Materials Research Proceedings **23** (2022) 269-275 https://doi.org/10.21741/9781644901953-30

Evaluation of Corrosion Inhibition on Rebar using Pomegranate Peel Extract as Organic Inhibitor

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Keywords: Pomegranate Peel Extract (PPE), Inhibitor, Carbonation, Chlorination, Corrosion

Abstract. Concrete is well known for its binding nature and Compressive strength. However, the tensile strength of the concrete is not so sufficient. Hence to improve the tensile nature and to enhance the flexibility in concrete steel rod is introduced as reinforcement. The rebar provides sufficient flexural strength to the concrete. Thus, the reinforced concrete is used in construction for its ease of access and long life. The major issue and problem faced by the rebar in concrete is corrosion which leads to reduction in the strength and age of the structure. The main objective of this research is to provide the protection for steel rebar against corrosion which improves the life of the structure. Many researchers worked on this to find a solution for corrosion. Corrosion inhibitors is one among the best method which helps us to protect the steel against corrosion. The pomegranate fruit which is highly antioxidant can fight against corrosion. An extract was obtained from pomegranate peel powder which can act as an organic inhibitor is used in this research. The inhibitor opted for this study is cheap, economic and renewable since it is organic. In this project the steel was coated with PPE extract and tested in different environment conditions and the efficiency of corrosion control was obtained with impressed voltage current. The result was compared with conventional uncoated rebar. The result proved that PPE is a good natural inhibitor for the steel, and the efficiency of the inhibitor is good enough to resist the corrosion in the rebar.

Introduction

Corrosion is one of the major distresses to the concrete which leads to the reduction in strength of the concrete. corroded rod will lose its bonding with the concrete, and leads to the structural failure. Thus, the solution for the corrosion in rebar is essential to increase the durability of the concrete and to enhance the life of the structure [1]. The pores in the concrete allows the atmospheric moisture and oxygen to it which is the main cause for corrosion [2]. Oher causes for corrosion are low concrete cover, presence of the salts like calcium, chlorine in the water which form carbonate and chloride. The concrete with pores in it allows the O_2 to pass through it and finally allow it to reach the surface of the steel and forms the ferrous oxide. Further the ferrous oxide compound forms the rust which ends in corrosion. In addition to oxygen the other agents that leads to corrosion are carbon-di-oxide and chloride. The chloride in the concrete when reacts with the steel forms (Fe-Cl) a complex called ferric chloride, this process called chlorination will end in the failure of the rebar. The root cause for chlorination process is thepermeability. It starts with process between the carbonic acid and the hydroxides present in the concrete [3]. The pH level of the concrete will increase rapidly to 12-13 due to the presence slaked lime. Chloride will act as the catalyst for the corrosion if it has sufficient concentration at the rebar surface to interrupt down the

passive layer over the rebar. The chloride ions will react with the Fe2+ when it dissolved in the solution and form an iron – chloride Complex. Further hydrolyses of the complex with the metal hydroxide will liberates chloride ions which will attack the steel [4]. Many researchers were working from a decade to find a better solution to resist the corrosion like steel coatings, cathodic protection, Electrical resistivity method, and inhibitors. Corrosion can restrict and the steel can be protected by using inhibitor is a well-known practice which has been used since 1960 [5]. Inhibitors are classified as organic and chemical inhibitors, organic type of inhibitors are preferred for their non-toxic nature, easy availability and low cost. Pomegranate is the fruit which has a rich anti-oxidant property, thus in this research an inhibitor is developed from the pomegranate peel. The extract from the pomegranate peel is developed as a natural organic inhibitor. The performance of inhibitor was studied and obtained with the help of the test like weight loss measurement, impressed voltage current test, and the pH. The results of a Pomegranate Peel Extract (PPE) coated rebar were compared with conventional steel.

Materials

Pomegranate. The anti-oxidant Nature of the Pomegranate consist of the chemicals which comprises of the structure that has effective corrosion inhibition performance [6]. The waste peel of the pomegranate fruit was collected from the juice shops. The peel was oven dried and powdered. The peel powder was sieved in 75 microns. The powder that passes the 75-micron sieve was taken for the extract preparation.

Fig 1. Pomegranate Peel Powder

Pomegranate Peel Extract Preparation. PPE is prepared with 20 grams of sieved powder. 20 gram of powder was dissolved in 100 ml of distilled water. The solution was boiled for 100 degrees Celsius and the solution was cooled for 24 hours at the room temperature. The solution has been filtered many times and the boiling process should be carried out till the solution changes to the form of extract. Finally, the obtained extract will be collected [7].

Test on specimens

Carbonation test. The two major phenomena in concrete which leads the path to corrosion are carbonation & chlorination. The protective layer of the concrete cover will be destroyed if carbonation happens in the concrete. in this an atmospheric CO_2 will reacts with the calcium hydroxide that present in the concrete. The strength and the quality of the concrete will depend upon the rate of the carbonation. Carbon attack will first destroy the passive film of concrete cover and it would break down the steel concrete bond, when it reaches the rebar. Thus, it leads to rust which finally ends in corrosion if sufficient moisture is present within the concrete. The carbonation process was explained with expression.

$$CO_2 + H_2O \rightarrow H_2CO_3 \quad (1)$$

$$H_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2H_2O \quad (2)$$

The depth of the carbonation in the concrete can be easily obtained with the help of the simple chemical test. The test can be carried out by spraying phenolphthalein indicator on the freshly broken concrete [2].

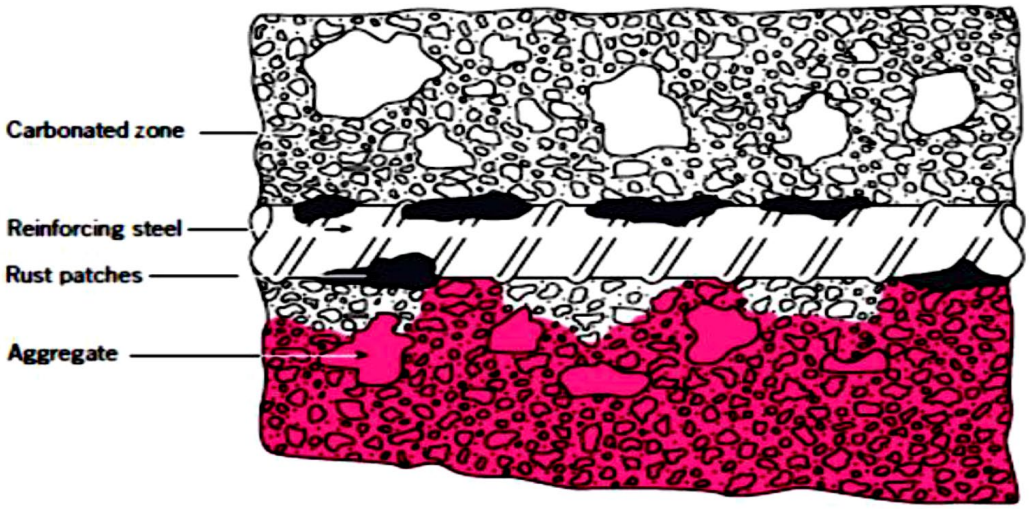

Fig.2. Carbonation test

pH & Chloride content test. The pH will increase rapidly with the presence of chloride. The test was conducted in a simple way by dipping the pH meter in the solution. The solution is prepared by dissolving the powder obtained by abrading the corroded steel in corroded region in the distilled water. Now the pH of the solution was observed by immersing the pH meter. If the value obtained in higher than 11.5, it shows that the solution is acidic and the rod is said to be corrosive.

Impressed voltage test. The corrosion is the long run process and it is not so easy to determine the corrosion rate of the steel in normal laboratory test and thus accelerated corrosion method is preferred to find the corrosion efficiency of the rebar. The impressed voltage current test used in this study is one of the accelerated corrosion methods. For this test PPE coated and uncoated conventional rebars of 200 mm length and 12 mm diameter were taken as the specimens. The rods were reinforced in the concrete such that 50 mm of the specimen to be exposed above the concrete cubes. The concrete with the rebar is made to be partially immersed in 3 % Na-Cl solution. The potential of 10 volt has been applied on the specimen as shown in fig 4. This set up has been kept without disturbed till the rod were attaining a weight loss of 20 %. The variation in time to weight loss for both rods has been observed and noted [8].

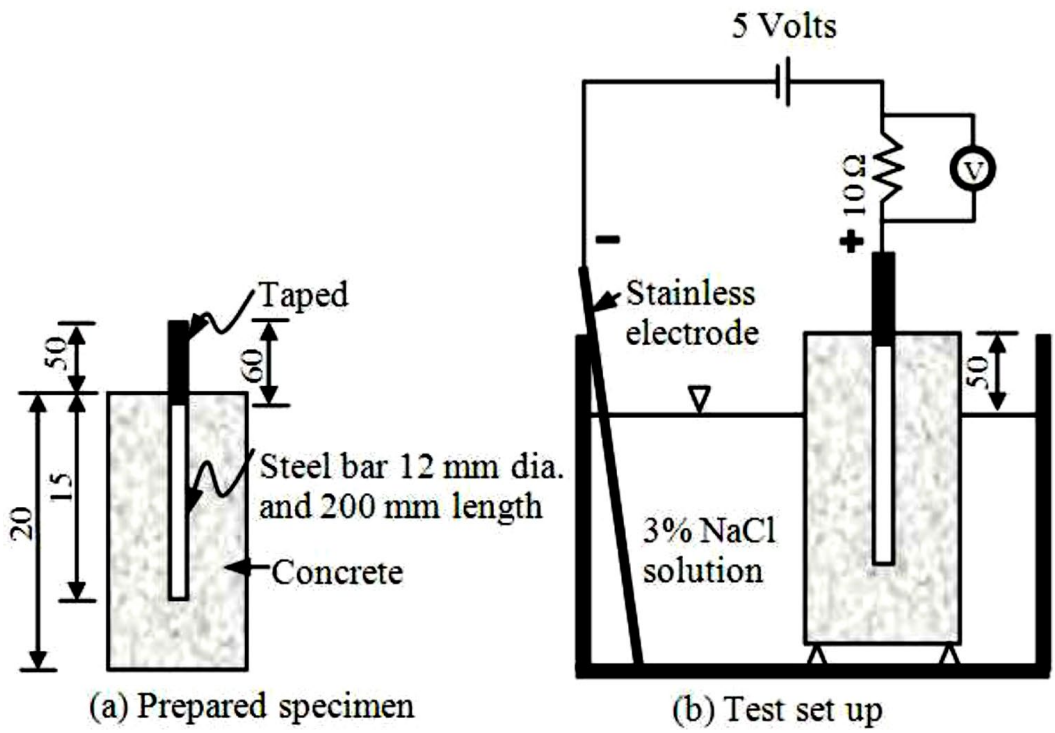

Fig 3. Impressed Voltage current Test

Weight loss measurement test. The corrosion rate of the concrete can be evaluated by the reduction the mass of the steel. In this test the steel samples opted for the test were tested in the two different acid solution HCl and H_2SO_4. The samples were cleaned dried and immersed in the 5% HCl and H_2SO_4 concentrations in 40 mg/litre at room temperature. The initial weights of the samples were noted as W1 before immersed into the solution. The samples were kept undisturbed for different exposure of time, 7, 14 and 28 days. The specimens were taken cleaned and weighed as W2. The loss of weight in the samples were obtained and estimated by using the following equation.

$$W = \frac{(w2-w1)}{A} \quad (3)$$

Were,

W – Weight loss in mg/cm^2

W1 & W2 are the weight of the samples before and after corrosion.

The inhibitor efficiency can be estimated by using the following expression

$$\eta = \frac{w-wp}{w} \times 100\ \% \quad (4)$$

Were,

η % = efficiency in percentage of the PPE Inhibitor,

W = weight loss in mg/cm^2 without pomegranate peel and

Wp = weight loss in mg/cm^2 with pomegranate peel added for the same exposure time for W.

Results & Discussion

Carbonation and pH test

Table1. Carbonation test

Specimen	Result	pH
Conventional steel	Dark pink colour	12.7
PPE coated steel	No colour change	6.2

Table. 1 shows the carbonated prone zone in the concrete and the pH value of the concrete. The phenolphthalein test explains that dark pink colour change observed in the conventional concrete shows that it was carbonated zone. The acidic nature of the solution which contains the dissolved constituents of the corroded samples. The pH value of the conventional steel with 12.7 clearly describes that it is prone to corrosion.

Impressed Voltage test

Table. 2. Accelerated corrosion Test

Specimen	Result
Conventional steel	20 %Weight loss in 8 hours
PPE coated steel	20%Weight loss within 11hours

Table 2 shows the weight loss comparison among the PPE coated and conventional steel sample. The constant potential was applied by the voltmeter to the samples and the weight loss of the samples were observed periodically. It seems that 20 % loss in weight of the samples occurs in 8 hours for the coated rebars whereas for the PPE coated rebars it took 11 hours. Thus, from the test it is observed clearly that the PPE as an inhibitor holds good against the corrosion.

Weight loss measurement test

Table.3. Weight loss measurement test

η in HCL		η inH_2SO_4	
Exposure in days	**η %**	**Exposure in days**	**η %**
7	81.20	7	83
14	88.21	14	86.23
21	94.23	21	95.21
28	95.10	28	94.60

Table 3 explains the inhibitor efficiency of the developed organic inhibitor. The Performance of PPE was studied and observed in two different acidic media HCl and H_2SO_4. Inhibition Efficiency of steel with PPE against corrosion was estimated. The table shows that PPE acts as a best inhibitor against corrosion.

Fig 6. η in HCl Vs η inH_2SO_4

The comparative study on efficiency of the inhibitor in HCl and H_2SO_4 is shown in the graph figure. 6. The figure describes that the efficiency rate of the inhibitor in acidic medium is strong enough to fight against the corrosion.

Conclusion

The observation on carbonation visualize that PPE coated rebars was not carbonated since there is no colour modification in the concrete contains the PPE coated rebars. The pink colour on the concrete with conventional rebars confirms the carbonation on it. The pH value of the concrete confirms the ingression of chlorine which leads to the chloride attack and ends in the corrosion. It was clearly explained with pH value greater than 11.5. The corrosion rate was studied by accelerated corrosion method with the 20 % weight loss of the samples. Inhibitor efficiency rate was evaluated and it proves that the Organic Inhibitor PPE hold good against corrosion the efficiency of the inhibitor reaches 95% as the time of exposure increased. Thus, PPE is suitable to act as an organic inhibitor.

Acknowledgements

Fig.4 the diagrammatic illustration of the carbonation test was taken from BRE part 1

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