

CONCRETE COATING USING GREENER MATERIAL POLYURETHANE AND LATEX



Engineering

KEYWORDS: Polyurethane; Latex

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ABSTRACT

The main purpose of this work is to develop protective coating to concrete structures against various actions such as alkali-silica reaction, leaching, thermal and moisture movements, carbonation, chloride ingress, sulphate attack and also by cracking of concrete. The prepared compositions of concrete coating are applied on concrete elements such as cylinder, circular disc, tiles (both small tiles and big tiles). Two different types of binders such as Polyurethane (water soluble, single carbonate system) and Latex was used for effective coating. To evaluate the performance of coating, various tests such as abrasion, chloride ion penetration, water absorption, flame test, heat resistance test, chemical immersion test etc were carried out. The results were analyzed focusing on the resistance of the best coatings.

Introduction

The durability of the concrete mainly depends on the factor quality and a good quality concrete is definitely a durable concrete. The durability can generally be increased by proper choosing of materials, proportioning, proper placing and proper curing of the structure. Typically concrete with higher strength and lower permeability is more durable. There is another method for increasing the durability of the concrete and that is the coating. Concrete coatings can provide decoration, dust reduction, water proofing, improved surface release properties, enhanced slip resistance, cleaning ability, protection against reinforcement corrosion due to carbonation and chloride ingress as well as resistance to chemical attack. Also it protects from damage caused by frost, abrasion, mechanical stress, salt penetration, water and from solar heat.

Also the coatings provided will prevent the deterioration of concrete due to the alkali-silica reaction, leaching, thermal and moisture movements, carbonation, chloride ingress, sulphate attack and also by cracking of concrete.

There are various materials available for concrete coating. Some of them are epoxies, epoxy phenolics, aggregate filled epoxies, silicones, silanes, cementitious coatings, epoxy polyesters, chlorinated rubbers, and thick filled elastomers etc. These coatings are suggested for certain service conditions such as severe chemical, moderate physical and severe physical conditions, water repellency, clean ability, aesthetics etc. Also to repair concrete in aggressive environments an elastomeric membrane coated with inorganic cement can be mechanically added to the substrate with studs.

In this paper, two types of materials namely Polyurethane and Latex were chosen as binders which are less polluted material to the environment. 19 types of coatings were prepared, compared and tested for best performance. The attempt in this work is to observe the behavior of the concrete coatings in addition to evaluate the resistance of these coatings against various conditions and recognize the best coatings in that regard.

Materials and Methods

Materials used For this study, water soluble Polyurethane (product of Asian paint) and water proofing latex purchased from Madurai were used as binders. The functional filler materials such as fly ash, OPC, Feldspar, High Alumina Clay, Kaolin, Micro silica, Black Clay, Zirconium dioxide were purchased locally. The chemical components like Al₂O₃, TiO₂, Silica Fume were procured from Himeda company which are LR grade. The concrete specimens used for various tests are Big Tiles of size 230 × 230 × 20mm, Small Tiles of size 100mm × 100mm × 10mm, disc of size 80mm diameter and 40mm length and small cylinder of size 100mm length and 40mm diameter.

Test specimens

The cylindrical specimen of size 100mm length and 40mm diameter were utilized to evaluate the water absorption capacity of the concrete coating shown in fig 1. The circular disc of dimension 80mm diameter and 40mm length were used to determine the chloride ion penetration into the coated specimen. Small Tiles of Dimension 100 X 100 X 10mm were used to determine the chemical resistance, fire resistance, abrasion resisting capacity of the coating. Big Tiles of dimension 230 X 230 X 20 mm were used to determine the heat resisting capacity of the coating.

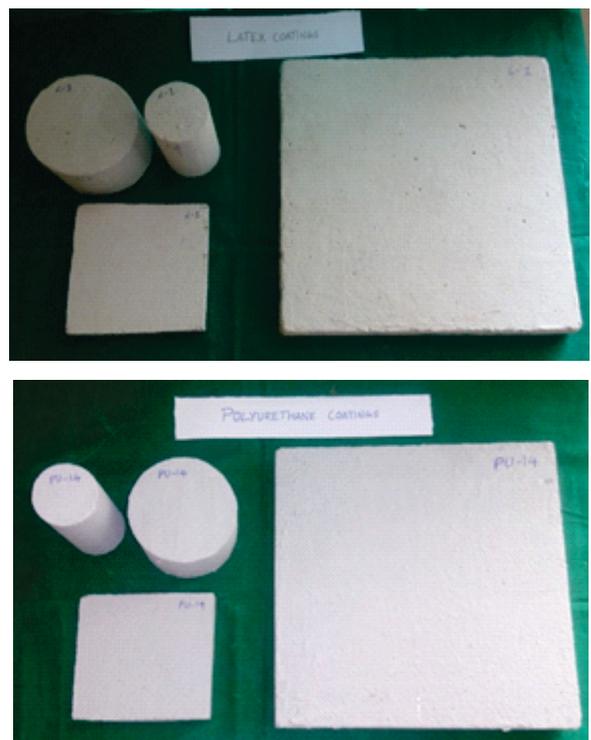


Fig.1. Test Specimens with Latex coating and Polyurethane Coating

Coatings used

The different types of coating system are prescribed in the table 1. After the concrete specimens have been cured for 28 days and dried for several days in the open sky (until it is completely dry), the surface was applied with the coatings twice (the second coating being applied after the first coating is completely dry).

Table 1 Compositions of Different Coating systems

Coating No.	Materials Used
1	Latex + Fly Ash + Al ₂ O ₃ + TiO ₂ + Silica Fume
2	Latex + Micro Silica + Common
3	Latex + Feldspar + Common
4	Latex + High Alumina Clay + Common
5	Latex + Fly Ash + Micro Silica + Common
6	Latex + Fly Ash + Zirconium dioxide + Common
7	Latex + Fly Ash + Clay + Common
8	Latex + Fly Ash + Micro Silica + Clay + Zirconium dioxide + Common
9	Latex + Fly Ash + Micro Silica + Clay + Common
10	Latex + Fly Ash + Feldspar + Common
11	Latex + Fly Ash + Kaolin + Common
12	Latex + Black Clay+ Common
13	Latex + Kaolin + Common
14	Polyurethane + Fly Ash + Micro Silica + Common
15	Polyurethane + Fly Ash + Feldspar + Common
16	Polyurethane + Fly Ash + Zirconium dioxide + Common
17	Polyurethane + Micro Silica + Common
18	Latex + OPC + Fly Ash + Feldspar + High Alumina Clay + Common
19	Latex + OPC + Micro Silica + Feldspar + High Alumina Clay + Common
* Common = Al ₂ O ₃ + TiO ₂ + Silica Fume	

Testing

Chloride Ion Penetration Test (ASTM C 1202)

The chloride ion penetration test covers the determination of the electrical conductance of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. The test method consists of monitoring the amount of electrical current passed through 40mm length and 80mm diameter disc specimens during 6 hours period. A potential difference of 60 volt direct current is maintained across the ends of the specimen, one of which is immersed in a 3% Sodium Chloride solutions and the other in 0.1 M Sodium Hydroxide solution.

he total charge passed in coulombs, has been found to be related to the resistance of the specimen to chloride ion penetration. The cell containing 3% NaCl solution will be connected to the negative terminal of the power supply, the other cell containing 0.1M NaOH shall be connected to the positive terminal of the power supply. After fixing the specimen within the cell, solutions are filled in the cell and 60 volt direct current is applied. At the time the test is initiated that is, when the power supply is turned on, the initial current is measured with the ammeter. After every 30 minutes till the completion of 6 hours, the current is monitored and recorded in each cell. The charge passed can also be computed by using trapezoidal rule. The charge passed is expressed in coulombs (1 coulombs is 1 ampere second).

$$Q=900[I_0+2(I_{30}+I_{60}+\dots+I_{300})+I_{360}]$$

Where

Q= Charge Passed (coulombs)

I₀= Current (amperes) immediately after voltage is applied

I_t= Current (amperes) at t minute after voltage is applied.

The measured charge is corrected by multiplying the value obtained from the above ratio of the cross sectional area of the standard and actual specimens i.e.

$$Q_s=QX(3.75/X)^2$$

Where,

Q_s= Charge passed (coulombs) through 3.75 inch (95mm) diameter

Q = Charge passed (coulombs) through y inch diameter specimen

X = Diameter of the standard specimen.



Fig.2.Chloride Ion Penetration Test Setup

Depending upon the charge passed through the specimen, the permeability characteristics can be stated. The table below gives the relationship between charge passed and chloride ion permeability.

Sl.No	Charge Passed	Chloride Ion Permeability
1	>4000 C	High
2	2000-4000 C	Moderate
3	1000-2000 C	Low
4	100-1000 C	Very Low
5	<100 C	Negligible

This is about Chloride ion penetration Test.

Water Absorption Test

For the determination of water absorption of the coated samples, specimen of size 40mm diameter and 100mm length were used. Before immersion of the coated sample in the water, the coated weight of the specimen is measured. The specimen is immersed in water for a period of 48 hours as shown in Fig.3. In this test, the mass of water absorbed by the coated mass of specimen gives the capacity of water absorption. It's normally expressed in percentage.

$$\text{Percentage of Water Absorption} = (B-A/A)X100$$

Where,

A = Mass of the Coated sample

B = Mass of the saturated sample

Heat Resistance Test

This test was carried out in a muffle Furnace with top loading attached with temperature Indicator and thermocouple as shown in Fig 4. The constant temperature ranges such as 75°C, 100°C and 150°C was arbitrarily chosen for this study. The tile to be tested will be placed horizontally over the top of the furnace and the temperature will be set by adding the knob, located in digital temperature indicator. Initially the set temperature of 75°C will be for a period of 30minutes. Now the bottom phase of the tile is exposed to the set temperature for 20minutes. Using laser Torch thermometer, the temperature of the bottom surface and top surface are measured and recorded.

This is then carried out for 100°C and 150°C set temperature with a soaking period of 15minutes. This test has been carried out for 230 X 230 X 20mm thick tiles for all coated mixes. The corresponding temperatures and temperature drops are recorded separately for all category of proposed coating.

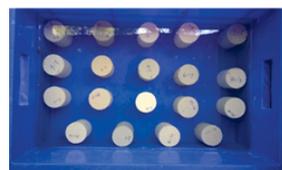


Fig.3.Water Absorption Test

Fig.4.Tiles placed in Muffle Furnace

Abrasion Test

The specimen of size 100mm × 100mm × 10mm was used for abrasion

test. Firstly, the coated specimen weight was measured and later it was scribed by using E4 320 emery sheet. After the abrasion, the specimen was weighted to determine the weight loss and thickness loss of the coating.

Fire Endurance Limit Test

The cement mortar tiles with different compositions of coating have its own rate of cracking potential. The cracking potential and the influence area due to flame exposure over the material were experimentally investigated using an accelerated flame torch designed and fabricated at CSIR-CECRI. Flame torch is held on the tiles of dimensions 100 x 100x 10 mm. The flame intensity exposed over the tile was maintained uniformly throughout the test period until the surface crack emerges out visibly. Also other visual monitoring such as pop outs, discoloration, charring, disintegration, delaminating, etc. is examined on the tile surface. The time taken for any damage to occur is called as the "Endurance Limit". This limiting value will vary based on various coating compositions. Higher the duration to cause any surface damage, the best is the coating composition against flame.



Fig.5.Flame being exposed over Tiles



Fig.6.Temperature measuring using Laser Torch

Chemical Resistance Test

The relative acid attack was determined in accordance with ASTM C267-97. The cement mortar tiles of dimension 100X 100 X 10 mm were cured in water at 28 Days before being subjected to acid attack. Nineteen composition of specimens were immersed in seven types of chemical solutions such as 0.5% of hydro chloric acid, 0.5% of sulfuric acid, 0.5% of nitric acid, 0.5% of lactic acid, 0.25M of calcium sulphate, 0.10M of Urea and 0.25M of sodium hydroxide. After immersing, the appearance of the specimen was visualized at each 5 days till 20 days to inspect any color changes, volume increase and micro cracks to 7 happen in the specimen. Visual inspection Figures are shown in Fig.7.



Sulphuric Acid



Hydrochloric Acid



Nitric Acid



Calcium Sulphate



Sodium Hydroxide



Urea

Fig.7.Immersion of Coated Specimens in various Chemicals Results and Discussion

The Table 1 shows the composition of various mixes for coating and the total coatings are evaluated for protection of concrete in aggressive medium. It compasses on nineteen coatings with polyurethane and latex as a binder. Following are the results that are used to evaluate its protection in normal and aggressive environments. Each test results are shown in Tables below.

Chloride Ion Penetration Test (ASTM C 1202)

This test was conducted on all the nineteen coated circular disc specimens and also on control specimen. The circular disc was coated on the circumference and on one side of the disc leaving the other side uncoated. The coated side is attached to the cell connected to the negative terminal containing 3% NaCl and the uncoated side is attached to the cell connected to the positive terminal containing 0.1M NaOH. This test is carried out for 6 hours and the charge passed was measured at every 30mins from the zero minute and it is indicated as I₀, I₃₀, I₆₀, I₉₀, I₁₂₀, I₁₅₀, I₁₈₀, I₂₁₀, I₂₄₀, I₂₇₀, I₃₀₀, I₃₃₀ and I₃₆₀. This value of charge passed is corrected by multiplying this value from the ratio of the cross sectional area of the standard and actual specimens and that is given in table².

Of the nineteen coated specimens, Latex combined with micro silica coated specimen exposed the higher chloride ion penetration value and all other coated specimens exposed low and very low chloride ion permeability values.

Water Absorption Test

This test was conducted for nearly 48 hours in cylindrical coated specimens and it is checked for swelling, peeling off, distortion, delaminating etc in the coated specimens. But there were no such indications in the specimens and all the specimens are found to perform well in water. Also the percentage of water absorption was found to be higher for L1, L3, and L12 designated specimen i.e. latex combinations with fly ash, feldspar and black clay.

Heat Resistance Test

This test was carried out in muffle furnace at 75 °C, 100 °C, 150°C. Here the temperature is measured at both top and bottom faces using laser torch and the temperature drop is calculated. The temperature drop was higher in the case of latex coatings compared to polyurethane coatings

Abrasion Test

In this test, the weight loss due to abrasion is determined and the results are shown in table 4. Weight loss of latex coating showed lesser value compared to polyurethane coating.

Flame Test

In this test, all the samples are exposed to flame and its resistance against flame is tested. The diameter of the ignition point is found to increase in all the cases and in some cases it is found to be very high and it is found to be failure. Latex specimen is found to withstand the ignition for a long time when compared to polyurethane specimens and its diameter is also to found to be lesser than polyurethane specimens.

Table 2 Chloride Ion Penetration Test (ASTM C 1202)

Designation	I0	I30	I60	I90	I120	I150	I180	I210	I240	I270	I300	I330	I360
	0	30	60	90	120	150	180	210	240	270	300	330	360
	mins	Mins	Min	min	min	Min	min	min	min	min	min	min	min
L1	0.0	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
L2	0.0	0.142	0.168	0.18	0.20	0.22	0.23	0.24	0.25	0.26	0.26	0.26	0.24
	98			9	4	1	7	9	7	2	2	6	8

L3	0.0	0.019	0.021	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04
	16			3	5	8	0	2	4	6	9	2	3
L4	0.0	0.017	0.020	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
	11			1	3	5	6	7	9	0	1	2	3
L5	0.0	0.018	0.021	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04
	14			3	4	6	9	0	3	4	6	8	0
L6	0.0	0.013	0.015	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
	08			6	7	8	9	0	1	2	3	4	5
L7	0.0	0.009	0.011	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
	08			2	4	5	8	8	0	1	3	4	5
L8	0.0	0.019	0.023	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.07	0.09	0.09
	16			6	1	4	4	0	8	6	9	2	7
L9	0.0	0.031	0.044	0.05	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.12
	14			2	9	2	3	6	4	0	3	2	1
L10	0.0	0.007	0.008	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	06			9	0	1	5	5	4	5	5	5	6
L11	0.0	0.009	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
	09			1	2	3	3	5	7	8	9	9	0
L12	0.0	0.005	0.007	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	03			8	9	0	1	3	4	4	4	4	5
L13	0.0	0.007	0.016	0.03	0.04	0.06	0.07	0.08	0.09	0.09	0.10	0.10	0.10
	04			3	7	1	3	2	2	7	0	1	0
PU1	0.0	0.004	0.005	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
	03			6	7	8	9	0	1	1	1	2	2
PU1	0.0	0.012	0.013	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.00	0.02
	05			5	1	8	0	2	1	4	5	6	7
PU1	0.0	0.007	0.010	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.05
	06			4	7	1	6	1	4	9	3	9	2
PU1	0.0	0.006	0.007	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	04			9	9	0	1	3	4	4	4	5	5
CL1	0.0	0.004	0.005	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
	02			6	7	7	8	9	9	0	1	1	3
CL1	0.0	0.003	0.005	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
	09			5	7	8	8	9	0	1	3	3	5

Designation	Charge Passed in coulombs	Chloride Ion permeability	Designation	Charge Passed in coulombs	Chloride Ion permeability
Control	332.42	Very Low	L10	336.13	Very Low
L1	367.21	Very Low	L11	394.8	Very Low
L2	6055.33	High	L12	294.69	Very Low
L3	825.37	Very Low	L13	1754.3	Low
L4	805.80	Very Low	PU14	233.68	Very Low
L5	780.47	Very Low	PU15	541.03	Very Low
L6	516.8	Very Low	PU16	1274.32	Low
L7	459.3	Very Low	PU17	302.75	Very Low
L8	1331.8	Low	CL18	217.56	Very Low
L9	1965.01	Low	CL19	227.92	Very Low

Table 3 Testing for the Heat Resistance of the Coated Tiles

Sl.No	Designation	30 minutes(75°C)		15 minutes(100°C)		15 minutes(150°C)		Swing for 75°C	Swing for 100°C	Swing for 150°C
		Top	Bottom	Top	Bottom	Top	Bottom			
1	Control	57.4	58.2	69.1	72.1	98.3	104.3	0.8	3.0	6.2
2	L1	56.6	60.8	63.6	68.7	89.2	96.7	4.2	5.1	7.5
3	L2	52.6	57.8	68.4	74.1	91.8	98.7	5.2	5.7	6.9
4	L3	52.4	57.3	60.3	65.8	74.3	87.6	4.9	5.5	13.3
5	L4	57.6	62.4	72.3	80.2	92.7	99.8	4.8	7.9	7.1
6	L5	51.7	54.6	56.0	58.6	74.8	85.2	2.9	2.6	10.4
7	L6	70.1	74.6	74.9	79.2	84.3	89.5	4.5	4.3	5.2
8	L7	62.4	67.4	70.3	76.6	79.6	91.4	5.0	6.3	11.8
9	L8	53.1	55.4	65.2	73.9	80.8	92.3	2.3	8.7	11.5
10	L9	52.7	56.2	65.3	70.9	76.4	90.4	3.5	5.6	1.4
11	L10	57.9	60.8	60.3	65.7	75.3	84.7	2.9	5.4	9.4
12	L11	52.8	56.1	62.3	68.4	80.1	90.8	3.4	6.1	10.7
13	L12	60	62.9	70.6	75.2	86.2	106.4	2.9	4.6	20.2
14	L13	63.4	66.1	73.9	77.1	88.0	94.8	2.7	3.2	6.8
15	PU14	50.5	54.7	63.6	79.5	81.0	108.8	4.2	15.9	27.8
16	PU15	52.5	54.8	61.9	65.7	82.3	90.1	2.3	3.8	7.8
17	PU16	54.6	56.3	67.7	71.6	91.2	96.4	1.7	3.9	5.2
18	PU17	53.9	56.7	63.4	67.5	84.0	93.3	2.9	4.1	9.3
19	CL18	53.0	54.9	64.0	67.7	84.3	87.0	1.9	3.7	2.7
20	CL19	58.4	60.4	65.5	68.9	91.9	103.8	2.0	3.4	11.9

Sl. No	Designation	Initial Weight(g)	Final Weight(g)	Loss of Weight(g)	Loss of Weight (mg)
1	L1	274	273.90	0.1	10
2	L2	298.97	298.90	0.07	70
3	L3	292.21	292.20	0.01	10
4	L4	266	265.97	0.03	30
5	L5	251.79	251.76	0.03	30
6	L6	262.21	262.20	0.01	10
7	L7	234.60	234.59	0.01	10
8	L8	285.81	285.78	0.03	30
9	L9	304.13	304.10	0.03	30
10	L10	248.02	248.01	0.01	10
11	L11	258.55	258.51	0.04	40
12	L12	282.62	282.61	0.01	10
13	L13	250.15	250.13	0.02	20
14	PU14	277.63	277.61	0.02	20
15	PU15	255.84	255.78	0.06	60

16	PU16	270.73	270.70	0.03	30
17	PU17	281.90	281.86	0.04	40
18	CL18	244.16	244.10	0.06	60
19	CL19	312.01	311.98	0.03	30

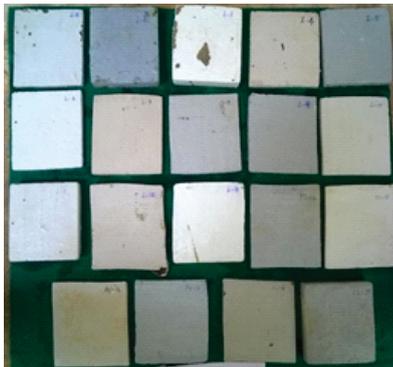
Sl. No	Designation	Dry Weight of the Specimen(g)	Coated Weight of the Specimen(g)	Wet Weight of the Specimen (g)	Water Absorption(%)
1	L1	288.21	290.44	299.62	3.16
2	L2	286.42	294.49	299.06	1.55
3	L3	270.68	274.92	284.01	3.31
4	L4	292.76	300.47	303.82	1.11
5	L5	291.33	296.78	302.52	1.93
6	L6	290.66	301.19	304.24	1.01
7	L7	284.96	286.33	290.20	1.35
8	L8	293.47	297.45	301.78	1.45
9	L9	286.24	295.67	300.66	1.68

10	L10	290.74	299.01	302.80	1.27
11	L11	285.68	289.22	295.29	2.09
12	L12	289.76	294.27	303.86	3.25
13	L13	292.52	299.93	304.05	1.37
14	PU14	286.73	293.82	296.74	0.99
15	PU15	294.86	303.08	306.17	1.01
16	PU16	290.56	298.37	301.81	1.15
17	PU17	279.82	284.31	288.01	1.30
18	CL18	294.96	305.62	309.77	1.35
19	CL19	284.14	291.21	293.21	0.68

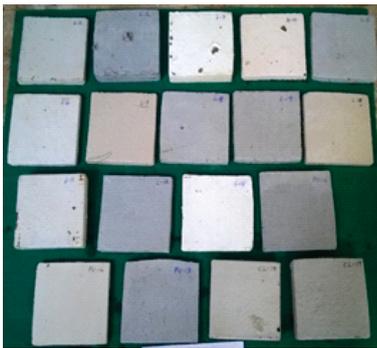
Chemical Immersion Test

The specimens are immersed in seven different chemicals for nearly 25 days and it is visually inspected after each 5 days from the zeroth day for any delamination, decolorization, any other chemical effects etc. The affected samples are shown below

Visual Inspection of Immersed Specimens after 25 days



Urea



Calcium Sulphate



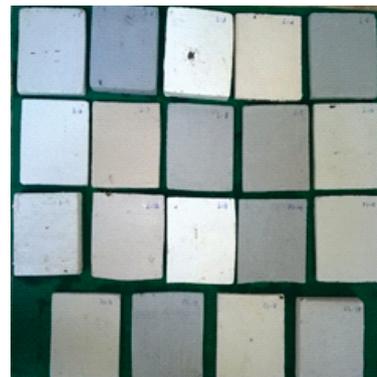
Sulphuric Acid



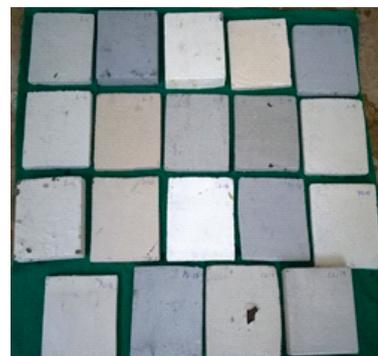
Nitric Acid

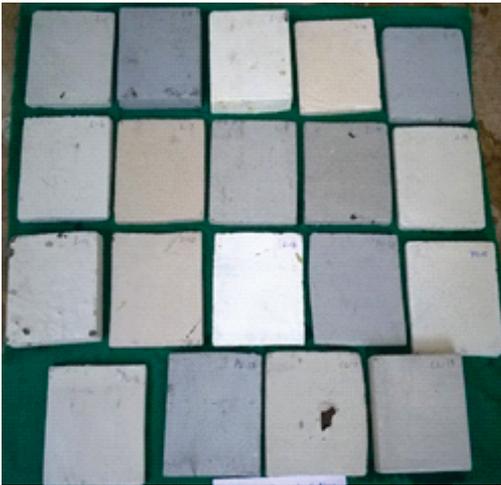


Hydrochloric Acid



Lactic Acid





Sodium Hydroxide

Conclusion

- On the basis of results presented in this paper, the following conclusions have been drawn
- From all the above test results, these coatings are found to be resistant against various chemical and other environmental effects. Among these, the best coating is found to be .
- Also the coatings developed are found to be eco-friendly and it does not pollute the environment.
- These Polymer based polyurethane and latex also being applied on steels provide a very effective protection against corrosion as a result of the combination of excellent adhesion to metal substrates and barrier properties.

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