Corrosion Inhibition of Steel Wire Mesh for Ferrocement

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ABSTRACT

Corrosion of steel in ferrocement affects its durability more as compared to the conventional reinforced cement concrete. This happens because of the small diameter of the wire meshes used in ferrocement. With the passage of time the effective strength of the wires gets reduced due to reduction in diameter and also the bond between the matrix and reinforcement gets affected. Presents work aims at improving the corrosion resistance of steel wire mesh both in tap and saline water with the help of two corrosion inhibitors namely Calcium Nitrite and Tannic Acid. Potentio-dynamic polarization tests were also conducted. Excellent corrosion inhibition has been observed for Calcium Nitrite both for mild steel plate specimens and the welded wire meshes.

Keywords: Corrosion inhibitors, ferrocement, wire meshes, durability, corrosion rate

1. INTRODUCTION

The protection of reinforcement in ferrocement is usually achieved through the use of galvanized wire mesh [1]. This can also be checked to some extent by making dense mortar with the use of additives such as fly ash, silica fumes and blast furnace slag [2, 3]. Some researchers have reported the improvement through increasing the effective cover [4]. These suggested ways have been proved to be ineffective with the passage of time thereby reducing the strength of the ferrocement components [5]. Studies undertaken on the chemical reactivity of corrosion inhibitors by earlier investigators highlight the worthiness of its application [6, 7]. ACI-549R strongly recommends that studies be undertaken to suggest durable and long term anti corrosion techniques to prevent penetration of water and salts that could lead to the corrosion of reinforcing wire mesh [8].

In some of the recent studies carried out to protect rebar in concrete using different types of corrosion inhibitors, it has been clearly established that in controlling/delaying onset of corrosion, inhibitors are extremely effective [9-10]. The present study is aimed at the assessment of the effectiveness of two corrosion inhibitors namely Calcium Nitrite (Type-I) and Tannic Acid (Type-II) in protecting welded steel wire meshes under normal (tap) water, saline water (normal water mixed with 4% NaCl), tap water with Type I and II inhibitors and saline water with Type I and II inhibitors.

2. EXPERIMENTAL INVESTIGATION

Immersion Test. Two types of metallic specimen viz. welded steel wire mesh and cement slurry coated welded steel wire mesh were chosen for the present study [Table-1]. A total of six exposure mediums were considered using normal water and saline water (distilled water mixed with 4% NaCl); both with and without corrosion inhibitors. Two corrosion inhibitors namely Calcium Nitrite (Type-I) and Tannic Acid (Type-II) were used for the present study. The doses of inhibitors were kept as 1, 3 and 5%. The exposure time was 1 month at room temperature**.**

Table - 1 Details of specimens for immersion test

Specimen Type	Size and Details	Exposure Time
Welded Steel Mesh (WSM)	Size of the Specimen = 25×20 *mm,* Diameter = 1.42 *mm*, Opening Size = 12.5 *mm*	1 month
Cement slurry coated Welded Steel Mesh(SCSM)	Size of the Specimen = 25×20 *mm,* Diameter = 1.42 *mm*, Opening Size = 12.5 *mm*	1 month

The efficiency of corrosion inhibitors on the basis of weight loss study was calculated as,

% Efficiency = $[(W_i - W_f) / W_i]$ 3 100 (1)

Where, W_i = initial weight and W_f = weight loss of the specimen.
Corrosion rate was calculated using the following equation [14]
Corrosion rate = $[(534W_f) / (DAT)]$ mpy (2)

Where, D=density of the specimen in gm/cm^3, A = surface area of the specimen in *sq. inch*, T=exposure time in *hours*
Efficiency and Corrosion rate so calculated have been presented in the Tables-2 and Figs. 1-4.

Table - 2 Efficiency of corrosion inhibitors

Exposure Medium	WSM		SCSM	
	Av. Weight loss (mg)	Efficiency (%)	Av. Weight loss (mg)	Efficiency (%)
Tap	11.90	--	9.610	--
Tap + 1% I	7.331	38.39	7.366	23.35
Tap + 3% I	2.524	78.79	2.861	70.23
Tap + 5% I	1.320	88.91	1.636	82.98

Tap + 1% II	8.733	26.61	6.750	29.76
Tap + 3% II	3.500	70.59	3.061	68.15
Tap + 5% II	1.933	83.76	1.962	79.58
Saline	16.130	--	10.400	--
Saline+ 1 %I	12.104	24.96	8.150	21.63
Saline+ 3 %I	4.868	69.82	3.558	65.79
Saline+ 5 %I	3.024	81.25	2.266	78.21
Saline+1%II	10.366	35.73	7.266	30.13
Saline+3%II	6.500	59.70	4.507	56.66
Saline+5%II	5.266	67.35	3.180	69.42

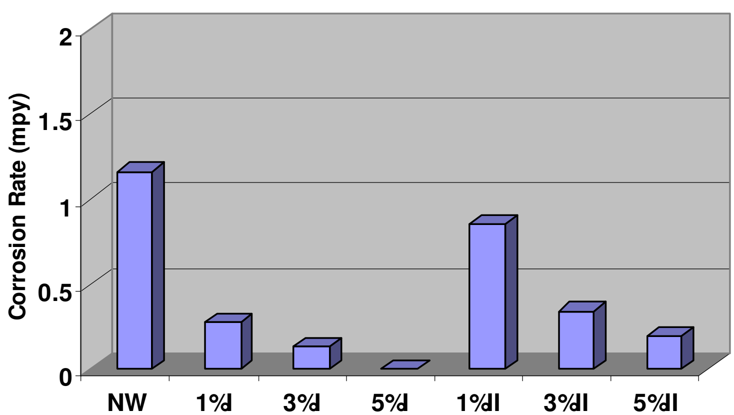


Fig.1 Corrosion Rate for Welded Steel Wire Mesh in Tap water

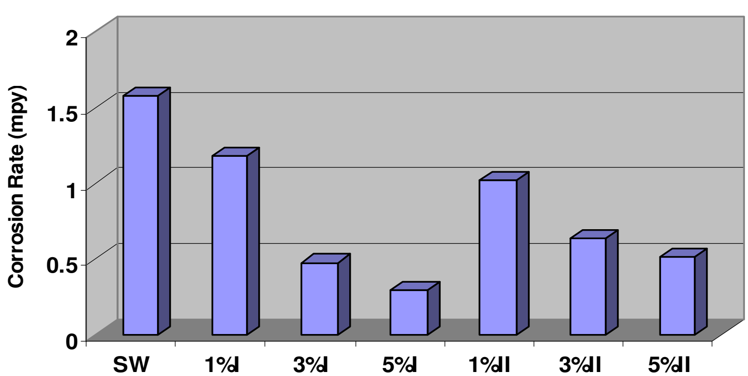


Fig.2 Corrosion Rate for Welded Steel Wire Mesh in Saline water

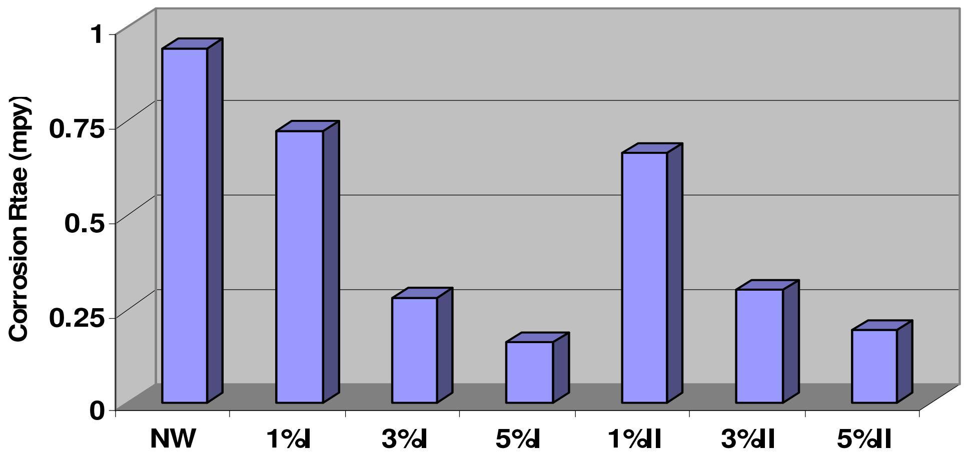


Fig.3 Corrosion Rate for Slurry Coated Welded Steel Wire Mesh in Tap water

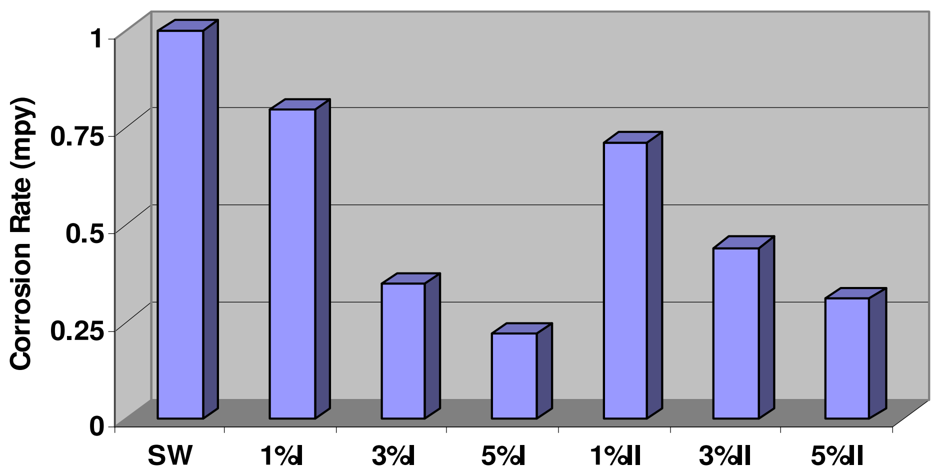


Fig.4 Corrosion Rate for Slurry Coated Welded Steel Wire Mesh in Saline water

Potentiodynamic Polarization Test. Potentiodynamic polarization studies were carried out using an ACM electrochemical work station. A platinum foil was used as the auxiliary electrode, a saturated calomel electrode was used as reference electrode and mild steel was used as working electrode. The experiments were carried out at a constant temperature of $28 \pm 2\ ^{\circ}C$ and a scan rate of $1 mVs^{-1}$ at o.c.p. The polarization curves were obtained after immersion of the electrode in the solution until a steady state was reached. The polarization curves are shown in Fig. 1. The results of potentio-dynamic polarization tests are presented in Table-3.

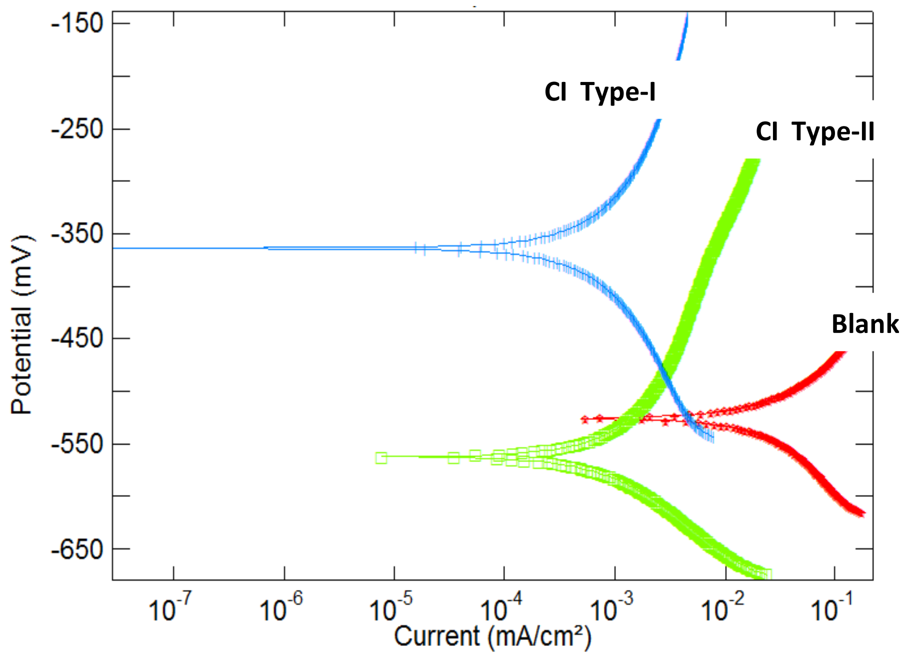
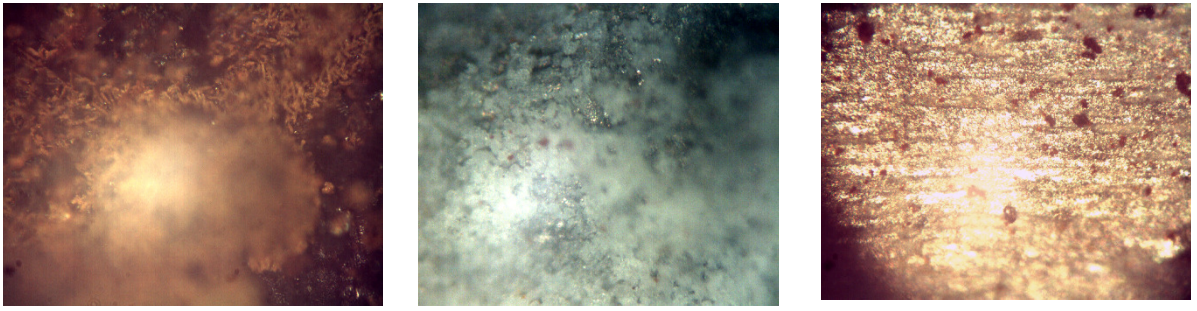


Fig. 5 Potentio-dynamic polarization curves of mild steel in NaCl containing5% calcium nitrite and tannic acid

Table - 3 Electro-chemical polarization parameters

System	E_{cr} (mv)	I_{cr} (mA)	Efficiency (%)
Saline Water (Blank)	-520	0.0300	-
Saline Water + Inhibitor Type-I	-362	0.0005	98.33
Saline Water + Inhibitor Type-II	-556	0.0009	97.00



Blank **Type-I Inhibited** **Type-II Inhibited**

Fig. 6 Micrograph of blank and inhibited specimens at 400X after 1 month exposure

3. DISCUSSION

It has been observed that the inhibitor Type-I not only delays the onset of corrosion in all the exposure conditions but also reduces the corrosion even in saline environment. With the varying dose of inhibitor Type-I, the efficiency calculated on the basis of immersion test, has been found to be ranging between 38.39-88.91% and 23.35-82.98% for naked and slurry coated welded wire meshes respectively under tap water condition, whereas the same ranges between 24.96-81.25% and 21.63-78.21% respectively under saline water condition. For the Type-II inhibitor with the varying doses, the efficiency ranges between 26.61-83.76%, 29.76-79.58% for naked and slurry coated welded wire meshes respectively under tap water condition. Whereas the efficiency ranges between 35.73-67.35% and 30.13-69.42% respectively under saline water condition.

In line with the efficiency results the corrosion rate and penetration ratio has been found to be lowest for Type-I inhibitor in tap water medium for all the three types of specimen. The rate of corrosion decreases with the increase of dose of inhibitor from 1 to 5 %. Even for the saline water medium the corrosion rate has been as low as of 0.296 and 0.222 *mpy* for naked wire mesh and slurry coated wire mesh specimen respectively. For the Type-II inhibitor a reasonably good reduction in corrosion rate has been observed with the increase of the dose of the inhibitor.

The efficiency of inhibitor Type-I has been found to be excellent. In meshes the efficiency is good at 3% of the inhibitor dose and improves further as the dose is increased to 5%. Perhaps the galvanised surface of the wire mesh prevents the formation of protective film at lower doses, which in turn retards the efficiency. It is expected that for longer duration of immersion, after the removal of galvanised coating layer, the formation of strong passivating film will take place, which will protect any further decay of steel wire meshes. Though the inhibitor Type-II also shows quite acceptable efficiency at 3 and 5% of the inhibitor dose, but apparent reason behind not being so effective at 1% dose seems to be the weak film of iron tenate over the surface of welded steel wire mesh.

The efficiency of corrosion inhibitors of Type-I and Type-II using the polarization curve is found to be 98.33 and 97.00% respectively, which confirms the results obtained from weight loss studies. The micrograph of the representative wire mesh specimen (WSM) after 1 month of exposure in saline is presented in Fig.6.

- **Conclusions**
- On the basis of limited experiments following conclusions are drawn:
- The level of efficiency exhibited by Type-I inhibitor for all the type of specimen is excellent.

- Under all the exposure conditions, Type-I inhibitor delays the onset of corrosion which leads to the reduction of corrosion rate.
- Type-II inhibitor also exhibits reasonably good efficiency thereby a lower corrosion rate.
- The results of weight loss study and potentio-dynamic study are confirmatory to each other.

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