Formulation of Anti-Corrosive Coatings using Polyvinyl Acetate for Concrete Surfaces

Nivetha S[1], Selvaraj R[2], Lakshmi R[3]

[1]Post Graduate Student, Kamaraj College of Engineering and Technology, Madurai, Tamil Nadu, India

[2]Senior Principal Scientist, CMPD, CSIR-CECRI, Karaikudi, Tamil Nadu, India

[3]Professor and Head-Civil Department, Kamaraj College of Engineering and Technology, Madurai, Tamil Nadu, India

Abstract: *The pores, capillaries, micro cracks, fissures, etc, created on the surface of concrete form defects. These surface defects allow for invasion of outer detrimental ions, which causes deterioration of concrete and corrosion of embedded steel in concrete. This corrosion of steel reinforcement becomes a severe concern to the life of Structures. One of the best ways to manage this durability issue is surface coatings to concrete. Coating usually covers all such defects and gives uniform durable surface finish. In this study, several coatings were developed by using polyvinyl acetate (PVA) as binder with functional pigments such as Silica fume, Nano silica, Kaolin, Alumina clay, TiO_2, Al_2O_3, etc., These coatings were subjected to Field exposure, Chemical exposure, Water absorption and Flame exposure and the best coatings were selected based on the screening tests and analysis. The selected coatings were finally subjected to various durability tests such as Sorptivity, Chloride ion diffusivity, Impressed voltage test and TAFEL extrapolation techniques.*

Keywords: Durability, Polyvinyl acetate, Flame test, Chloride diffusion, Nano silica, Silica fume

1. Introduction

The reduction in service life of Reinforced Concrete structures has become a serious problem in Construction industry global wide [1]. Due to this reduction of service life, considerable resources must be diverted to repair and rehabilitation of the deteriorated Concrete structures. Deterioration of Concrete structures takes place due to exposure of the structures to various environmental conditions. However, the major problem of deterioration of Reinforced Concrete structures is due to Corrosion of embedded steel in Concrete.

Chlorides from the marine environment and Carbon dioxide from the atmospheric air are the two major factors responsible for reinforcement corrosion. The Chlorides and Carbon dioxide penetrate through the pores, voids, capillaries, fissures and other surface defects of Concrete like micro cracks, and causes Corrosion of embedded steel in the Concrete structures. This Corrosion of steel eventually reduces the cross section of the Steel reinforcing bars and thus greatly reduces load carrying capacity of the members/structures.

Diffusion of Chlorides and Carbon dioxide can be controlled by strict and improved construction practices to some extent. However, a coating on Concrete surface will act as a membrane and prevents entry of Chlorides and Carbon dioxides. Though, several studies have been conducted on Concrete surface coating with several formulations by many researchers [2-9], Surface coating with Polyvinyl acetate has not been studied systematically.

In this research work, Polyvinyl acetate was used as binder and several coatings (22 no's) were formulated and rigorous studies were conducted from Field exposure studies to laboratory Corrosion studies and the results are discussed.

2. Experimental Investigation

2.1 Materials

To interpret the behaviour of PVA in surface coatings for corrosion resistant properties on concrete surface, various functional pigments such as Fly ash, Silica fume, Nano silica, Alumina clay, Bentonite, Al_2O_3, TiO_2 and Kaolin were selected.

2.2 Specimen preparation

Cement mortar specimens of ratio 1:3 with water to cement ratio of 0.4 were cast for testing purposes. Uncoated specimen, in every test, will be considered as Control whose test values were taken as benchmark.

2.2.1 Hollow core water absorption test
Hollow core Disc Water Absorption, a non-standard test, was invented in CSIR-CECRI, Karaikudi. Disc specimens of 83 mm diameter and 50 mm thick in which centrally a hollow space was created by removing the cement-mortar to a size of 40 mm diameter and 25 mm depth were cast.

2.2.2 Flame test
Tiles of size 100 mm x 50 mm x 10 mm were cast and experimentally investigated using an accelerated Flame Torch designed and fabricated at CSIR-CECRI, Karaikudi. A high temperature flame of the torch was held against the coated tiles which are clamped to a stand.

2.2.3 Field exposure study
Tile specimens of size 100 mm x 100 mm x 10 mm were used for this test. Specimens were exposed to open sky at an angle of 45° facing South in a specially fabricated Wooden stand.

2.2.4 Preparation of surface coatings

Twenty two different combinations of coatings were developed using PVA (as binder) and other functional materials which are represented below:

1. PVA + Fly ash + Silica fume
2. PVA + OPC + Fly ash + Silica fume
3. PVA + Kaolin + Silica fume
4. PVA + Kaolin + Fly ash + Silica fume
5. PVA + Bentonite + Fly ash + Silica fume + TiO_2
6. PVA + OPC + Silica fume + TiO_2
7. PVA + Fly ash + Silica fume + TiO_2
8. PVA + Kaolin + Fly ash + Silica fume + TiO_2
9. PVA + Al_2O_3 + Fly ash + Silica fume + TiO_2
10. PVA + OPC + Fly ash + Silica fume + TiO_2
11. PVA + Al_2O_3 + Kaolin + Silica fume + TiO_2
12. PVA + Al_2O_3 + Bentonite + Silica fume + TiO_2
13. PVA + Al_2O_3 + Alumina clay + Silica fume + TiO_2
14. PVA + Alumina clay + Bentonite + Silica fume + TiO_2
15. PVA + OPC + Nano silica + TiO_2
16. PVA + Fly ash + Nano silica + TiO_2
17. PVA + OPC + Fly ash + Nano silica + TiO_2
18. PVA + Alumina clay + Fly ash + Nano silica + TiO_2
19. PVA + OPC + Al_2O_3 + Nano silica + TiO_2
20. PVA + OPC + Bentonite + Fly ash + Nano silica
21. PVA + Al_2O_3 + Nano silica + TiO_2
22. PVA + OPC + Fly ash + Nano silica

Figure 2.1: Core filled with water   Figure 2.2: Refilling the core

2.3 Test Methods

All the above coatings were applied on various test specimens. These coated specimens along with one uncoated specimen were subjected to different test methods. From the above coatings, the best coatings were selected based on regress tests and analysis.

2.3.1 Water absorption Test (ASTM C642 - 97)

Water Absorption test was conducted on all the 22 coated Tile specimens each of 100 mm x 50 mm x 10 mm. After the coatings were dried completely, the specimens were immersed in water in Plastic Bucket for a period of 48 hours. Before placing the specimens in Bucket, Dry weight was measured for each specimens and Saturated weight after 48 hours of immersion was also carried out.

2.3.2 Hollow core Water Absorption Test

The internal hollow core space was coated doubly and allowed for drying. Then, the hollow core space was filled with water to its top level of the specimens as shown in Fig. 2.1. The quantity of water poured was measured in millilitre (ml). With interval of time, with slow absorption of water both in Radial as well as in Vertical direction, again the water was filled as shown in Fig. 2.2. Now, the quantity of water poured inside the core was noted. It was continued at a 1 hour interval for 8 hours and then final measurements were taken after 48 hours.

2.3.3 Chemical Resistance Test

Chemical resistance test has been carried out with 5 solution media namely 1 % Hydrochloric acid (HCl), 1 % Sulphuric acid (H_2SO_4), 1 % Magnesium sulphate ($MgSO_4$), 1 % Urea and Distilled water. The coated cement-mortar Tile specimens immersed were, of size 50 mm x 50 mm x 10 mm, placed in separate Plastic Trays for a period of 45 days. During the period of exposure, it was observed for any color change, shrinkage, bulkage, cracking, twisting, edge cracking, dissolution of specimens, etc.

2.3.4 Flame Test

The Flame test was carried out in a specially fabricated Vertical stand fitted with Gas torch to produce sharp flame which targets the coated specimens clamped into it. The temperature of the target was measured using Infra-Red Thermometer, reading digitally the temperature of surface.

This test has been carried out for all the 22 coated cement-mortar Tile specimens of size 100 mm x 50 mm x 10 mm with one uncoated specimen.

2.3.5 Field Exposure Study

Totally, 22 coated specimens and 1 uncoated specimen were exposed to open sky in a wooden stand. The exposure period was 45 days. After exposure, the specimens were carefully studied for any discoloration, cracking, wrinkling, shrinkage, edge cracking, chaulking, etc.

2.3.6 Sorptivity Test (ASTM C1585 - 13)

Sorptivity test was conducted using cement-mortar Cylindrical specimens of diameter 50 mm and height 80 mm with outer coating with Araldite. The bottom circular surfaces were coated with selected coatings and dried. Weight of the specimens was measured with the help of digital balance. Then, placed in a disc in which only 5 mm depth of water was poured.

Once the specimens were placed in water, it will try to absorb water from the base to the top by Capillary action (Wick action). With certain intervals of time, for duration of 60 minutes, the water absorption was measured and the Co-efficient of water absorption was calculated using the Eqs. 2.1.

$$K_a = (Q/A)^2 \text{ x } (1/t) \qquad \text{…2.1}$$

2.3.7 Impressed Voltage Test

12V DC Impressed Voltage Test was conducted using cement-mortar Cylindrical samples of 50 mm diameter and 80 mm height with centrally placed 10 mm diameter TOR Steel coated with selected coatings. It was placed in 3.5 % NaCl solution (Electrolyte) and the cylinder was surrounded by Stainless Steel plates (Cathode) and the centrally embedded TOR Steel was made as Anode. 12V DC current was applied between the Anode and Cathode. It was allowed for hours together by impressing the voltage.

2.3.8 Chloride Ion Diffusivity Test (ASTM C1202 - 12)

Chloride ion Diffusion Test has been carried out using PVC cells on either side of mortar specimens fixed with m-seal. One cell was filled with 3.5 % NaCl solution (equivalent to

Sea water) and the other cell with 0.1 M NaOH solution. An Electric supply of 60V DC was applied across the mortar specimens which was the driving force for Chlorides to diffuse through the mortar from NaCl side to NaOH side.

When the DC power source was switched ON, for every 30 minutes interval, the current was measured in terms of Amps and recorded.

2.3.9 Tafel Extrapolation Techniques

This experiment has been carried out with the help of Potentiostat/Galvanostat equipment known as 'Autolab' which was designed with IR drop compensator due to high Electric resistance of cement mortar. A cell comprising of 3 Electrode systems namely Working Electrode (WE), Counter Electrode (CE) and Reference Electrode (RE) was used in the test.

Cement-mortar Cylindrical specimens cast with centrally placed 10 mm diameter TOR Steel were used as Working electrode, perforated Stainless Steel plate was used as Counter electrode and Silver/Silver chloride (Ag/AgCl) electrode was used as Reference electrode. A 3.5 % NaCl solution was used as Electrolyte. This autolab system automatically registers Anodic and Cathodic curves. Tangents in anodic and cathodic curves were selected to arrive at E_{corr} and I_{corr} and other values such as Current density (A/cm^2) and Corrosion rate (mm/yr).

3. Results and Discussion

3.1 General

The results, from various tests conducted on coated mortar specimens and Control (uncoated specimen) as mentioned above, were tabulated and discussed below.

3.2 Water Absorption Test

The results for all the coated specimens are given in Table 3.1. The Lowest water absorption was found in specimen 9 followed by specimens 11, 12 and 7. The Highest water absorption was obtained for coated specimen 7 (4.98 %) and Control specimen (9.46 %). From the study, it can be concluded that the specimen 9 was found to be the best among 22 coated specimens.

The percentage of water absorption was computed using Eqs. 3.1.

% of water absorption = $\dfrac{\text{Saturated wgt – Dry wgt}}{\text{Dry wgt}} \times 100$ **... 3.1**

3.3 Hollow core Water Absorption Test

The results are tabulated in Table 3.2. This water absorption was quite good in agreement with the conventional Water Absorption Test as discussed before.

3.4 Chemical Resistance Test

The observations were made after 9 days, 20 days, 35 days and 45 days and are discussed in Table 3.3.The best

chemical resistant coatings were selected based on passing of the specimens from all five media.

Table 3.1: Determination of Rate of water absorption

Specimen No.	Dry Weight (in g)	Saturated Weight (in g)	Rate of Water Absorption (in %)
Uncoated	108.78	119.07	9.46
1	134.68	139.85	3.84
2	129.08	133.82	3.67
3	159.08	161.74	1.67
4	148.04	151.53	2.36
5	107.36	109.90	2.37
6	138.36	146.68	6.01
7	136.82	143.63	4.98
8	127.18	129.86	2.11
9	128.36	129.65	1.03
10	123.64	127.32	2.98
11	151.36	153.06	1.12
12	142.66	144.27	1.13
13	118.10	124.02	5.01
14	123.38	126.88	2.84
15	139.15	142.10	2.12
16	149.08	156.80	5.18
17	127.20	128.69	1.17
18	129.39	131.95	1.98
19	130.09	132.68	1.99
20	117.89	120.08	1.86
21	104.59	106.70	2.02
22	131.60	138.80	5.47

3.5 Flame Test

The results are tabulated in Table 3.4. From the test, it can be concluded that the best coatings were specimen 11 followed by specimens 9, 10 and 6.

3.6 Field Exposure Study

A periodic examination after 9 days, 20 days, 35 days and 45 days were conducted. Out of 22 coated specimens, the specimens 12 and 14 showed fading of original colour i.e., from slight brownish to yellowish but no chaulking.

Specimens 5 and 6 showed chaulking after 9 days. Same thing continued till the end of 45 days. Slight chaulking was observed on coated surface for the specimens 5, 6, 8, 13, 14, 15, 16, 17 and 18. It can be attributed to the fact that the presence of TiO_2 was not fully bonded with the binder and other admixtures added.

Therefore, specimens 1, 2, 3, 4, 7, 9, 10, 11, 19, 20, 21 and 22 performed well without any change in colour, cracking and other defects.

3.7 Selection of the coating

From the above 5 tests on 22 coatings, Five coatings were selected for further studies. The selected coatings were specimens 7, 9, 10, 11 and 19. These coatings were subjected to Sorptivity and other Corrosion studies such as TAFEL Extrapolation, Chloride Diffusion and Impressed Voltage test.

Table 3.2: Determination of Quantity of water absorbed

Specimen No.	Total Quantity of Water Poured (in ml)	Cumulative Quantity of Water Absorbed (in ml)									
		1hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs	7 hrs	8 hrs	24hrs	48hrs
Uncoated	117	11	13	17	20	21	24	25	30	51	75
1	53	1	2	2	4	4	4	4	5	8	12
2	48	2	2	2	4	4	4	4	5	8	12
3	51	3	3	3	7	7	7	7	9	10	13
4	50	1	1	1	3	3	3	3	4	6	9
5	49	1	1	1	4	4	4	4	5	7	10
6	102	1	1	1	2	2	2	2	4	34	67
7	51	0	0	0	2	2	2	2	3	7	10
8	45	1	1	1	3	3	3	3	4	6	10
9	41	1	1	1	2	2	2	2	4	5	8
10	53	3	3	3	5	5	5	5	7	10	15
11	42	1	1	1	4	4	4	4	5	6	11
12	45	1	1	1	4	4	4	4	6	7	12
13	50	0	0	0	2	2	2	2	3	7	11
14	51	1	1	1	3	3	3	3	5	8	14
15	55	1	1	1	4	4	4	4	5	7	16
16	53	1	1	1	3	3	3	3	5	9	15
17	48	1	1	1	3	3	3	3	4	5	11
18	51	1	1	1	3	3	3	3	4	6	10
19	48	1	1	1	1	1	1	1	2	3	8
20	49	1	1	1	2	2	2	2	3	5	11
21	49	0	0	0	1	1	1	1	3	6	10
22	73	1	1	1	3	3	3	3	5	23	33

Table 3.4: Results of Chemical resistance Test

Specimen No.	Time Taken For Charring (in sec)	Charred Core Diameter(in mm)	Flame Influence Diameter (in mm)
Uncoated	15	16	35
1	40	29	35
2	34	29	31
3	20	27	36
4	44	24	29
5	75	29	35
6	115	16	29
7	135	21	33
8	38	21	29
9	121	15	26
10	158	18	31
11	229	13	20
12	105	21	27
13	44	18	24
14	18	24	35
15	32	24	30
16	76	20	27
17	64	22	30
18	57	19	22
19	126	19	32
20	100	24	33
21	52	23	28
22	19	26	30

was. From the test, it can be concluded that the specimen 9 was found to be the best (0.10 g) followed by specimens 7 and 19. Specimen 10 absorbed more water (8.00 g)
Table 3.4 Properties of Flame exposed specimens

Table 3.5 Determination of coefficient of water absorption

Name	Initial Mass at t = 0 min (in g)	Mass After Capillary Suction at t = 60 min (in g)	Quantity of Water Absorbed Q (in g)	Co-efficient of Water Absorption K_a (in mm^2/sec)
Control	299.30	307.93	8.63	5.37 E^{-9}
7	284.94	285.05	0.11	8.72 E^{-13}
9	293.03	293.13	0.10	7.21 E^{-13}
10	281.80	289.80	8.00	4.61 E^{-9}
11	287.55	289.04	1.49	1.60 E^{-10}
19	293.30	293.62	0.32	7.38 E^{-12}

3.9 Impressed Voltage Test

The specimen which breaks earlier shows the poor coating. The specimen which sustains for longer duration without cracking will be the best coating. From the test, the Control specimen (Uncoated) broke completely after 3 hours of applied voltage. Other coated specimens remain uncracked even after 100 hours

3.8 Sorptivity Test

Quantity of water observed for all coated specimens comparing uncoated specimen are tabulated in Table 3.5. Lower the quantity of water absorbed, best the specimen

Table 3.4: Results of Chemical resistance Test

45 Days	Surface Itching in Uncoated specimen, Slight Discoloration in specimens 5, 14 and 20, Surface Itching in specimen 15	Surface damage in Uncoated specimen and it appeared like Sand paper, Slight dislargement of Cement particles in specimen 1, Surface scaling in specimens 3 and 4, Blister Formation in specimens 5 and 15 in a few locations.	Uncoated specimen discolored, Slight Discolouration in specimens 2 and 20, Holidays were seen in the surface of specimen 3, Surface Itching in specimen 14, No swelling in other coatings	White patches were formed in Uncoated specimen and specimens 2, 4, 20 and 22	No changes
35 Days	Surface Itching in Uncoated specimen, Slight Discoloration in specimens 5, 14 and 20, Surface Itching in specimen 15	Surface damage in Uncoated specimen and it appeared like Sand paper, Slight dislargement of Cement particles in specimen 1, Surface scaling in specimens 3 and 4, Blister Formation in specimens 5 and 15 in a few locations.	Uncoated specimen discolored, Slight Discolouration in specimens 2 and 20, Holidays were seen in the surface of specimen 3, Surface Itching in specimen 14, No swelling in other coatings	White patches were formed in Uncoated specimen and specimens 2, 4, 20 and 22	No changes
20 Days	Slight Discoloration in specimens 5 and 14, Surface Itching was seen in specimen 15	Slight dislargement of cement particles in specimen 1, Blister Formation in specimens 5 and 15 in a few locations	Holidays were seen in the surface of specimen 3, Surface Itching in specimen 14	No changes	No changes
9 Days	Slight Discoloration in specimens 5 and 14, Surface Itching in specimen 15	Slight Dislargement of Cement particles in specimen 1, Blister Formation in specimens 5 and 15 at few locations	Holidays were seen in the surface of specimen 3, Surface Itching in specimen 14	No changes	No changes
Medium	HCl	H_2SO_4	$MgSO_4$	Urea	Distilled water

3.10 Chloride Ion Diffusivity Test

In this test, all the one side coated specimens were placed in the cells. The coated surface was immersed in NaCl solution. The coating will act as a membrane to prevent the diffusion of Chlorides. The charge passed (Coulombs) was computed using Eqs. 3.2 as per the expression given in ASTM 1202 and presented in Table 3.6.

$$Q_x = 900 \ [I_0 + 2I_{30} + 2I_{60} + 2I_{90} + \ldots + 2I_{330} + I_{360}] \qquad \ldots 3.2$$

All the coated specimens showed very low values. The minimum value of 190 Coulombs for specimen 9 was obtained as against the Control's value of 2609 Coulombs.

Table 3.6: Results of Chloride diffusion test

Specimen No.	*Charge Passed, Q_x (in Coulombs)*	*Ranking As Per ASTM C1202*
Uncoated	2609	Moderate
7	213	Very Low
9	190	Very Low
10	321	Very Low
11	307	Very Low
19	276	Very Low

3.11 Tafel Extrapolation Techniques

The tests were conducted on 0th day, 5th day, 10th day, 14th day, 20th day and 25th day lastly. The experiment was terminated when a stable Corrosion rate was obtained on 25th day. Experimental setup was shown in Fig. 3.1. On 0th day, the Corrosion density and Corrosion rate were high for Control specimen. Corrosion rate was progressively high for Control till 25th day and it reached 3.813 mm/yr on 25th day. By going through carefully with period, it was observed that till 10th day, the readings were fluctuated showing that the system was not stable enough. Beyond these periods, the readings were almost following some sequences and are tabulated in Table 3.7 and 3.8.

Figure 3.1: Tafel Extrapolation Test setup

4. Conclusion

- In Water Absorption Test, the Lowest water absorption was found in specimen 9 followed by specimens 11, 12 and 7 whereas the Highest water absorption was obtained for coated specimen 7 (4.98 %) and Control specimen (9.46 %).
- In Hollow core Water Absorption Test, this water absorption was quite good in agreement with the conventional Water Absorption Test as discussed before.
- In Chemical resistance Test, some specimens passed through surface defects such as color change, shrinkage, bulkage, cracking, twisting, edge cracking, dissolution of specimens, etc.
- In Flame Test, the uncoated specimen showed earlier formation of charring (in 15 secs) with large diameter. The specimens coated with Al_2O_3 and Kaolin (6, 9, 10, 11, and 19) showed delayed char formation (in 229 secs) with small charred diameters.

Table 3.7: Rates of Corrosion (mm/yr) for coated specimens

Specimen No.	Corrosion Rate (mm/yr)					
	0th Day	5th Day	10th Day	14th Day	20th Day	25th Day
Control	6.055×10^{-1}	5.516×10^{-1}	1.128×10^{-0}	1.862×10^{-0}	3.014×10^{-0}	3.813×10^{-0}
7	4.997×10^{-2}	4.010×10^{-2}	5.309×10^{-1}	4.911×10^{-1}	3.222×10^{-1}	2.917×10^{-1}
9	7.095×10^{-2}	6.923×10^{-2}	1.114×10^{-2}	0.891×10^{-2}	0.619×10^{-2}	0.431×10^{-2}
10	1.479×10^{-2}	2.355×10^{-2}	4.466×10^{-2}	3.893×10^{-2}	3.214×10^{-2}	3.110×10^{-2}
11	1.420×10^{-2}	2.020×10^{-2}	4.925×10^{-2}	3.894×10^{-2}	3.114×10^{-2}	3.719×10^{-2}
19	4.608×10^{-2}	4.985×10^{-2}	3.095×10^{-2}	3.110×10^{-2}	3.070×10^{-2}	3.610×10^{-2}

Table 3.8: Corrosion Density (A/cm^2) for coated specimens

Specimen No.	Corrosion Density (A/cm^2)					
	0th Day	5th Day	10th Day	14th Day	20th Day	25th Day
Control	1.851×10^{-4}	1.686×10^{-4}	3.447×10^{-4}	1.118×10^{-4}	3.427×10^{-4}	1.671×10^{-4}
7	1.527×10^{-5}	1.934×10^{-5}	1.623×10^{-5}	1.532×10^{-5}	1.213×10^{-5}	3.410×10^{-5}
9	2.168×10^{-5}	1.903×10^{-5}	2.010×10^{-5}	1.312×10^{-5}	1.432×10^{-5}	2.280×10^{-6}
10	4.522×10^{-6}	7.198×10^{-6}	1.365×10^{-5}	5.381×10^{-6}	1.087×10^{-5}	4.922×10^{-6}
11	4.339×10^{-6}	6.173×10^{-6}	1.505×10^{-5}	3.935×10^{-6}	1.780×10^{-5}	4.664×10^{-6}
19	1.408×10^{-5}	1.524×10^{-5}	9.460×10^{-6}	1.872×10^{-5}	2.693×10^{-5}	1.022×10^{-5}

- In Field Exposure Study, specimens 1, 2, 3, 4, 7, 9, 10, 11, 19, 20, 21 and 22 performed well without any change in colour, cracking and other defects.
- From the results of the above 5 tests, five coatings (7, 9, 10, 11 and 19) were selected as best coatings and carried for further corrosion tests.
- In Sorptivity Test, it can be concluded that the specimen 9 was found to be the best followed by specimens 7 and 19, with less quantity of water absorbed through capillary pores.
- In Chloride Diffusivity Test, all the coated specimens showed very low values. The minimum value of 190 Coulombs for specimen 9 was obtained as against the Control's value of 2609 Coulombs.
- In Impressed Voltage Test, the Control specimen (Uncoated) broke completely after 3 hours of applied voltage. Other coated specimens remain uncracked even after 100 hours.
- In Tafel Extrapolation Technique, specimen 9 was found to be the best among other coatings with Current density of 2.28×10^{-6} A/cm^2 and corresponding Corrosion rate of 0.431×10^{-2} mm/yr.

References

[1] Rasheeduzzafar, Dakhil, F. H., and Al-Gahtani, A. S. (1985). "Corrosion of reinforcement in concrete structures in the Middle East." *Concrete Int.: Des. and Constr.*, 7(9), 48 – 55.

[2] Mohammed Ibrahim, Al-Gahtani, A. S., Mohammed Maslehuddin and Dakhil, F. H. (1999). "Use of Surface Treatment Materials to improve Concrete Durability." *J. Mater. Civ. Eng.*, 11(1), 36 – 40.

[3] Cabrera, J. G., and Hassan, K. G. (1990). "The effect of polymeric surface treatment compounds on the water absorption and chloride diffusion of concrete exposed to hot dry environments." *Protection of concrete*, R. K Dhir and J. W. Green, eds., E & FN Spon, London, 697 – 715.

[4] Fukute, T., and Hamada, H. (1990). "Surface coatings for improving performance of concrete under marine environments." *Protection of concrete*, R. K. Dhir and J. W. Green, eds., E & FN Spon, London, 317 – 330.

[5] Kamal, M. M., and Salama, A. E. (1990). "Protection of reinforced concrete elements against corrosion by polymer coating." *Protection of concrete*, R. K. Dhir and J. W. Green, eds., E & FN Spon, London, 281 – 291.

[6] Katawaki, K. (1990). "Recent developments of protection techniques for concrete structures in Japan." *Protection of concrete*, R. K. Dhir and J. W. Green, eds., E & FN Spon, London, 355 – 366.

[7] Leeming, M. (1990). "Surface treatments for the protection of concrete." *Protection of concrete*, R. K. Dhir and J. W. Green, eds., E & FN Spon, London, 135 – 148.

[8] Maslehuddin, M., Rasheeduzzafar, Al-Amoudi, O. S. B., and Al-Mana, A. I. (1994). "Performance of concrete in a very aggressive environment.' *ACI Special Publication, SP – 144*, American Concrete Institute, Detroit, 191 – 211.

[9] Rasheeduzzafar, Dakhil, F. H., and Al-Gahtani, A. S. (1984). "Deterioration of concrete structures in the environment of Middle East." *ACI J. Proc.*, 81(1), 13 – 20.