Group D:
  a beam & a lollypop specimen with painted and modified plastering (traditional mortar + waterproof admixtures RHEOMIX 141M® + waterproof paint SANITON®).

Table- I: Sieve analysis test results for fine & coarse aggregates

Fine Aggregate	**Sieve size (mm)**	4.75	2.36	1.18	0.60	0.30	0.15
	Pass %	99.6	98.9	74.1	60.3	33.0	6.0
Coarse Aggregate	**Sieve size (mm)**	37.5	31.5	28.0	20.0	10.0	5.0
	Pass %	100	100	100	67.8	10.6	0.0

Table- II: Properties of fine and coarse aggregates

Property		Fine Agg.	Coarse Agg.
Specific gravity		2.50	2.50
Unit weight (t/m^3)		1.412	1.570
Crushing value (Los Anglos)	%	---	23.0
fine materials (by volume)	%	3.0	---
Absorption	%	---	1.8

Table- III: Mix proportions by weight for (1 m^3) of concrete

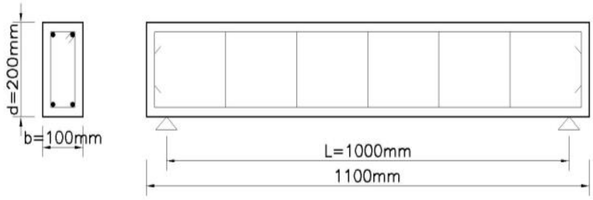
Cement (OPC) (Kg)	Sand (Kg)	Crushed Stone (Kg)	Water (Liter)
375	655	1070	190

All test specimens (beams & lollypops) were subjected to accelerated corrosion using the galvano-static method in which a current was impressed through the reinforcing steel bar by applying a fixed potential across the anode (reinforcing steel bar) and an external cathode (a steel cylindrical pipe surrounds the specimen) [2], [10] &[12].

An electronic voltmeter was used to measure the current intensity in the circuit by recording the potential difference between connectors of a fixed resistor of 100 Ohm. The circuit current was calculated as the product of the measured potential difference divided by the resistance.

Test specimens were immersed in a 15% Sodium chloride (NaCl) solution at the room temperature and was connected to a constant 15 Voltage power supply. The steel cylindrical plate was submerged in the solution and was cleaned periodically to prevent depositing of salt on the surface.

The corrosion cell is shown in Fig. 2. Full details of the test specimens and their plastering are given in Table-IV.



Beam total depth (d) = 200 mm
Beam breadth (b) = 100 mm
Beam span (L) = 1000 mm
Total length = 1100 mm

Fig. 1.Typical dimensions of RC beams

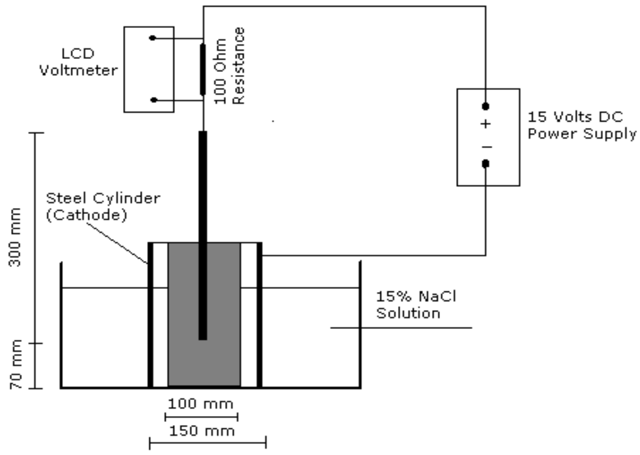


Fig. 2.Accelerated Corrosion Cell

Table- IV: Details of test specimens

Test Specimens		Plastering Case	Exposure	Test
4 RC Beams	1 beam	No Plastering	Accelerated Corrosion	Three Point Load Flexure Test
	1 beam	Traditional Plastering		
	1 beam	Traditional Plastering + Admixtures		
	1 beam	Traditional Plastering + Admixtures + Surface Paint		
4 Lollypop Specimens	1 Spec.	No Plastering	Accelerated Corrosion	Total Mass Loss Test
	1 Spec.	Traditional Plastering		
	1 Spec.	Traditional Plastering + Admixtures		
	1 Spec.	Traditional Plastering + Admixtures + Surface Paint		

IV. TEST PROCEDURE, RESULTS, AND DISCUSSION

As mentioned earlier, the test specimens of this part (beams & lollypops) were divided, according to the protection level given by the plastering layer, to four groups A, B, C and D.

It can be seen easily that the protection level is increased gradually from the first group (group A) to the fourth group (group D).

The Lollypop specimen was used to estimate the total mass loss for each group. During the progress of the accelerated corrosion test, the resulting current values "I" are recorded every 2 hours for a duration of 250 hours (i.e. current was recorded after 0, 2, 4, 6,...., 248, 250 hours from the beginning of the test). The following equations are used to calculate the corrosion current intensity in the circuit:

$$I = V/R \qquad (1)$$

Where: I = Corrosion current intensity
V = Potential difference, across 100Ω resistance.
R = Resistance (100 Ω).

Then, the total mass loss will be calculated from the area under the curve of corrosion current versus time using Fara-day's equation:

$$Mt = [M / (Z*F)] [\int I.dt] \qquad (2)$$

Where: Mt = Total mass loss (gm)
M = Atomic weight of metal (55.85 gm/mol for iron).
∫I .dt = Electrical charge.
Z = Ionic charge (2 for iron).
F = Faraday's constant (96485.3 C/mole of e).

Fig. 3 shows one of the lollypops during the test and Fig. 4 shows typical "time - current" relationship for lollypop specimen of group "D". Table-V gives the calculated total mass loss (Mt) for lollypops. Fig. 5 shows the total mass loss for all lollypops as a percentage from the control case (case "A"). The four beams representing the four protection levels (A, B, C & D) were put in the accelerated corrosion cell (exactly like the lollypops) for 250 hours but no time/current readings were recorded. The goal of using these beams was to estimate how the protection level (given by the plastering) can affect the failure loads of the beams.

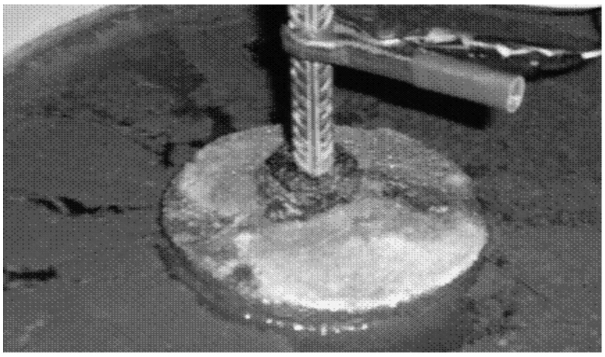


Fig. 3. The lollypop specimen during the test

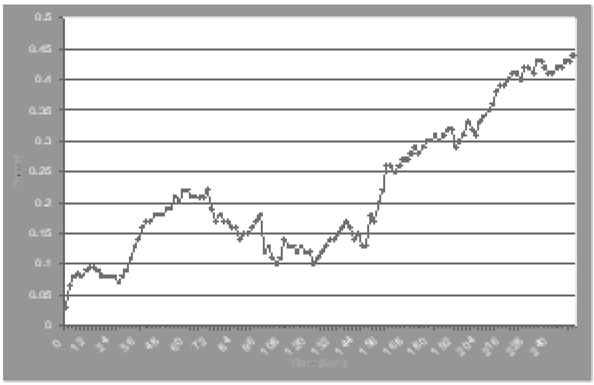


Fig. 4. Typical "time-current" relationship for lollypop "D"

Table-V: Total mass loss for lollypop test specimens

Protection Level	Total Mass Losses (gm)	% Total Mass Loss from Case "A"
A	215	100
B	100.59	46.47
C	63.37	29.47
D	55.85	25.97

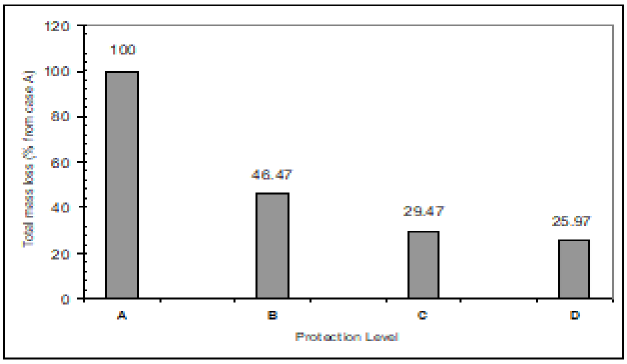


Fig. 5. Total mass loss of Lollypops as a % from case "A"

After accelerating corrosion, the 4 beams were tested in flexure using three point load arrangement. The span was 1000 mms and the mid-span load was applied gradually until failure. The failure loads were recorded for the 4 beams. Table-VI gives failure loads for the 4 beams; Fig. 6 shows typical failure mode for all of them, Fig. 7 shows the failure loads as a percentage from case "A".

Fig. 6. Typical Failure mode for the four beams

Table-VI: Failure loads for RC beams

Protection Level	Failure Load (Tons)	% Failure load from Case "A"
A	4.30	100
B	6.15	143
C	8.30	193
D	8.30	193

Based on the total mass loss test results of lollypop specimens (shown in Fig. 5) and failure loads test results of beams (shown in Fig. 7), it can be seen easily that the traditional plastering layer without any admixtures or paints (level "B") can provide about 50% increase in the protection level (compared with level "A" (case of no plastering)). Level "C" (case of waterproof admixtures) provides about 70% to 90% increase in the protection level compared to level "A".

Levels "C" and "D" give almost the same results which mean that the waterproof paint almost has no effect in the presence of waterproof admixtures.

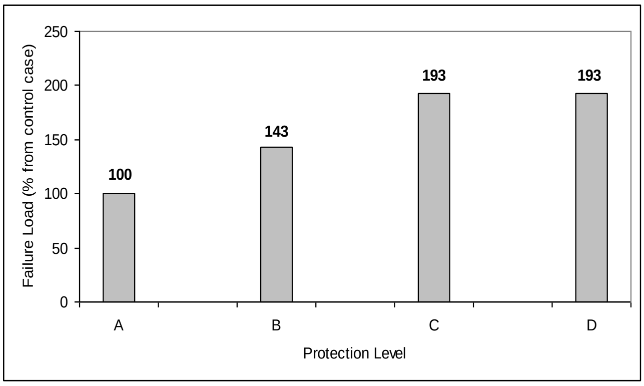


Fig. 7.Failure loads of beams as a % from case "A" (control case)

V. CONCLUSIONS

Based on the obtained results and the aforementioned discussion, the following points can be concluded:

1. Plastering layer from traditional mortar alone (without any admixtures) can provide about 50% increase in the protection level against corrosion (compared to the case of no plastering).
2. Plastering layer from traditional mortar + waterproof admixtures provides about 70% to 90% increase in the protection level against corrosion (compared to the case of no plastering).
3. When using waterproof admixtures in the mortar, there is no need to use any waterproof paint since the admixtures alone is enough to provide satisfactory protection level.

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