Analysis Of Corrosion Inhibitors On Reinforced Steel For Different Concrete Grades.

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Abstract - *In this paper it represents the experimental results of that the surface application of the organic and inorganic corrosion inhibitors which do increase the efficiency of resistance from corrosion to reinforced concrete steel structure with help of further increase of grade of concrete. In the result analysis, it is observed that the control specimen i.e., without any application of corrosion inhibitors doesn't provide any resistance to corrosion. While among the organic and inorganic corrosion inhibitors the organic (Neem Powder) provided the highest efficiency to corrosion inhibition in comparison to inorganic (Zinc powder). As per all the above tests conducted and their results achieved it is to concluded that the organic and inorganic corrosion inhibitors with reference to the used grade of concrete can provide an efficient resistance to corrosion inhibition in reinforced steel in various structures like RCC, Buildings, Bridges, Commercial buildings, Girders, piers, abutments etc. In can be used in various harsh environment conditions and in cost efficient way subjected to grade of concrete.*

***Key Words*: Corrosion 1, Inhibitors 2, Organic 3, Inorganic 4, Zinc 5, Neem 6.**

1.INTRODUCTION

As per NACE international (National Association of Corrosion Engineers), "a corrosion inhibitor is a substance when added to an environment, either continuously or intermittently to prevent corrosion by forming a passive film on the metal." In other processing industries, inhibitors are the first line of defense against corrosion.

The use of corrosion inhibitors can delay the onset of chloride-induced corrosion, prolong the time to initiation of corrosion, and thereby reduce the corrosion rate. Calcium nitrite is the most commonly used anodic corrosion inhibitor for reinforced concrete. This inhibitor is a passivating inhibitor, which forms a passive film on the surface of steel and significantly reduces the corrosion rate of steel in chloride contaminated concrete. Recently, organic inhibitors gained more attraction in the construction industry due to their promising application as admixtures in reinforced concrete with improved protection efficiency and low cost. Organic inhibitors are used as an admixed corrosion inhibitor or migrating corrosion inhibitors (MCI). Migrating inhibitors are also called as surface applied inhibitors. Both admixed and migrating corrosion inhibitors prevent steel corrosion by forming a thin layer of protective barrier film on the surface of the rebar through adsorption mechanism. Amines and alkanol amines and their salts are used as organic inhibitors in concrete. It has been reported that the alkanol amine-based inhibitors could be able to decrease the corrosion rate of the carbonation induced corrosion effect only for the chloride-induced corrosion of reinforcement. Furthermore, the results indicated that penetrating corrosion inhibitors when applied to the surface of existing or new structures can able to reduce the corrosion rate below 0.1 μ/cm.994. There are various methods of incorporating corrosion inhibitors in concrete. Among the different methods available, the application of surface applied corrosion inhibitors on steel reinforcement bars embedded in concrete is relatively a newer concept. The mechanism of the inhibitoris that it is chemically adsorbed on the surface of the metal and forms a thin protective layer with inhibitor effect or by combination between inhibitor ions and metallic surface.

Previously, there has been whole lot of research on surface-applied corrosion inhibitors (SACI) directly applied to existing concrete structures which has been suffered by corrosion due to mostly chloride attacks. Similarly, many researchers have studied the effect of corrosion inhibitors when directly mixed in the mixing process of fresh concrete. This paper reviews the corrosion inhibitor, corrosion prevention process and the recent advances on the inhibiting effect of various green corrosion inhibitors on steel reinforcement bars embedded in concrete.

1.1 Related Works.

There are many authors who have studied the effects of corrosion inhibitors on reinforced steel, following is the summery of some authors' study. [1] Haleem et al. investigated the pitting corrosion behaviour of phosphates, tungstate, and molybdates in chloride-contaminated Ca (OH) solution and found that pitting corrosion current reaches steady state values, which depend on the way of introducing the inhibiting anions in the solution. Studies revealed that sodium phosphate forms a protective layer on the surface of the steel in chloride-contaminated synthetic concrete pore solution. Besides pretreatment of steel with 0.5 M inhibitor solution for 72 h forms a protective layer which further enhanced the protection efficiency. [2] Ormellese et al. reported that amines and alkanol amines had poor corrosion inhibition effect on steel in chloride containing alkaline solutions. They further observed that polycarboxylates are more efficient against pitting corrosion. Comparison of carboxylates with amines/alkanol amines and amino acids were investigated in the same study, and the results are summarized in Predeferri's diagram showing pitting potential vs. chloride concentration. From the figure, it is evident that amines/alkanol amines had only moderate effectiveness, while carboxylates showed the best behaviour at low and medium chloride levels. It was reported that amines were reported to reduce the compressive strength of cement paste and the reducing effect increased with increasing dosage.

2.METHODOLOGY.

In the present experimental work, the inhibitors were used inthe form of coats applied on the Rebar. The grade of concreteused was M20, M30, M40 and M50. To check the grade of concrete compressive strength of cubes was tested. Further to check the effect of corrosion inhibitors Half-cell potential and Weight loss measurements were carried out. These are the direct methods for checking the rate of corrosion Increase in weightloss shows the degradation of bras. Beam specimens of size 100x100x600mm inserted with 25 mm bars were used. The specimens were cured in normal water for 15 days and for 42 days in saline environment. Half-cell potential readings were taken after an interval of 7 days. Neem powder and Zinc powder were used as inhibitors. Weight loss measurements method is then used to determine the corrosion inhibition on the used steel bars.

2.1 Experimental Work.

In the present research work, five beam moulds of size 100 x 100 x 600 mm for each grade of concrete were fabricated for the casting of specimens. A total of 20 specimens were casted for the experimental procedure for each concrete grade mix i.e., M50, M40, M30 and M20. At the time of casting, the interior of mould is lubricated so that the specimens can be easily removed after 24 hours. Further two mild steel bars are used in each specimen for reinforcement which are weighted on weighing machine for weight loss measurement tests before reinforcing it into the specimens. These two bars of 25mm and length 800mm are then placed in each specimen with a cover of 20 mm from sides and 20 mm cover from the bottom of the mould. After filling the mould with a layer of concrete up to 20 mm, the steel bars are then placed and the rest of the mould is filled to the top with proper compaction. After 24 hours of casting the specimens are carefully removed from the mould. The specimens are then cured in potable water for 15 days. After normal curing period the specimens are shifted to saline tank containing 3.5 % NaCl solution for further curing. This is done so the chloride ions will penetrate the concrete surface reaching for the steel bars thereby initiating corrosion.

The most useful variable measured in corrosion monitoring is the potential of corroding metal i.e., E_{corr}. The difference in voltage between rebar with concrete around it and a reference electrode gives the corrosion potential. Half-cell potentiometer consisting of copper sulphate half-cell as reference electrode is used to monitor the corrosion potential in the present research work. The instrument gives the readings in milli-Volts. Lesser the voltage less will be the corrosion potential and hence the risk of metal getting corroded is less and vice versa. The corrosion potential readings are taken after every 7 dayswhile the specimens are in saline curing. The graphs are shown below present the corrosion potential verses the exposure in days forconcrete specimens with and without coated bars cured in 3.5% NaCl solution. After the testing of half-cell potentiometer on the reinforced concrete beam specimens the reinforced steel bars are then removed with care by breaking each specimen in CTM machine and are cleaned with emery paper for further weight loss measurement tests.

Following are the details below shown in tabular form for the results obtained from the half-cell potentiometer tests done on reinforced steel in concrete beam samples i.e., specimens.

Table -1: M20 grade Control specimens (without coating).

M20			
Nos of Days	Control specimens (mV)		Average
	Bar 1	Bar 2	
7	-98	-100	-99
14	-194	-220	-207
21	-301	-307	-304
28	-411	-424	-417.5
35	-521	-501	-511
42	-602	-599	-600.5

Table -2: M20 grade Neem and Zinc (2 times coating).

M20						
Nos of Days	Neem 2 Coats (mV)		Average	Zinc 2 Coats (mV)		Average
	Bar 1	Bar 2		Bar 1	Bar 1	
7	-100	-98	-99	-228	-230	-229
14	-164	-163	-163.5	-304	-306	-305
21	-211	-206	-208.5	-367	-370	-368.5
28	-258	-254	-256	-450	-451	-450.5
35	-340	-351	-345.5	-509	-510	-509.5
42	-409	-414	-411.5	-592	-595	-593.5

Table -3: M20 grade Neem and Zinc (4 times coating).

M20						
Nos of Days	Neem 4 Coats (mV)		Average	Zinc 4 Coats (mV)		Average
	Bar 1	Bar 2		Bar 1	Bar 1	
7	-98	-97	-97.5	-260	-261	-260.5
14	-141	-143	-142	-334	-331	-332.5
21	-181	-179	-180	-416	-412	-414
28	-229	-231	-230	-446	-448	-447
35	-276	-278	-277	-498	-503	-500.5
42	-334	-333	-333.5	-535	-532	-533.5

Table -4: M30 grade Control specimens (without coating).

M30			
Nos of Days	Control specimens (mV)		Average
	Bar 1	Bar 2	
7	-95	-94	-94.5
14	-111	-118	-114.5
21	-286	-294	-290
28	-377	-382	-379.5
35	-469	-480	-474.5
42	-587	-582	-584.5

Table -5: M30 grade Neem and Zinc (2 times coating).

M30						
Nos of Days	Neem 2 Coats (mV)		Average	Zinc 2 Coats (mV)		Average
	Bar 1	Bar 2		Bar 1	Bar 1	
7	-96	-97	-96.5	-224	-227	-225.5
14	-152	-156	-154	-299	-300	-299.5
21	-201	-209	-205	-351	-354	-352.5
28	-240	-248	-244	-439	-441	-440
35	-311	-310	-310.5	-496	-500	-498
42	-387	-382	-384.5	-571	-575	-573

Table -7: M30 grade Neem and Zinc (4 times coating).

M30						
Nos of Days	Neem 4 Coats (mV)		Average	Zinc 4 Coats (mV)		Average
	Bar 1	Bar 2		Bar 1	Bar 1	
7	-92	-94	-93	-255	-256	-255.5
14	-128	-124	-126	-313	-312	-312.5
21	-177	-175	-176	-403	-400	-401.5
28	-202	-205	-203.5	-431	-429	-430
35	-258	-255	-256.5	-476	-477	-476.5
42	-289	-287	-288	-514	-515	-514.5

Table -8: M40 grade Control specimens (without coating).

M40			
Nos of Days	Control specimens (mV)		Average
	Bar 1	Bar 2	
7	-92	-90	-91
14	-109	-106	-107.5
21	-277	-279	-278
28	-351	-355	-353
35	-483	-491	-487
42	-564	-566	-565

Table -9: M40 grade Neem and Zinc (2 times coating).

M40						
Nos of Days	Neem 2 Coats (mV)		Average	Zinc 2 Coats (mV)		Average
	Bar 1	Bar 2		Bar 1	Bar 1	
7	-94	-92	-93	-211	-214	-212.5
14	-139	-142	-140.5	-272	-274	-273
21	-198	-196	-197	-335	-330	-332.5
28	-230	-231	-230.5	-402	-399	-400.5
35	-299	-300	-299.5	-465	-459	-462
42	-361	-358	-359.5	-555	-550	-552.5

Table -10: M40 grade Neem and Zinc (4 times coating).

M40						
Nos of Days	Neem 4 Coats (mV)		Average	Zinc 4 Coats (mV)		Average
	Bar 1	Bar 2		Bar 1	Bar 1	
7	-88	-90	-89	-236	-238	-237
14	-111	-110	-110.5	-300	-297	-298.5
21	-135	-131	-133	-387	-383	-385
28	-179	-181	-180	-402	-403	-402.5
35	-225	-227	-226	-444	-445	-444.5
42	-267	-265	-266	-500	-505	-502.5

Table -11: M50 grade Control specimens (without coating).

M50			
Nos of Days	Control specimens (mV)		Average
	Bar 1	Bar 2	
7	-88	-90	-89
14	-101	-99	-100
21	-245	-231	-238
28	-312	-306	-309
35	-420	-432	-426
42	-512	-509	-510.5

Table -12: M50 grade Neem and Zinc (2 times coating).

M50						
Nos of Days	Neem 2 Coats (mV)		Average	Zinc 2 Coats (mV)		Average
	Bar 1	Bar 2		Bar 1	Bar 1	
7	-90	-89	-89.5	-201	-200	-200.5
14	-120	-123	-121.5	-246	-250	-248
21	-164	-161	-162.5	-308	-309	-308.5
28	-199	-201	-200	-384	-388	-386
35	-249	-251	-250	-439	-435	-437
42	-293	-288	-290.5	-499	-500	-499.5

Table -13: M50 grade Neem and Zinc (4 times coating).

M50						
Nos of Days	Neem 4 Coats (mV)		Average	Zinc 4 Coats (mV)		Average
	Bar 1	Bar 2		Bar 1	Bar 1	
7	-82	-83	-82.5	-216	-217	-216.5
14	-98	-100	-99	-268	-261	-264.5
21	-122	-125	-123.5	-348	-345	-346.5
28	-159	-161	-160	-387	-390	-388.5
35	-200	-202	-201	-408	-410	-409
42	-240	-236	-238	-461	-458	-459.5

Following are the details below shown in tabular and graphical form for percentage of corrosion Inhibition in specimens.

Table -14: Change in Percentage of Corrosion Inhibition.

Percentage of Corrosion Inhibition						
Grade	Specimens	Control specimen	Neem 2 Coats	Zinc 2 Coats	Neem 4 coats	Zinc 4 coats
M20	Half Cell Potential (42 Days)	-600	-411	-593	-333	-533
	% Change	0	31.5	1.17	44.5	11.17
M30	Half Cell Potential	-584	-384	-573	-288	-514

	(42 Days)					
	% Change	0	34.25	1.88	50.68	11.99
M40	Half Cell Potential (42 Days)	-565	-359	-552	-266	-502
	% Change	0	36.46	2.30	52.92	11.15
M50	Half Cell Potential (42 Days)	-510	-290	-499	-238	-459
	% Change	0	43.14	2.16	53.33	10.00

Following are the details below shown in tabular form for the results obtained from the Weight loss measurement tests done on steel bars before reinforcing and after breaking of concrete beam samples i.e., specimens.

Table -15 Weight loss Measurements of Bars in concrete beam (M20 & M30).

Weight loss Measurements of Bars in concrete beam.				
Bar No.	M20		M30	
	Wt. in grams Before	Wt. in grams After	Wt. in grams Before	Wt. in grams After
Bar1 (Control specimen)	274	273	286	285
Bar2 (Control specimen)	308	307	283	282
Bar1 (Neem 2 Coats)	275	275	269	268.6
Bar2 (Neem 2 Coats)	271	271.5	270	270
Bar3 (Zinc 2 Coats)	289	288.1	299	298.2
Bar4 (Zinc 2 Coats)	290	289.2	280	279.3
Bar5 (Neem 4 coats)	270	270	259	258.8
Bar6 (Neem 4 coats)	282	281.7	267	266.8
Bar7 (Zinc 4 coats)	279	279	266	266.5
Bar8 (Zinc 4 coats)	295	294.5	273	273.6

Table -16 Weight loss Measurements of Bars in concrete beam (M40 & M50).

Weight loss Measurements of Bars in concrete beam.				
Bar No.	M40		M50	
	Wt. in grams Before	Wt. in grams After	Wt. in grams Before	Wt. in grams After
Bar1 (Control specimen)	292	291	292	291
Bar2 (Control specimen)	275	273.9	275	273.9
Bar1 (Neem 2 Coats)	286	285.7	286	285.7
Bar2 (Neem 2 Coats)	274	273.5	274	273.5
Bar3 (Zinc 2 Coats)	276	275.3	276	275.3
Bar4 (Zinc 2 Coats)	280	279.4	280	279.4
Bar5 (Neem 4 coats)	267	267.8	267	267.8
Bar6 (Neem 4 coats)	259	258.7	259	258.7
Bar7 (Zinc 4 coats)	283	283.6	274	273.6
Bar8 (Zinc 4 coats)	295	295	287	286.7

Following are the Figure of material , casting and testing details shown below while conducting the experiment.

Fig -1: Neem powder (green), Zinc powder (grey) and Half-cell Potentiometer instrument

Fig -2: Wooden Concrete beam molds and Casting of Specimens.

Fig -3: Curing in special saline tanks.

Fig -4: Testing of specimens with Half-cell potentiometer.

3. CONCLUSIONS

With reference to the above results and analysis it is to be concluded that the surface application of the organic and inorganic corrosion inhibitors do increase the efficiency of resistance from corrosion to reinforced concrete steel structure with help of further increase of grade of concrete. Therefore, it thus proves that the corrosion inhibitors are the effective way to increase the corrosion inhibition capacity for the required grade of concrete.

In the above result analysis, it is observed that the control specimen i.e., without any application of corrosion inhibitors doesn't provide any resistance to corrosion. While among the organic and inorganic corrosion inhibitors the organic (Neem Powder) provided the highest efficiency to corrosion inhibition. Also, the organic inhibitor (Neem Powder) provided the highest efficiency to corrosion inhibition when applied to a reinforced steel with higher grade of concrete in these tests i.e., M50.

Among all the grades of concrete the M50 grade reinforced steel concrete beam with 4 coats of organic corrosion inhibitors (Neem Powder), displayed highest efficiency of 53%. The results also showed that inorganic corrosion inhibitors (Zinc Powder) even with 4 coats of application to the reinforced steel concrete beam with M50 grade concrete provided only 10% of efficiency to corrosion inhibition.

In weight loss measurement the control specimen dose shows clear corrosion inhibition as compared to surface applied corrosion inhibitors Neem and Zinc on reinforced steel in all grade of concrete beam. This is due to chloride ingress, the chloride ions reacting with the ferrous ions to form ferric chloride and finally ferric chloridecombining with the hydroxyl ions to form hydrated ferric hydroxide as corrosion product. On the other hand, the surface applied organic corrosion inhibitors Neem powder 4 coats dose show a very less weight loss as compared to control specimen i.e. 0.1 grams in 42 days at the highest grade of M50 in these tests. The surface applied inorganic corrosion inhibitors zinc powder 4 coats also showed less weight loss as compared to control specimen.

As per all the above tests conducted and their results achieved it is to concluded that the organic and inorganic corrosion inhibitors with reference to the used grade of concrete can provide an efficient resistance to corrosion inhibition in reinforced steel in various structures like RCC, Buildings, Bridges, Commercial buildings, Girders, piers, abutments etc. In can be used in various harsh environment conditions and in cost efficient way subjected to grade of concrete.

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BIOGRAPHIES

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