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Influence of Organic Inhibitor on the Corrosion Potential of Steel in Concrete

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Abstract - *This paper describes the details of an experimental study on the influence of an organic inhibitor on the corrosion potential of embedded steel in concrete. Diethanolammine(DEA) has been considered as the corrosion inhibitor for the study. Normal strength concrete with a cement content of 300 and 400 kg per cubic meter of concrete with varying w/c ratios (0.40 and 0.50) has been considered as control concrete. Diethanolammine at 1% and 2% by weight of cement has been considered as the variable for the study. Alternate wetting and drying method suggested by ASTM standard was adopted to determine the corrosion potential of embedded steel. Based on the present study, it could be concluded that, the role of DEA in reducing the corrosion potential of embedded steel in concrete is better for concrete with higher w/b ratio (0.50) and a DEA content more that 1% is not preferable due to the possibility of reduced compressive strength of concrete.*

Key Words: Corrosion Inhibitor, Accelerated Corrosion Test, Diethanolammine, Organic Inhibitor, Alternate Wetting and Drying, Steel in Concrete

1. INTRODUCTION

Corrosion in reinforcement is one of the factors resulting in early, premature deterioration, and sometimes failure, of concrete structures[1]. It is an unfortunate fact that very large number of existing concrete structures worldwide are in a state of deterioration/distress. For a given exposure environment, corrosion rate in reinforcement depends on parameters like permeability, presence of cracks, cover to reinforcement, binder type and w/b ratio[2].

Due to its excellent inhibition performance, low cost and labor saving, corrosion inhibitors are considered as one of the most effective, long-term corrosion protection methods for reinforcement in concrete[3-6]. Traditional corrosion inhibitors are divided into inorganic (mainly nitrites) and organic (alkanolamine and their inorganic, organic acid salt mixtures) substances [7].

Many studies have been made in the past on the effectiveness of inorganic inhibitors. However, it has been reported that, the addition of corrosion inhibitors affects the other performances of the cementitious materials, and some are not environment friendly, particularly nitrites. Hence, there is a shift in the focus of present day research towards organic inhibitors. Many organic compounds are available to replace inorganic inhibitors in pursuit of the solution for the prevention of corrosion in embedded steel in concrete and one of such promising compound is Diethanolammine(DEA). However, not many studies about its effectiveness has been reported in literature. Hence, present study aims in understanding the effect of Diethanolammine in inhibiting the corrosion of steel in concrete.[8,9]

Out of the different methods of test available for the accelerated corrosion test of embedded steel in concrete, alternate wetting and drying method as per the ASTM standard has been followed in the present study [10].This method of test is preferable to study the influence of inhibitors in concrete on the corrosion potential of embedded steel in it.

Concrete with two cement content (300 kg and 400 kg per cubic meter of concrete) and two water to binder ratios (0.40 and 0.50) have been considered for the present investigation. Based on the literature review carried out, it has been decided to consider 1% and 2% DEA by weight of cement as dosage of admixture in concrete.

2. MATERIALS USED

Cement used was of 53 grade Ordinary Portland Cement. The physical properties of cement were tested as per the Indian Standard specifications and were found satisfying the codal requirements. The cement used had a specific gravity of 3.01.

Crushed granite coarse aggregate of nominal size 12 mm and manufactured fine aggregate (crushed granite) was used for the present study. The specific gravity of coarse and fine aggregate was 2.46 and 2.88 respectively. The aggregates had 3.2 % and 0.41 % water absorption, respectively for coarse and fine aggregate.

The reinforcement bars used in the present study was of 12 mm diameter HYSD bars.

Potable water was used for making concrete as well as for curing of specimens.

Super plasticizer with a commercial name Conplast SP430 was used to make concrete workable.

3. PREPARATION OF TEST SPECIMENS

A total of 18 mixture proportion was prepared for the present study. These proportions have been arrived at based on the ASTM method.

Different constituent materials of concrete were mixed in a pan mixture as per the procedure specified in Indian standard[11]. The specimen for corrosion test was prepared as per the ASTM standard [10].Specimens of size 280 mm × 115 mm × 150 mm (L × W × H) were prepared in steel moulds. Prior to placing concrete in the moulds, two 12 mm diameter HYSD reinforcing bars were placed at 25 mm from the bottom of the mould (cathode) and one bar was placed at 25 mm from the top (anode). These bars were of 360 mm long and were given an epoxy insulation as per ASTM guidelines so that, a 200 mm length of bar is unprotected within the concrete specimen.

Concrete was placed in the moulds in three layers and compacted with the help of a table vibrator. The specimens were removed from the mould after 24hours from the time of casting and were kept for water curing for next 27 days. Cubes of size 150 mm were also prepared along with the corrosion test specimens to determine the compressive strength of concrete.

After 28th day from the date of casting, the top surface of the specimen was roughened using a steel wire brush. The specimen was then kept in the laboratory environment for normal drying of the specimen for two weeks. At the end of the drying period, the four vertical sides of the concrete prism were coated with epoxy. A dam of size 150mm × 75mm × 75 mm made with Perspex sheet was then fixed centrally over the top of the roughened face. The top surface outside the dam was also coated with epoxy. On one side of the protruding steel, a 100 ohm resistor was placed between the top and bottom bars. Figure 1 shows the typical photograph of corrosion test specimen as well as the corresponding cubes ready for the test.

4. TEST PROCEDURE

Corrosion test was started after one month of drying process in the laboratory environment. The test specimens were placed over two 20 mm size PVC to ensure air flow under the specimen during the test period.

Fig. 1: Corrosion test specimens and cubes

The first cycle of wetting and drying was started by filling the dam with 3% NaCl solution to a height of about 40 mm. The ponding was done for a period of two weeks, after which the salt solution was vacuumed off and the specimen was kept for another two weeks for drying under laboratory environment. A plastic loose fitting cover was placed over the dam to minimize evaporation of the salt solution. This cycle of wetting and drying continued till the end of the measurement. Figure 2 shows the specimen kept under test condition.

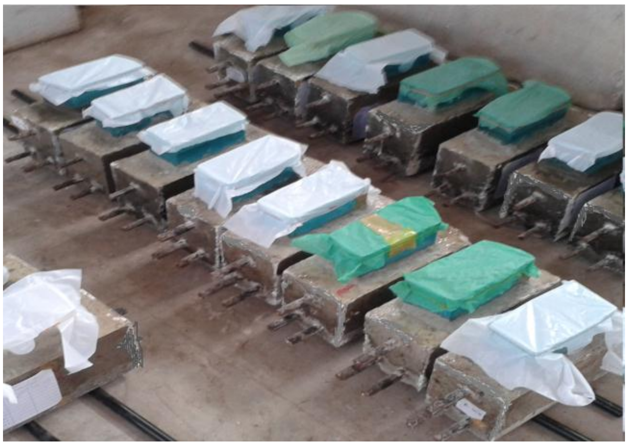

Fig. 2: Specimen kept under wet cycle

Voltage across a 100 Ω resistor was measured at the beginning of the second week of ponding using a voltmeter. From the measured voltage, Vj, the current through the resistor, Ij, was calculated using the equation

$$I_j = V_j/100$$

The total integrated macrocell current over a time period, which is a measure of corrosion potential of embedded steel in concrete was then calculated using the relation

$TC_j = TC_{j-1} + [(t_j-t_{j-1}) \times (i_j + i_{j-1})/2]$

Where;

TC = total corrosion (coulombs)

t_j = time (seconds) at which measurement of the macrocell current is carried out

i_j = macrocell current (amps) at time, t_j

5. RESULTS AND DISCUSSIONS

A total of 36 corrosion test specimens and cubes were prepared for the present study. Each value in the chart represents the average of three test results. The specimen ID CC1 and CC2 corresponds to concrete with 300 kg and 400 kg cement content per cubic meter of concrete respectively. W1 and W2 correspond to the w/b ratio of 0.40 and 0.50 respectively. A1 and A2 correspond to 1% and 2% of DEA in concrete.

Chart 1 and 2 shows the variation of compressive strength of test specimens with different parameters considered, respectively for concrete with 300kg and 400 kg cement content per cubic meter of concrete.

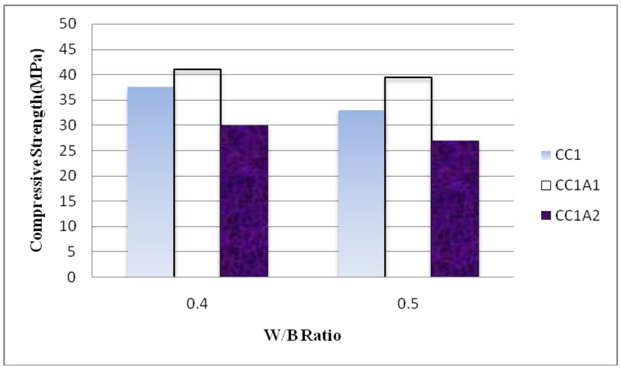

Chart -1: Variation of Compressive strength of specimens with 300 kg cement content

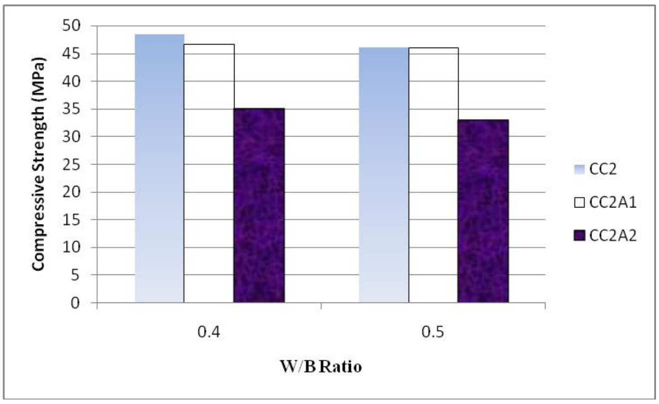

Chart -2: Variation of Compressive strength of specimens with 400 kg cement content

From these charts, it could be observed that, 2% DEA content reduces the compressive strength of concrete (9 % to 32 %). There is more reduction in strength for concrete with 400 kg cement content than 300 kg. On the other hand, 1% DEA in concrete enhances the compressive strength of concrete.

For the comparison of corrosion potential of reinforcement in concretes the total corrosion current calculated on the 120th day from the date of test has been considered. Table 1 shows the total corrosion current calculated on the 120th day for all the specimens tested and charts 3 to 5 shows the variation of corrosion current with time for different category of specimens considered.

Table -1: Total Corrosion at 120th Day

Specimen Designation	Total Corrosion current, Tc (C)
CC1W1	5.21
CC1W2	38.9
CC2W1	3
CC2W2	100.8
CC1A1W1	8.6
CC1A1W2	27.4
CC1A2W1	12.6
CC1A2W2	32.9
CC2A1W1	12.76
CC2A1W2	16.4
CC2A2W1	32.4
CC2A2W2	37.5

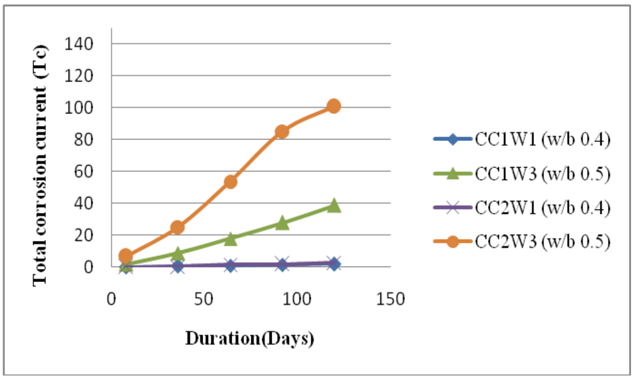

Chart -3: Variation of total corrosion current with time for control concrete

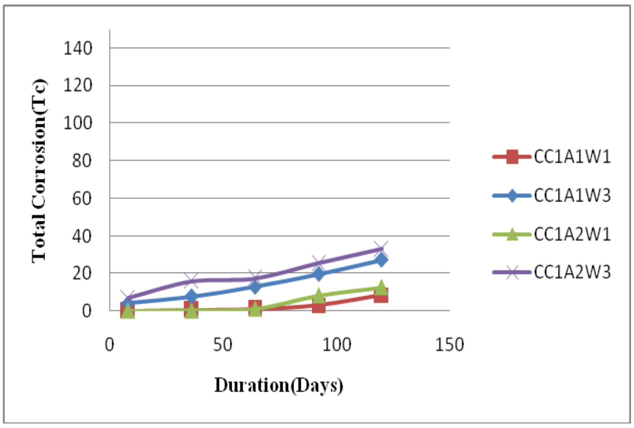

Chart -4: Variation of total corrosion current with time for concrete with 300 kg cement and DEA

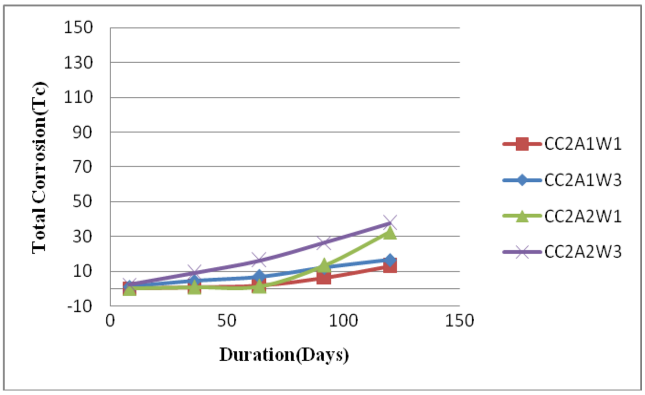

Chart -5: Variation of total corrosion current with time for concrete with 400 kg cement and DEA

From chart 3, it could be observed that, the primary parameter influencing the corrosion potential of steel in concrete is the w/b ratio.

From charts 3 to 5, it could be observed that, the addition of DEA reduces the corrosion potential of steel in concrete when the w/b ratio is 0.50. On the other hand, the role of DEA in reducing the corrosion potential of steel is not significant for a w/b ratio of 0.40.

Based on the 120th day's observation for a concrete with w/b ratio of 0.50, it could be noted that, the addition of 1% DEA reduces the corrosion potential of embedded steel by about 84%.

6. CONCLUSIONS

Following conclusions could be made based on the study carried out

1. Total water content used in concrete is the primary factor causing corrosion in embedded steel.
2. Addition of Diethanolammine in concrete more than 1% by weight of cement reduces the compressive strength of concrete.
3. The influence of Diethanolammine in reducing the corrosion potential of steel in concrete is more for a concrete with higher w/b ratio (0.50).
4. For a concrete with w/b ratio of 0.50, the addition of 1% DEA reduces the corrosion potential of embedded steel by about 84%.
5. The role of Diethanolammine in reducing the corrosion potential of steel is not significant for a concrete with low w/b ratio of (0.40).

Based on the present study, it could be concluded that, the role of DEA in reducing the corrosion potential of embedded steel in concrete is better for concrete with higher w/b ratio (0.50) and a DEA content more that 1% is not preferable due to the possibility of reduced compressive strength of concrete.

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