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An Experimental Investigation on Inhibiting Chloride Induced Reinforcement Corrosion using Encapsuled Nicotiana Tabacum Extract

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Abstract:
Carbon steel pertaining to construction industry offers profuse material property is by far widely adopted but has paltry corrosion resistance in acidic environment. Corrosion is a natural oxidation reduction process, which can only be reduced but cannot be completely ruled out. Corrosion causes material loss, strength degradation, internal stresses, leading to deterioration of structure. Remedial measures involving heavy metals are banned in marine infrastructure for in fear of its toxicity and potential capacity of genetic modification in flora and fauna. Green corrosion inhibiting bioactive agents are nontoxic and biodegradable containing hetero atoms of phosphorous, sulphur, nitrogen and oxygen are natural corrosion inhibitors. Present work focuses on lowering chloride induced reinforcement corrosion rate by adopting corrosion inhibition practice using encapsulednicotianatabacum extract from soxhlet apparatus and ethanol for samples immersed in 1N Nacl solution and evaluated by weight loss method and electrochemical test is showing promising result of reduction in corrosion rate with increase in extract concentration.

Index Terms*—green corrosion inhibitor; bio active agents; mild steel corrosion; nicotianatabacum; encapsulation; electro chemical test*

I. INTRODUCTION

Corrosion is a naturally occurring electro chemical process affects material strength by metal degradation. Mild steel offers ideal material property hence is extensively used in construction industry. Mild steel in naked is susceptible to excessive corrosion in acidic aqueous environments. Corrosion protection often involves inspection and restoration or replacement of metal of which the later one is a costly affair [1]. External coatings containing heavy metals like lead, cadmium, chromium and many other such toxic materials are strictly prohibited by environmental laws for in fear of its potential in genetic modification and organ or tissue failure in plants and animals [2]. Chemicals containing heteroatoms of phosphorous, sulphur, nitrogen and oxygen in a decreasing rate manner has best corrosion inhibition capacity. Any plant and plant product is known to contain proteins, polysaccharides, cellulose, polyphenols, amino acids, pyridine alkaloids, phytochemicals, resins, tannins and many other active compounds having capacity to inhibit metal corrosion. Plant extracts are nontoxic, bio degradable, extraction and synthesising is cheap. Using nature against nature is the best way possible to counteract these ailments. The inhibiting compounds form a protecting layer on

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the metal surface thus delaying corrosion or decreasing corrosion rate [3].

Nicotiana Tabacum is the scientific name for tobacco which can be predated in history was primarily used for its medicinal purposes. Tobacco leaves were crushed and mixed with water or oils were externally applied for skin infections and sometimes orally consumed for its medicinal values but gradually the sole purpose of its cultivation today is only for its neurotic misbalancing chemicals. Tobacco leaves extracts are best proven pesticides [4]. Nicotiana Tabacum extracted with ethanol shows the presence of sulphur, nitrogen and oxygen in Ultra Violet spectrum [1]. Tobacco is a cash crop has a unique ability to absorb heavy metals from the soil and store it in their leaves [5]. The reason for selecting tobacco in this project is to study and divert its mainstream attention from mere consumable to application in construction industry.

II. Corrosion Mechanism

Electro chemical reactions involved in corrosion

Anodic reaction,

$F_e \longrightarrow F_e^{2+} + 2e^-$

Cathodic reaction,

$2e^- + H_2O + 1/2\ O_2 \longrightarrow 2\ OH^-$

Formation of Ferrous hydroxide,

$F_e^{2+} + 2\ OH^- \longrightarrow F_e(OH)_2$

Formation of Ferric hydroxide,

$4F_e(OH)_2 + O_2 + 2H_2O 4F_e(OH)_3 \longrightarrow$

Formation of Hydrated ferric oxide (rust)

$2F_e(OH)_3 \longrightarrow F_eO_3\ H_2O + 2H_2O$

III. Mechanism of green corrosion inhibitor

Inhibiting solution replacing adsorbed water molecules on metal surface,

$Inh_{(sol)} + xH_2O_{(ads)} Inh_{(ads)} + H_2O_{(sol)}$

Dissolution of metal ions,

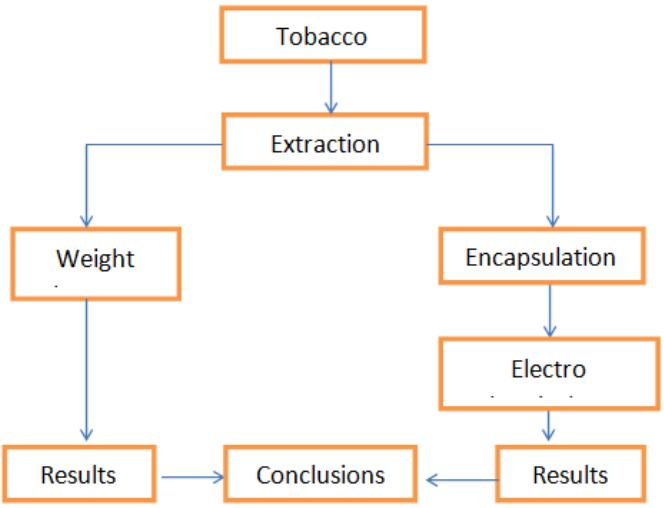
$M \longrightarrow M^{2+} + 2e^-$

Formation of metal inhibitor complex,

$M^{2+} + Inh_{(ads)} (M^{2+} -- Inh)_{(ads)}^{2+}$

Active ingredients in plant extract vary among different plant species and sometimes among same species in terms of concentration.

IV. Methodology



V. Extraction

Extraction was done by using,

1. Ethanol has non polar ends hence dissolves most essential oils, flavouring agents, colouring agents and medicinal molecules which are also known as bio active molecules which are in fact most responsible for active corrosion inhibition.
2. Soxhlet apparatus makes use of solvent repeatedly for continuous extraction reducing cost by increasing solvent efficiency.
3. Rotary evaporator is used to separate ethanol from extract in the round bottom flask of soxhlet equipment.
4. The efficiency of extraction by soxhlet apparatus using ethanol and rotary equipment was found to be 10.55%.

VI. Weight loss test on mild steel

8 mm mild steel rods of 2.5 cm each were initially weighed and suspended in 1N Nacl solution containing 0g, 0.25g, 0.5g and 0.75g of the extraction were left for 30 days which were reweighed after surface abrasion and cleaned with concentrated sulphuric acid.

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Fig.1 Containers with 1N Nacl each and 0g, 0.25g, 0.5g, 0.75g concentration of extract from left to right

The following formulas were used to calculate,

1. Weight loss (gm)
   $W = W_1 – W_2$
2. Corrosion rate (mm/year)
   $C_r = KW/ DAT$
   Where,
   K = corrosion rate constant = $8.76*10^4$
   D = density of mild steel = 7.85 g/ cm^3
   A = exposed surface area of mild steel specimen in cm^2
   T = specimen exposure time in corrosive media in hours
3. Mass loss (gm)
   ML = KW/ DA
4. Inhibition Efficiency (%)
   $IE = [(W_i – W_o)/ W_i] * 100$
   Where,
   W_i = weight loss with corrosion inhibitor (gm)
   W_o= weight loss without corrosion inhibitor (gm)

From the Fig.6 we can observe the gray covering on the sample after corrosion is actually the extract protection layer.

Fig.2 Mild steel before and after corrosion

VII. Results of weight loss test

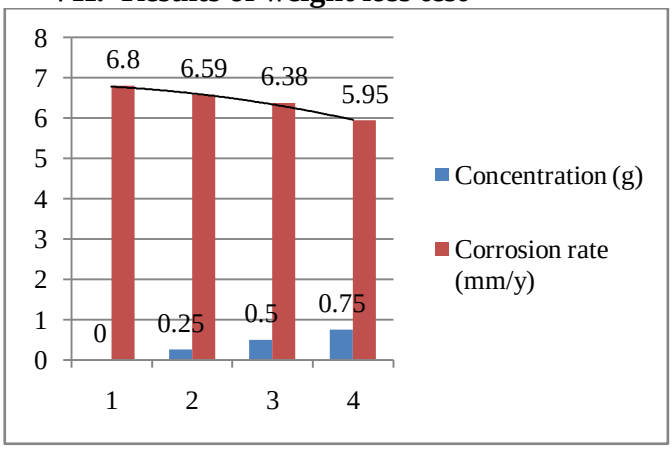

Fig.3 Graph showing Corrosion rate (mm/year) vs extract concentration (g)

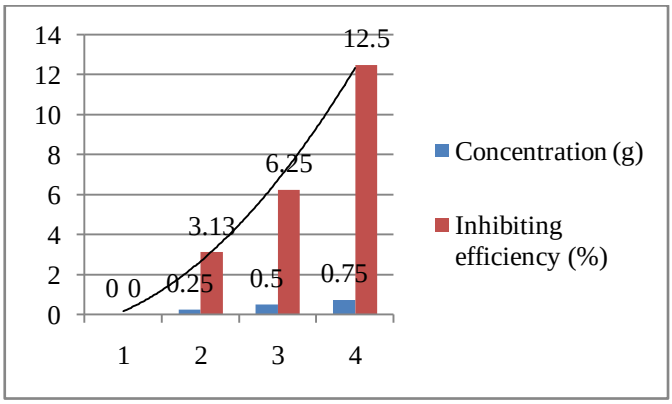

Fig.4 Graph showing Inhibition efficiency (%) vs extract concentration (g)

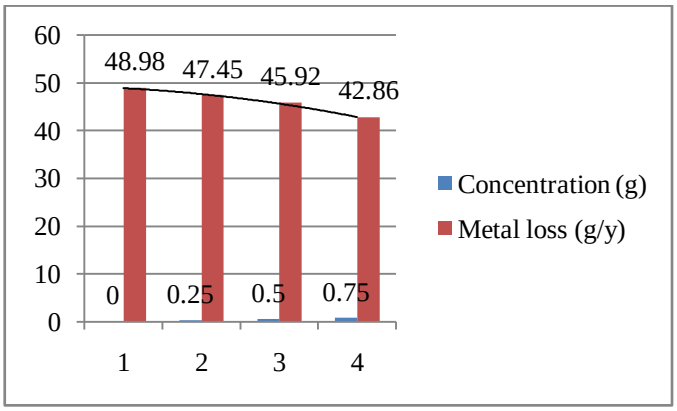

Fig.5 Graph showing metal loss per year vs extract concentration (g)

From the Fig. 3,4,5 we can see as the concentration of extract increases the,

1. corrosion rate decreases
2. Inhibition efficiency increases
3. Metal loss decreases

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VIII. Encapsulation

Size zero hard gelatine capsules are filled with extract and a thin layer of waterproof adhesive is coated on its surface for later extract release.

Fig.6 Capsules

When capsules are placed in concrete it is impossible for tamping hence a flowing concrete is designed for self-compaction.

IX. Incorporation

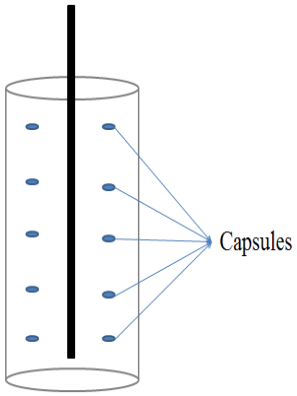


Fig.7 Capsules in reinforced concrete cylinder of dia 150mm and height 300mm

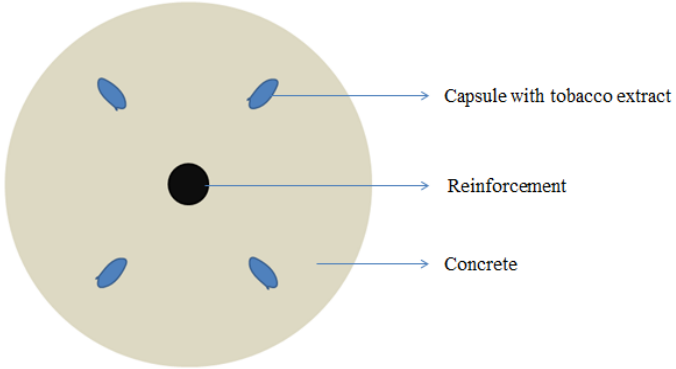


Fig.8 Capsules around reinforcement

A total of 20 capsules with 4 numbers in each of 5 layers are placed while concreting with a mild steelrod at the center. Each capsule contains 50mg of tobacco extract.

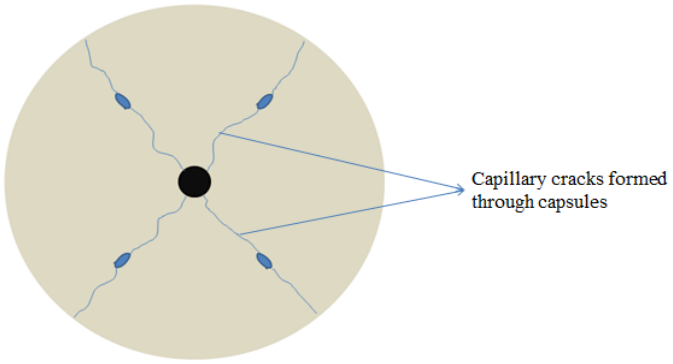
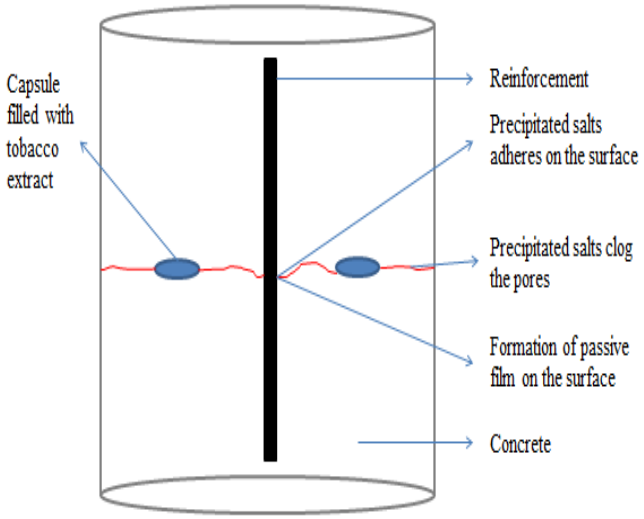


Fig.9 Capillary cracks through capsules



Water from outside the cylinder flows to inner core through the capillaries formed along the capsules. Since water flows from high pressure area to low pressure area the tobacco extract is carried towards the reinforcement. Concrete covers the reinforcement through bonding and once the concrete film on the surface of reinforcement is eroded corrosion starts. Water seeps through pores, hence water contact a relatively smaller area forms anode and the rest of the steel forms cathode is a dangerous situation, since electron acceptor area is more than the electron donor area, hence in reinforced concrete pitting corrosion occurs. Tobacco extracts contain mixed corrosion inhibitors capable of suppressing both cathodic and anodic

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reactions. The anodic inhibitor will forms dense passive film on the surface, while cathodic inhibitor will precipitate the salts. The precipitated slats adhere on the surface and also clog the pores to prevent seeping water.

X. Electro Chemical Test

Corrosion rate depends on the difference of electro potential between the metals, higher the difference increases the corrosion rate. To obtain the result in a relatively less duration, externally the voltage between the anode and cathode is increased using a constant DC battery.

Fig.11 Accelerated corrosion test

Externally 30V is maintained between mild steel as anode and stainless steel as cathode, is immersed in a 1N Nacl electrolytic solution. This setup was maintained for 10 days.

XI. Results of electro chemical test on reinforced concrete cylinder

Table 1 Tabulated results of electro chemical test on reinforced concrete cylinder

Sl. No.	Specimen	Voltage (V)	Current (mA)	Resistance (ohms)
1	Reinforced Concrete cylinder without corrosion inhibitor	0	0	∞
2	Reinforced Concrete cylinder without corrosion inhibitor	30	2	15000
3	Reinforced concrete cylinder with corrosion inhibitor	0	0	∞
4	Reinforced concrete cylinder with corrosion inhibitor	30	0	∞

Fig.12 Reinforced concrete specimens after 10 days of accelerated electro chemical test

After 10 days of continuous accelerated corrosion the concrete cylinders were taken out of electrolyte solution. The surface of the specimen without corrosion inhibitor was covered with blue green algae, whereas the surface of specimen with corrosion inhibitor was covered with both algae and tobacco extract. The extract in the capsules reached the surface due to diffusion. But the capsules could sustain concreting action and also curing period.

XII. Conclusions

1. The tobacco extract from the soxhlet equipment using ethanol is gooey.
2. The extraction process is simple and relatively cheap.
3. Tobacco extract forms a dense passive film on the mild steel thus protecting it from corrosion.
4. Tobacco extract precipitates slats by decreasing its solubility. These salts adhere on the mild steel surface and protects from corrosion.

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5. Tobacco extract acts as both anodic inhibitor and cathodic inhibitor.
6. Encapsuled tobacco extract sustained both concreting phase and curing phase.
7. Presence of encapsuled tobacco extract in reinforced concrete, gives higher resistivity suggesting no transfer of charges between anode and cathode thus provides corrosion resistance.
8. Presence of encapsuled tobacco extract in reinforced concrete, blocks the pores by precipitating slats thus reducing corrosion rate.
9. Increasing tobacco extract concentration, increases corrosion inhibition efficiency by decreasing corrosion rate thus achieving lower metal loss.
10. Hot continues tobacco extract using ethanol shows a promising result by reducing corrosion rate.
11. Encapsulation of tobacco extract does not interfere with the hydration process of cement thus suggesting no ailments in intended designed concrete results.

Scope for Future Work

Present experiment shows a promising result on reducing corrosion rate but the shelf life of capsules under stress is uncertain. The capsules used will attract more stress cracks rendering weak transition zone.

Micro encapsulation of tobacco extract using bacterial capsules may prove commendable, since while tobacco extract protects reinforcement from corrosion, bacteria will seal cracks and stops further progression.

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