Use of rice husk ash as natural inhibitors in reinforced concrete

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Abstract. Infrastructure in the coastal area is mostly made of steel and reinforced concrete steel which is susceptible to corrosion due to direct contact with sea water and also climatic conditions. There are several ways that can slow down the rate of corrosion reaction, one of which is by adding certain substances that act as inhibitors of corrosion reactions. This study is to determine the effect of using Rice Husk Ash as a natural inhibitor to reinforcing reinforced concrete reinforcement. The inhibitors used were rice husk ash mixed with reinforced concrete mixture as much as 5% and 10%. This corrosion measurement by calculating the weight lost from the reinforcement (inhibition efficiency). From the experimental results show that the higher the concentration given the lower the corrosion rate, and the optimal conditions obtained the effect of the use of natural inhibitors (rice husk ash) to reinforcing steel corrosion on the addition of 10% inhibitor of rice husk ash ash by 96%.

1. Introduction
Reinforced concrete is one of the most popular materials in the world of construction and civil engineering. Reinforced concrete is a composite material consisting of concrete and steel reinforced in concrete. Concrete is a mixture of cement, fine aggregate, coarse aggregate, air, water and sometimes other additional mixes which then harden to resemble stone. The main properties of concrete are very strong in holding compressive loads (high compressive strength) but weak in holding tensile forces. While steel is reinforcement used in reinforced concrete which has the property to withstand tensile forces. Infrastructure in the coastal area is mostly made of steel and reinforced concrete steel which is susceptible to corrosion due to direct contact with sea water and also climatic conditions. This causes the importance of controlling corrosion in infrastructure as an effort to prevent corrosion and increase the life time of the structure.

There are several ways to improve the performance of concrete, one of which is adding mineral additives such as pozzolan to the concrete mixture. One of the pozzolanic substances is rice husk ash. Some studies using rice husk ash to improve concrete performance include: The use of rice husk ash in a concrete mixture with a concentration of 7.5% produces optimum [1,2]. Suprati et al [3] examined the use of rice husk ash in the process of making paving blocks, the results of the study showed that using the husk ash can improve the quality of paving blocks.

The use of husk ash as an added ingredient in concrete mixes can improve its compressive strength, but the addition of ASP with a large enough concentration can reduce the compressive strength of the concrete [4]. Rice husk ash has the potential to be used as a substitute for cement because it can save the use of cement and accelerate the process of increasing the compressive strength of concrete [5].
The use of husk ash in concrete mixtures in addition to improving the properties of concrete can also function as an inhibitor in reinforcing steel. Several studies related to the use of rice husk ash as an inhibitor include: Research using black rice husk ash as an inhibitor, states that black rice husk ash extract can achieve an optimum efficiency of 91% at an extract concentration of 2000 ppm [6]. The use of rice husk extract in various concentrations (0, 10, 15, 20, and 25 ppm) with different soaking times shows that rice husk extract acts as a good inhibitor for mild steel. Rice husk extract was able to reduce the corrosion rate to 4.77 mmpy with 90% efficiency [7]. Research by using rice husk extract on carbon steel corrosion in acid media, resulted that the inhibition efficiency increased with increasing rice husk extract concentration. The highest efficiency of inhibitors was 94.24% with inhibitor concentration of 0.25 gr / ltr in sulfuric acid media while 89% inhibitor efficiency with inhibitor concentration of 0.20 gr / ltr in chloride acid media [8]. Utilization of rice husk and Potassium Iodide as inhibitors in mild steel in H2SO4 solution. The results stated that the addition of potassium iodide can significantly increase the efficiency of rice husk extract. The highest efficiency was 95.89% at 1250 ppm inhibitor concentration at 313 K (Pramudita et al, 2019). Rice husk ash is very potential to be developed into a safe and environmentally friendly bio-inhibitor [7,9]. Research using husk ash at 5% of the weight of cement due to acid rain. The results showed a decrease in the amount of corrosion that occurred [10]. The use of corrosion inhibitors in specimens shows that corrosion inhibitors have a tendency to protect reinforcement from corrosion [11,12]. The addition of soda ash to concrete mixes shows better corrosion protection than concrete samples without soda ash [13].

2. Literature Review

2.1. Concrete
Concrete is a composite or a mixture of several rocks in the form of aggregates (fine and coarse) and added with cement paste, it can be said that cement is a binding agent between fine and coarse aggregates and water.

2.2. Reinforcing steel
Reinforcing steel is steel used in concrete construction or better known as reinforced concrete. Reinforced concrete containing steel and planned on the basis that the material is used to bear the forces. Reinforcing steel in concrete structures serves to withstand the tensile force.

2.3. Corrosion of Concrete Reinforcement Steel
Corrosion is the process of damage to material caused by the influence of the material environment or better known as rusting. Corrosion that occurs in reinforcing steel is an electrochemical reaction involving the transfer of electrons from one type of material to another. This reaction occurs if there is an anodic or oxidation reaction and a cathodic or reduction reaction.

2.4. Inhibitors
An inhibitor is a chemical that when added to a certain amount of concentration in an environment, can effectively reduce the rate of corrosion. Inhibitors react with metal surfaces exposed in an environment and will provide protection on these surfaces.

In the use of inhibitors can be determined the efficiency of the use of these inhibitors. Calculation of efficiency is obtained through the percentage decrease in corrosion rate with the addition compared to the corrosion rate without adding inhibitors. This calculation can be described as follows.

\[
\text{inhibitor efficiency} = \frac{X_a - X_b}{X_a} \times 100
\]

\[X_a = \text{corrosion rate without inhibitors}\]
Xb = corrosion rate with inhibitors

2.5. Rice husk ash

Rice husk ash is obtained by burning rice husk in a controlled manner without causing environmental pollution. When properly burned, the result has high SiO₂ content and can be used as a concrete additive. Rice husk ash exhibits high pozzolanic characteristics and contributes to producing concrete with high strength and impermeability. Rice husk ash basically consists of amorphous silica (90% SiO₂), 5% carbon and 2% K₂O. High levels of silica in rice husk ash can be used as a basic material for making silica-based material. One of the uses of silica is as an anti-corrosion carbon steel coating.

Corrosion Rate Analysis Weight Loss Method

This method is used based on the weight loss experienced by the metal by calculating the mass of the metal that has been cleaned of the oxide and the mass is expressed as the initial mass and then carried out in a corrosive environment such as seawater for a certain time. After that the mass is recalculated from a metal after it has been cleaned from the corrosion formed and the mass is stated as the final mass. By taking some data such as submerged surface area, immersion time and density of the metal tested, a corrosion rate is produced. According to ASTM G31-72 the corrosion rate is calculated using equation 2:

\[
\text{Corrosion Rate (CR)} = \frac{K \times W}{A \times T \times D}
\]

K: Constants
T: Time of exposure
A: Area (cm²)
W: Losing weight (grams)
D: Density (\(\rho\)) gr / cm³

3. Research Method

3.1. Test Specimens

The sample used was Ø10 mm reinforcement steel with a length of 300 mm totaling 36 pieces. The concrete mix material consists of portland cement, fine aggregate from Loto quarry beach sand and Togafo quarry sand. Rough type of broken stone from the Togafa quarry. The water used is fresh water and sea water with a salinity of 3.5%. Concrete mixture is divided into 3 types including: without the addition of rice husk ash, with the addition of rice husk ash 5%, and 10%. Concentration of rice husk ash on cement weight. The specimen is cylindrical in diameter 101.6 mm and height 300 mm, steel reinforcement is planted as deep as 200 mm. Details of the test specimen as shown in Figure 1. The test specimen was immersed in seawater with a salinity of 3.5%.

![Figure 1. Details of the specimen](image)
3.2. Test Set-Up
This test is carried out using currents as a tool to speed up the corrosion process in each sample soaked in a 3.5% NaCl solution, shown in Figure 2.

![Figure 2. Corrosion testing mechanism](image)

In this test the series is arranged in series using carbon graphite as the cathode and reinforcing steel as the anode. This testing process refers to ASTM C 31-72. This test is carried out using a 5 V DC current that comes from the power supply as a tool to speed up corrosion. This process aims to accelerate the transfer of Fe + ions and electrons.

4. Results and Discussion

4.1. Visual Observation
Corrosion begins at the part of the steel facing the cathode, this occurs because when facing the cathode it automatically makes it easy for the steel to release electrons from the anode to the cathode. Besides corrosion also occurs more quickly on the part between the reinforcing steel covering the concrete. Besides corrosion also occurs faster on the part between the steel reinforcement that is free with reinforced steel reinforced concrete, this happens because the homogeneity of the steel surface is due to different concentrations of O2. Changes in concrete and steel surfaces as shown in 3 and figure 4.

![Figure 3. Changes in concrete after corrosion testing](image)

a. before testing    b. after testing
4.2. Corrosion rate
The corrosion rate of reinforcement planted in concrete specimens using fresh water and seawater as a mixing material, reinforced concrete specimens using rice husk ash with variations of 0%, 5% and 10% of the weight of cement. Corrosion rate can be seen in Figure 5.

From Figure 5 it can be seen that with the addition of the concentration of rice husk ash (inhibitor), the corrosion rate decreases in both types of test specimens using fresh water and seawater as a concrete mixing material.

![Figure 5. Graph of corrosion rate to inhibition concentration](image)

### 4.3. Efficiency of inhibitors
The addition of rice husk ash can increase efficiency to reduce the rate of corrosion, the higher the concentration of rice husk ash (inhibitor) is given, the higher the efficiency of the inhibitor. This is
evidenced by the addition of a 10% inhibitor able to reduce the rate of corrosion for all variations of the concrete mixture.

![Graph of the efficiency of inhibitors on the concentration of inhibitors](image)

**Figure 6.** Graph of the efficiency of inhibitors on the concentration of inhibitors

### 4.4. Morphological structure of corrosivity

To see the process of corrosivity on steel and concrete surfaces is done using Scanning Electron Microscopy (SEM) instrumentation. This analysis is to see the morphological structure of steel and concrete surfaces in the corrosion process. Display of the results of the analysis using SEM instrumentation is presented in the form of microscopic images of the surface of steel and concrete materials in the range of 500 to 30,000 times magnification, with an area of surface observation between 1-2 micrometers. In general, based on analysis using SEM instrumentation shows that, steel surfaces in some conditions both without and with the addition of inhibitors damage occurs due to the corrosion process. Whereas on concrete surfaces, the surface morphology structure of concrete looks more stable when compared to steel surfaces. Basically, the corrosion activity which is the oxidation process of iron (ferum) steel-based materials only occurs in certain metals, so this activity does not occur in concrete material which is based more on silica from sand or cement. From the surface morphology structure of steel corrosivity, it can be seen that steel with the addition of 4% (c) tobacco extract inhibitors has a tighter surface structure than the others. Like in picture 7.

From Figure 8 it can be seen that the appearance of the morphological structure of the concrete surface shows the uneven surface of the concrete in some concrete samples both without and using inhibitors. This condition can be caused by the fact that it is not dense and dense with concrete surfaces, or it can also be a process of deposition of an oxidation reagent matrix (a corrosion agent) attached to the surface of the test concrete.
Figure 7. Morphological structure of steel corrosivity using SEM, magnification of 20,000X.

Figure 8. Concrete morphological structure with SEM magnification 1000X

5. Conclusions
The effect of using rice husk ash inhibitors with a concentration of 5% and 10% on the corrosion rate of reinforcing steel in the corrosive media conditions of the salt showed that the inhibitor concentration was inversely proportional to the corrosion rate meaning that the higher the concentration of the inhibitor used the lower the corrosion rate of the reinforcing steel.

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