

Corrosion Inhabitation Of Iron Steel By Natural Inhibitors

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Abstract: *Traditionally reduction of corrosion has been managed by various method including Acalypha Indica and Phyllanthus Amarus, reduction of the metal impurity content. The Inhibition efficiency for Acalypha Indica and Phyllanthus Amarus. However, the use of corrosion inhibitors has proven to be the easiest and cheapest method for corrosion production these inhibitors slow down the corrosion rate and thus prevent monetary losses due to Steel is a major material in construction. Using the tests for corrosion resistance test. And finally submit the report.*

1. INTRODUCTION

Concrete is a composite material made of cement, water and aggregates which has been used as the largest quantity for construction material in many decades. Cement is a major component of concrete, when mixed with water forms a paste that sets and hardens due to hydration reactions. Corrosion is the destructive attack of a material by reaction with its environment. The serious consequences of the corrosion process have become a problem of worldwide significance. In addition to our everyday encounters with this form of degradation, corrosion causes plant shutdown, waste of valuable resources, loss or contamination of product, reduction in efficiency, costly maintenance and expensive overdesign. It also jeopardizes safety and inhibits technological progress. The multidisciplinary aspect of corrosion problems combined with the distributed responsibilities associated with such problems only increase the complexity of the subject. Corrosion control is achieved by recognizing and understanding corrosion mechanisms by using corrosion-resistant materials. Mild steel is widely used in many industries because of economically cost-effective and easy fabrication, but it is prone to undergo corrosion in aggressive environmental conditions. The environment may be liquid, gas or mixture of solid and liquid.

Corrosion is the degradation of a metal either by direct chemical or electrochemical reaction when in contact with aqueous corrosive surroundings. It is an endless and costly problem, often difficult to eradicate completely. It is a foremost problem that has safety, conservation and

economic impacts in various chemical, motorized, metallurgical, natural and medical engineering applications and more particularly in the design of a much more varied number of mechanical parts which equally vary in size, functionality and useful lifespan.

Corrosion can cause life-threatening damage to metal and alloy structures causing financial punishment in terms of renovation, replacement, product losses, safety and environmental pollution. Metal degradation may result in elevated productivity loss arising from the malfunctioning of the corroded instruments and contamination of main industrial products (e.g. chemical products) by the aqueous corrosion products. Leakage of products leads to loss in efficiency. If the corrosion contaminated materials are left untreated, the industry may have to face equipment failure. Due to these harmful effects, corrosion is an unattractive observable fact that must be prevented. Prevention would be more realistic and practicable than complete eradication.

Though, presence of porosity in concrete allows the oxygen to diffuse through it which becomes dissolved in pore solution and at the end reaches the surface of the steel. Further, there are two more aggressive agents namely chlorides and carbon dioxide (CO₂) which can cause corrosion to the steel bar. These aggressive agents can penetrate through concrete cover without causing significant damage and then promote the corrosion of steel by removing the protective passive oxide layer on the steel. Carbonation begins with chemical reaction between carbon dioxide (CO₂) gas from the atmosphere and the alkaline hydroxides from the concrete. CO₂ readily dissolves in water to form the carbonic acid which does not attack the cement paste, while neutralizing the alkalis in the pore water and producing calcium carbonate that lines the pores. Presence of Calcium hydroxide in the concrete increases the alkalinity and maintains the pH level of 12–13. Further, the carbonates attack inside the concrete results information of Calcium carbonate which reduces the p^H (<8) level and causes the corrosion of reinforcement.

Chloride attack involves no drop in the overall pH while it acts as catalysts to corrosion when there is sufficient concentration at the rebar surface to breakdown the passive layer. Chloride ions not consumed in the process while they help to destroy the passive layer over steel surface, allow the corrosion process to proceed quickly. When chloride ions appeared in solution around iron, it reacts with Fe_2^+ of passive film over steel surface and forms an iron-chloride complex. Subsequent hydrolyzes of iron-chloride complex resulting ferrous hydroxide and also liberate the chloride ions for further attack over iron surface.

1.1 Corrosion Inhibitors

A corrosion inhibitor is a substance which when added in ppm concentrations to a corrosive environment minimizes or prevents corrosion. These substances can adsorb both physically and chemically at the metal-solution interface and obstruct the contact surface between the metal and the corrosive agents. A good corrosion inhibitor should have a readily adsorption capacity on the metal surface through either physisorption or chemisorption processes. Due to their industrial importance, most corrosion inhibitors have been synthesized from economical raw materials or chosen from compounds containing heteroatom in their aromatic or long carbon chain. Over the years, significant efforts have been deployed to discover appropriate corrosion inhibitors of natural starting point in various corrosive media. In acid media, nitrogen based materials and their derivatives, sulphur-containing compounds, aldehydes, thioaldehydes, acetylenic compounds, and various alkaloids, for example, palavering, strychnine, quinine and nicotine are used as inhibitors. In neutral media, benzoate, nitrite, chromate and phosphate act as good inhibitors. Inhibitors decrease or prevent their action of the metal with the media.

2. METHODOLOGY

Figure 1. Shows the methodology adopted in this study

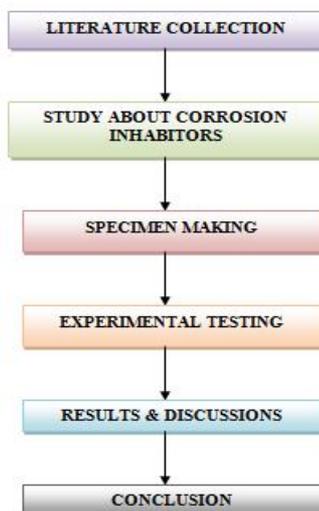


Figure 1 Methodology

3. CORROSION INHABITATION

3.1 Corrosion Inhabitation Basics

In general, concrete provides reinforcing steel with excellent corrosion protection. The high alkaline environment in concrete results in the formation of a tightly adhering film, which passivates the steel and protects it from corrosion.1,2 Passivation means the metals do not lose electrons (anodic reaction), which render metals to be inactive/inert for corrosive environment. Though, presence of porosity in concrete allows the oxygen to diffuse through it which becomes dissolved in pore solution and at the end reaches the surface of the steel. Further, there are two more aggressive agents namely chlorides and carbon dioxide (CO_2) which can cause corrosion to the steel bar. These aggressive agents can penetrate through concrete cover without causing significant damage and then promote the corrosion of steel by removing the protective passive oxide layer on the steel. Carbonation begins with chemical reaction between carbon dioxide (CO_2) gas from the atmosphere and the alkaline hydroxides from the concrete. CO_2 readily dissolves in water to form the carbonic acid which does not attack the cement paste, while neutralizing the alkalis in the pore water and producing calcium carbonate that lines the pores. Presence of Calcium hydroxide in the concrete increases the alkalinity and maintains the p^H level of 12–13. Further, the carbonates attack inside the concrete results in formation of Calcium carbonate which reduces the p^H (<8) level and causes the corrosion of reinforcement.

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Corrosion of reinforcement has huge economic implications as well as social issues including endangering the safety of people who are working in industries. Federal highway administration of USA has estimated the annual cost of corrosion damage of highway bridges as \$13.6 billion per year.4 Corrosion accidents over concrete structure may cause loss of human lives which has to be given priority than money. Steel bar corrosion in concrete can be reduced by the following well-known methods; selection of corrosion-resistant steel, use of coatings, addition of concrete sealers, use of membranes, use of thicker concrete cover, addition of corrosion inhibitors and cathodic protection.

In general, traditional concrete corrosion inhibitors can be classified as inorganic corrosion inhibitors (mainly nitrites) and organic corrosion inhibitors (alkanolamine and their inorganic, organic acid salt mixtures). The corrosion inhibitors can be classified based on their mechanisms of protection as; anodic, cathodic, mixed and adsorption inhibitor. Corrosion inhibitors can be introduced into reinforced concrete either as preventive measures to new structure or as surface applied inhibitors for preventive and restorative purposes. Thus based on mode of applications inhibitors can be classified as; migrating inhibitors (can penetrate into the hardened concrete) and admixed inhibitors (added to fresh concrete for new structures).

3.2 Corrosion Inhibitors

Corrosion inhibitors are one of the best methods to combat premature falling of building materials, worldwide due to reinforcement corrosion under harsh environmental conditions. Environmental concerns require corrosion inhibitors to follow certain rules. Most of the conventional inhibitors that have been developed till today are non-biodegradable and highly toxic to human beings. Inhibitor biodegradation or biological oxygen demand (BOD) which is a measure of inhibitor persistence duration in the environment should at least be 60%. Recent studies have shown the ability of several inorganic and synthetic organic inhibitors to cause temporary or permanent damage to human organs, such as kidney or liver. The former was a chemical which was considered lethal for 50% of animals in 24 h exposure time and latter also had lethal properties in air or water and was known to kill 50% of test population.

These studies have clearly indicated the hazardous effects of most of the inorganic or synthetic organic inhibitors and also their detrimental effects on the environment, which have compelled and motivated researchers to shift their focus to develop cheap, non-toxic and environment friendly corrosion inhibitors. Over the years numerous studies have shown the effectiveness of green inhibitors against the corrosion of various steel types especially under acidic environment. But rebar embedded into concrete is under alkaline environment of pH nearly 12-13. So, this review is particularly focused on green inhibitors active in simulated alkaline environment of concrete to protect reinforced bar from its premature deterioration.

3.3 Corrosion Inhibitors Classification

Generally, corrosion inhibitors are classified as anodic or mixed reactants, depending on their reaction mechanism. Anodic corrosion inhibitors, which are mostly nitrite-based, display corrosion protection through a partial interface process. Oxidation of ferric ions forms a ferric-oxide film around the reinforcing steel. Nitrite-based inhibitors are considered the most effective products on the market. Concerns are with their toxicity, solubility, and possible increase of corrosion rate in the case of low dosage or in the presence of cracks, and also the relatively high costs of this type of additive. Thus, the use of amino

alcohol-based mixed corrosion inhibitors has increased recently, but studies related to these types of inhibitors are lacking.

3.4 Green Inhibitors

Most of these eco-friendly inhibitors are usually extracted from aromatic herbs, spices and from seeds, leaves or barks of medicinal plants, collectively termed as green inhibitors. These extracts are admixed to the concrete slabs in different concentrations. The steel reinforcements are embedded into these concrete blocks. The natural constituents of these extracts contain N, O, and S containing hetero cyclic macromolecules, which are reached to the steel surface by diffusion and adsorbed at the steel concrete interface by electronic interaction with the metal and metal oxide. There they form protective layers to repel water molecules and inhibit ingress of destructive species like Cl^- , SO_4^{2-} , and CO_2 which are responsible for the depassivation of steel.

White juice of banana stem was reported to show increase in compressive strength with admixture concentration 0.1%; but, it was found to decrease with further addition of admixture concentration 0.1%–0.35%. Decrease in compressive strength was attributed to the adsorption of admixture on the surface of anhydrous cement grains which protected it from further water attack. Corrosion inhibition potential of banana stem juice admixture with different concentrations (0.05, 0.10, 0.20 and 0.30% - mL/100 gm cement) was screened in corrosive media (sat. $\text{Ca}(\text{OH})_2$ & 1–5% NaCl). The results concluded that steel manifests high degree of passivation when admixed at concentration of 0.1 and 0.2%.

3.4.1 Bambusa Arundinacea

One of the most important hydrophobic green plant inhibitor to repassivate the chloride induced corrosion of steel was extracted from *Bambusa arundinacea*. *Bambusa arundinacea* as an effective mixed type corrosion inhibitor for steel reinforcement in concrete, when it is added to fresh concrete. In fact the polarization resistance, high concrete resistivity and chloride binding property by double layer capacitance data have shown its ability to inhibit the initiated corrosion of steel embedded into chloride contaminated concrete even better than calcium nitrite inhibitor. Further study by S.A. Asipita et al. to compare the inhibitor efficiency of *Bambusa arundinacea* leaf extract to that of two well established and effective corrosion inhibitors, calcium nitrite and ethanolamine showed that the pore blocking ability of *Bambusa arundinacea* extract in chloride contaminated concrete was far better than both of these two conventional inhibitors.

3.4.2 Vernonia Amygdalina

The inhibitor efficiency of *Vernonia amygdalina* (bitter leaf) extract on the corrosion behavior of embedded mild steel rebar in concrete was investigated by C.A. Loto by electrochemical potential measurement, pH and gravimetric (weight loss) methods. The test results

revealed the inhibitor efficiency as well as pH changing property of the leaf extract. Corrosion potential measurement of the mild steel rebar embedded into concrete in presence of different concentrations (25%, 50%, 75% and 100%) of the inhibitor had shown maximum corrosion inhibition of the reinforcement by 25% inhibitor concentration with maximum positive potential value. On the other hand weight loss experiment also supported the potential measurement analysis. In this experiment weight loss was determined to be minimum, 0.1 with 25% inhibitor concentration. As the inhibitor concentration increased, weight loss of the rebar also increased. Both these experiments signified higher effectiveness of the inhibitor with lower concentration. Further characterization of the leaf extract by IR spectroscopic techniques and quantitative analyses had shown that the plant extract contained alkaloids, saponin and tannin. These chemical constituents of bitter leaf were expected to be strongly adsorbed to the surface of the embedded steel and thus enhancing its corrosion resistance in corrosive environments.

3.4.3 Chamaerops Humilis L. Leaves

The methanolic extract of Chamaerops humilis L. leaves was reported to effectively decrease the reinforcement steel corrosion enhancing the stability of the oxide film formed in alkaline solution and assured the formation of a more compact protective layer on the surface of the metal. The effect of the extract on the oxide film protective property on the reinforcement steel surface in alkaline medium (pH > 13) was investigated by electrochemical techniques. Using polarization resistance the inhibition efficiency was found to be 42% with 0.5g/L of inhibitor concentration at 25°C. Nyquist plots from EIS study for reinforced steel (R.S) electrode showed as the inhibitor concentration increased the diameters of the capacitive loops hanged, indicating an improvement of protective performance of surface film formed on electrode surface, and thus activity of reinforced steel was effectively reduced.

3.4.4 Morinda Lucida

Some recent studies have shown the inhibitory effect of leaf-extract of Morindalucida on the corrosion-degradation of steel-reinforced concrete in 3.5% NaCl i.e. in simulating saline/marine environment using electrochemical analysis according to ASTM G16-95 R04. The optimal inhibition efficiency of Morindalucida extract ($\eta = 95.64 + 1.50\%$) was found in presence of 0.1667% admixture concentration.

3.4.5 Tobacco

Tobacco plants produce 4,000 chemical compounds including terpenes, alcohols, polyphenols, carboxylic acids, nitrogen containing compounds (nicotine), and alkaloids, which may exhibit electrochemical activity, such as corrosion inhibition property. Some previous work on extracts of tobacco had shown it to be in Table 1

Table 1: Important Constituents of Some Green Inhibitors Used in Reinforcement Concrete Corrosion

GREEN INHIBITOR	INHIBITORY CHEMICAL CONSTITUENTS	EFFECTS ON CONCRETE PROPERTIES
Bambusaarundinacea	Not reported	Increase concrete strength
Vernoniaamygdalina	alkaloids, saponin and tannin	No effect on concrete property
Methanolic extract of Chamaerops humilis L. leaves (MECHLL)	Lucenin 2 (42%), Dascycarpidan-1-methanol, acetate (ester) (11%), 1, 3-D-5-hexan-2-one-2, dinitrophenylhydrazone (10%) and 9-Hexadecenoic acid (8%)	No effect on concrete property
Morindalucida	Not reported	Both can increase or decrease concrete compressive strength
Tobacco	terpenes, nicotine, alkaloids	No effect on concrete property
Rhizophora mangle L bark- extract	tannin	Increase concrete compressive strength

Effective in preventing the corrosion of steel and aluminium in saline environments; and in fact, exhibiting a greater corrosion inhibition effect than chromates. The investigation further added the combined effect of a mixture of both the extracts which was clearly better than the effect of kola leaves extracts alone, but not as good as the corrosion performance of the tobacco extract alone.

3.5 Mechanisms of Lithium Nitrite and Amino Alcohol

Inhibitors

3.5.1 Lithium Nitrite Inhibition Mechanism

Reinforcing steel corrosion in a reinforced concrete structure is prevented by the formation of a film on passive state metals on the reinforcing steel surface by the high alkalinity of the concrete. This film on passive state metals (Fe₂O₃) is stable, with strong bonding in an alkaline environment, but it becomes unstable and dissolves in the presence of chloride ions.

3.5.2 Amino Alcohol Inhibitor Mechanism

Amino alcohol corrosion inhibitors control corrosion by attacking the cathodic activity, blocking sites where oxygen picks up electrons and is reduced to hydroxyl ion. Also, inhibition of corrosion occurs through a mechanism whereby amino alcohols displace chloride ions and form a durable passivating film. In this view, although the amino alcohols adsorb on non-corroding sites, which may seem more cathodic than anodic, they can just as easily be said to adsorb on potentially anodic sites as well. Thus, the value of chlorides reaching to the steel surface is significantly less so corrosion is inhibited. Several studies of the corrosion inhibition effect of amino alcohols on steel report their performance as a function of concentration and pH in saline solutions.

4. MATERIALS COLLECTION

4.1 Cement

A cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete. Cements used in construction are usually inorganic, often lime or calcium silicate based, and can be

characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster). Non-hydraulic cement will not set in wet conditions or underwater; rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting.

4.2 Coarse Aggregate

Aggregates are inert granular materials such as sand, gravel, or crushed stone that, along with water and Portland cement, are an essential ingredient in concrete. For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete.

Aggregates, which account for 60 to 75 percent of the total volume of concrete, are divided into two distinct categories--fine and coarse. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Coarse aggregates are any particles greater than 0.19 inch, but generally range between 3/8 and 1.5 inches in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.

4.2.1 Composition

Aggregates consisting of materials that can react with alkalis in cement and cause excessive expansion, cracking and deterioration of concrete mix should never be used. Therefore it is required to test aggregates to know whether there is presence of any such constituents in aggregate or not.

4.3 Fine Aggregate

Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. As with coarse aggregates these can be from Primary, Secondary or Recycled sources.

- Grading.
- Durability.
- Particle shape and surface texture.
- Abrasion and skid resistance.
- Unit weights and voids.
- Absorption and surface moisture.

4.3.1 Basic Properties of Aggregates Used In Concrete

4.3.1.1 Composition

Aggregates consisting of materials that can react with alkalis in cement and cause excessive expansion, cracking and deterioration of concrete mix should never be used. Therefore it is required to test aggregates to know whether there is presence of any such constituents in aggregate or not.

4.3.1.2 Size and shape

The size and shape of the aggregate particles greatly influence the quantity of cement required in concrete mix

and hence ultimately economy of concrete. For the preparation of economical concrete mix one should use largest coarse aggregates feasible for the structure. IS-456 suggests following recommendation to decide the maximum size of coarse aggregate to be used in P.C.C & R.C.C mix.

4.3.1.3 Porosity and absorption

The minute holes formed in rocks during solidification of the molten magma, due to air bubbles, are known as pores. Rocks containing pores are called porous rocks. Water absorption may be defined as the difference between the weight of very dry aggregates and the weight of the saturated aggregates with surface dry conditions. Depending upon the amount of moisture content in aggregates, it can exist in any of the 4 conditions.

- Very dry aggregate (having no moisture)
- Dry aggregate (contain some moisture in its pores)
- Saturated surface dry aggregate (pores completely filled with moisture but no moisture on surface)
- Moist or wet aggregates (pores are filled with moisture and also having moisture on surface)

4.4 Water

The amount of water in concrete controls many fresh and hardened properties in concrete including workability, compressive strengths, permeability and water tightness, durability and weathering, drying shrinkage and potential for cracking. The ratio of the amount of water, minus the amount of water absorbed by the aggregates, to the amount of cementitious materials by weight in concrete is called the water-cementitious ratio and commonly referred to as the w/cm ratio. The w/cm ratio is a modification of the historical water-cement ratio (w/c ratio) that was used to describe the amount of water, excluding what was absorbed by the aggregates, to the amount of the portland cement by weight in concrete.

4.5 Phyllanthus Amarus Leaf

Most efficient corrosion inhibitors are organic compounds containing electronegative functional groups and p-electrons in triple or conjugated double bonds. For these compounds, the presence of heteroatoms (such as sulphur, phosphorus, nitrogen and oxygen) and aromatic rings in their structures facilitates the adsorption of the inhibitor on the metal surface. In spite of the wide range of organic inhibitors that have been synthesized and used as corrosion inhibitors, there is increasing concern about the toxicity of most corrosion inhibitors in industry because the toxic effects do not only affect living organisms but also poison the environment.

However, the use of ethanol extract of *Phyllanthus amarus* as an inhibitor has not been reported elsewhere. Therefore the objective of the present study is aimed at investigating inhibitive and adsorption properties of ethanol extract of *phyllanthusamarus* leaves for the corrosion of mild steel in H_2SO_4 . Figure 2 shows the *Phyllanthus Niruri* plant

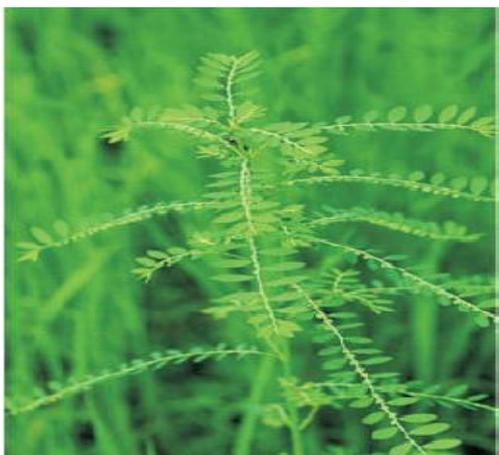


Figure 2 Phyllanthus Niruri plant

Phyllanthus niruri is a widespread tropical plant commonly found in coastal areas, known by the common names gale of the wind, stonebreaker or seed-under-leaf. It is a relative of the spurges, belonging to the Phyllanthus genus of Family Phyllanthaceae. The major compounds in ethanol extract of P. amarus are benzene, 1, 2 – dimethoxy – 4 – [[(4-methylphenyl) sulfonyl] methyl] – (53.78%), Phenethylamine, 2-methoxy-alpha-methyl-4, 5-(methylenedioxy) (28.57%) and phenanthylamine, 2-methoxy (8.40). The remaining compound in this extract are cyclopentane, phenyl (3.36%), 3-(3-(1-Axirdinyl) propoxy) – 2, 5-dimethylpyrazine (2.52%) and 3-(Cycloprophylamino) propioitriole (1.68%).

5. SPECIMEN MAKING

5.1 Experimental

5.1.1 Materials Preparation

Mild steel of composition (wt%) (as determined by quantitative method) Mn(0.6), P(0.36), C(0.15), S(0.07) and Fe(98.79) was used for the study. Dimension of the specimen 100 x 50mm cylinder.

5.1.2 Preparation of Extract

The Phyllanthus Niruri (PN) plant an aqueous extract of Phyllanthus Niruri was prepared by grinding 25 g of Phyllanthus Niruri with double distilled water, filtering and suspending impurities, and making up to 250 ml. The extract was used as corrosion inhibitor in our project. After 48 hours, the samples were cooled and filtered.

5.1.3 Weight-Loss Method

Mild steel specimens in triplicate were immersed in 100 mL of the solutions containing various concentrations of the inhibitor in the presence and absence of Ni for one day. The weight of the specimens before and after immersion was determined using a Shimadzu balance, model AY62. The corrosion products were cleaned with Clarke's solution.

5.2 Calculation Methods

5.2.1 Gasometric Method

Hydrogen evolution measurements were carried out at 303 and 333 K using a gaso meter designed for this purpose.

5.2.2 Thermometric Method

From the rise in temperature per minute, the reaction number (RN) and inhibition efficiency were calculated

6. TEST PROCEDURE

6.1 Corrosion Mechanism

The whole mechanism of corrosion in concrete at different concentrations of sulphuric acid is of two steps. The first step is by an ion exchange reaction between cations and hydronium ions followed by an electrophilic attack of acid protons on Si-O-Al bonds. In geopolymer concrete, the exchanged calcium ions diffuse towards acid solution reacting with sulphate ions resulting in formation of gypsum crystals. Deposition of gypsum crystals inside corroding matrix provides a protective effect inhibiting the total process of deterioration. Concrete is usually highly alkaline and is easily attacked by acid solutions. As the pH of the solution decreases, the stability of the cement binder is disturbed and may lead to severe degradation of the material. In case of geo polymer concrete, the gypsum layer formed provides a protective effect not initiating any kind of degradation. The first step of any corrosion process involves in the formation of shrinkage cracks which become wide enough later to allow diffusion of sulphate anions which react with the calcium ions thereby leading to deposition of gypsum crystals. The content of calcium in geopolymer concrete balances the negative charge of Al in the coordination structure. Therefore knowing that the extent of damage is dependent on the amount of CSH one may expect that a decrease in the calcium content of geopolymer cements results in a higher acid resistance by reducing the amount of CSH and producing a more protective corroded layer.



Figure 3 Corrosion test setup

6.2 Acid Attack Test

For acid attack test concrete cube of size 150 x 150 x 150 mm are prepared for various percentages of silica fume addition. The specimen are cast and cured in mould for 24 hours, after 24 hours, all the specimen are demoulded and

kept in curing tank for 7-days. After 7-days all specimens are kept in atmosphere for 2-days for constant weight, subsequently, the specimens are weighed and immersed in 5% sulphuric acid (H₂SO₄) solution for 60-days. The pH value of the acidic media was at 0.3. The pH value was periodically checked and maintained at 0.3. After 60-days of immersing in acid solution, the specimens are taken out and were washed in running water and kept in atmosphere for 2-day for constant weight. Subsequently the specimens are weighed and loss in weight and hence the percentage loss of weight was calculated.

7. TEST RESULTS

7.1 Accelerated Corrosion Technique

7.1.1 Specimen 1(Proposed Concrete)

Table 2 shows the Corrosion test results for specimen 1

Table 2: Corrosion test results for specimen 1

S.NO	DETAILS	VALUE
1	Area (cm ²)	188.39
2	Rest Potential (mV)	-371.68
3	Metal	Mild Steel
4	Metal factor	1159
5	LPR(Ohm.cm ²)	809840
6	B _a (mV)	34.225
7	B _c (mV)	30.628
8	I _{corr} (mA/cm ²)	8.678E-06
9	Corrosion Rate (mm/month)	0.0001010
10	Corrosion rate (mils/mo)	0.0039582
11	Intercept (mA/cm ²)	6.409E-06

Figure 4 shows the comparison of corrosion rate between Specimen 1 Vs specimen 2(CC)

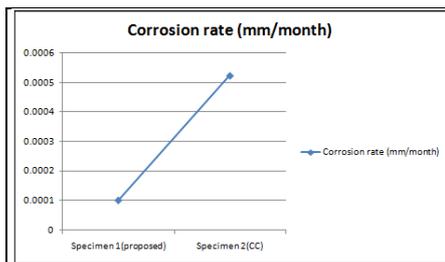


Figure 4 comparison of corrosion rate between Specimen 1 Vs specimen 2(CC)

7.1.2 Specimen 2(Normal Concrete)

Table 3 shows the Corrosion test results for specimen 2

Table 3: Corrosion test results for specimen 2

S.NO	DETAILS	VALUE
1	Area (cm ²)	188.39
2	Rest Potential (mV)	-215.19
3	Metal	Mild Steel
4	Metal factor	1159
5	LPR(Ohm.cm ²)	198910
6	B _a (mV)	43.204
7	B _c (mV)	43.297
8	I _{corr} (mA/cm ²)	4.727E-05
9	Corrosion Rate (mm/month)	0.0005241
10	Corrosion rate (mils/mo)	0.0215125
11	Intercept (mA/cm ²)	3.441E-05

Figure 5 shows the Specimen after corrosion testing



Figure 5 Specimen after corrosion testing

7.2 Acid Attack Test

Acid resistance was tested on 150 mm size concrete cube specimens at the age of 24 hours at 70°C of heat curing. The cube specimens were weighed and immersed in water diluted with five percent by weight of Hydro Chloric acid for 28 days. Then, the specimens were taken out from the acid water and the surfaces of the cubes were cleaned. Then, the weight and the compressive strength of the specimens were found out and the average percentage of loss of weight and compressive strength were calculated. Table 4 shows the Acid attack test Results

Table 4: Acid attack test Results

Mix Proportion	Comp. Strength At 28days In N/mm ²
M1(CC)	40.4
M2(PC)	39.8

Figure 6 shows the Graph shows acid attack test results

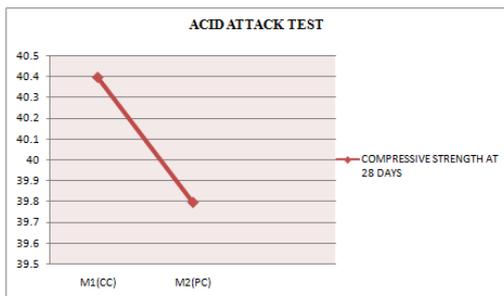


Figure 6 Graph shows acid attack test results

8. CONCLUSION

In our project focused on various green inhibitors that reduce corrosion of steel reinforcement embedded into concrete. Green inhibitors create minimum natural hazards to the environment. The study shows that green inhibitors are found to be extremely effective against rebar corrosion especially in chloride contaminated concrete. The extract of the leaves of *Phyllanthus amarus* used in this work exhibited good inhibition efficiency. The inhibition efficiency increases with increase in the concentration of the extract. The adsorption of the components of the extract on to the metal surface in 0.5N H₂SO₄ follows the Temkin adsorption isotherm. The more cost-effective corrosion protection options include epoxy-coated reinforcement in combination with another system such as a membrane, overlay, or corrosion inhibitor. The increase in the cost of a new deck with epoxy-coated steel over black steel reinforcement is very small, so even if it is not expected to improve the service life of a structure, epoxy-coated steel is a low cost backup to other corrosion protection methods.

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