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Effect of Zinc Coating Thickness on the Corrosion Behavior of Galvanized Corrugated Iron Sheets in Fresh Water, Brine (3.5%NaCl) and Sea Water Environments

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Abstract- Corrugated iron sheet is the most widely used material for making roof of the low cost houses. The main problem of these sheets is corrosion. In order to protect corrosion, corrugated iron sheets are galvanized. In the market, there are varieties of galvanized corrugated iron sheets with different coating thickness levels. The purpose of this study is to know the effect of zinc coating thickness on the corrosion behavior of galvanized corrugated iron sheets. For this regard, two types of galvanized iron sheets were collected from the local market. Thickness of the two sheets was measured by using coating thickness meter. Then corrosion test was done in three different environments i.e. fresh water, sea water and brine (3.5% NaCl solution) in a water/salt spray bath. After 35 hours exposure time, samples of each group were investigated and weight losses were measured. The samples were exposed in the corresponding environment for another two cycles (35 hours each). For each cycle, same investigation procedure was followed and weight losses were measured. Finally it was found that, with increasing the thickness of zinc coating, corrosion resistance of the galvanized corrugated iron sheet also increases. In this paper, the underlying corrosion mechanisms, response of the samples toward different environments and other details will be discussed.

Keywords- *Coating thickness, Galvanized corrugated iron sheet, Corrosion resistance.*

I. INTRODUCTION

Corrosion can be defined as the chemical or electrochemical reaction between a material and exposed environment that causes the subsequent deterioration of the material [1]. It causes serious damage to all engineering applications and infrastructure and becomes a threat to public safety. It also has a huge economic impact on the society [2].

Corrugated iron sheet is a remarkably cheap material used for making the roof of the houses at low cost normally in rural areas. During their uses, they get exposed in different environments like marine, acid rain, fresh water etc and get corroded easily [3]. To protect this corrosion a wide range of metallic coating such as zinc, zinc-aluminum alloy etc and organic coating like paint are used and this method appears to be the cost effective method of corrosion control. But zinc is most widely used because of its low cost, high performance, ease of manufacturing and availability and that is why these sheets are galvanized. [4-5]. From previous research it was found that, zinc coating provides cathodic protection to substrate steel [4]. It acts as sacrificial anode and in effect the thicker the top coating, the more it provides protection against corrosion [7].

As galvanized corrugated iron sheet get exposed to different environments during service, its response towards corrosion in different environments is important. According to American Galvanizers Association, natural fresh water, lake water, rain water, sea water etc has different constituents and that's why the responses of galvanized steel are different in different environment. Sea water contains high amount of Ca^{2+} and Mg^{2+} ions and these ions form protective scale on galvanized steel. [6] The harder the percentage of these ions, the harder the water is considered. From the experiment carried out by American Galvanizers Association it was found that corrosion rate of galvanized steel is higher in soft water than the hard water [2].

Though many researches have been conducted to study the corrosion behavior of galvanized steel in different environments, the particular case of galvanized corrugated iron sheet is scarce. In this work an attempt was taken to study the corrosion behavior of galvanized corrugated iron sheet in three different environments i.e. fresh water, brine (3.5% NaCl) and sea water and to investigate the effect of zinc coating thickness on the corrosion rate of it. Here salt spray bath was used to conduct the corrosion test.

II. MATERIALS & METHOD

Two galvanized corrugated iron sheets of 0.42mm thickness were brought from local market. From these two sheets, two samples of 30cm×1.7cm size were cut for coating thickness measurement. A digital coating thickness meter was used to determine the thickness of the specimens. The tip of the machine was placed on top and bottom surface of the specimens so that coating thickness of both surfaces can be determined. Thickness was measured from eight spots of the each sample and approximately one inch gap was kept between two nearest spots.

For corrosion test, samples of 10cm×1.7cm size were cut and a hole was made in each specimen by using a drilling machine. In both cases, samples were cut by hand shear cutting machine. The specimens were then cleaned with water and detergent to remove the dirt. Water was removed from the specimens by using tissue paper. The specimens were then placed in an oven at 110°C for 2 hours to remove all the moisture and after removing from the oven, weight (W_i) of the each specimen was measured using an electronic balance.

To conduct the corrosion test, specimens were placed into a salt spray bath where they get exposed to the fresh water environment. Here, water was collected from the tap of the laboratory. In the salt spray bath, specimens were placed on the rack hanging from the rod by using polymeric string which is not usually corroded in this environment. Temperature in the exposure zone was 35°C whereas air saturated tower temperature was 46° C and air pressure was maintained 12 Psi. Samples were kept exposed in that environment for 5 days (35hrs). Five days (one cycle) later, specimens were taken out of the chamber, polished with emery paper to remove the corroded products, cleaned again with detergent & water and dried in an oven at 110°c for 2 hours. Final weight (W_f) of the each specimen was then taken. After that, the specimens were again kept into the salt spray bath in fresh water environment and same procedures were followed for another two cycles.

The same corrosion test were conducted again for two other environments i.e. brine (3.5% NaCl) and sea water. Brine was prepared by the dissolution of 3.5% reagent grade NaCl salt in distilled water and sea water was collected from the Bay of Bengal. The difference between the two weights stated above denotes the weight loss due to corrosion. Corrosion rate in mdd was calculated by the following formula:

Corrosion rate = $\frac{\Delta W}{TA}$

Where, ΔW= weight loss due to corrosion in mg.

T= Exposure time in days.

A= Area of the sample in dm2.

III. RESULTS & DISCUSSIONS

Comparison between the coating thicknesses of two galvanized CI sheets measured by coating thickness meter is shown in the figure 1. From the figure it can be seen that galvanized CI sheet 2 (19.14 µm on average) has the higher zinc coating thickness than the galvanized CI sheet 1 (13.78 µm on average). It also depicts that top surface of the galvanized CI sheet has thicker coating than the bottom surface. It might be given deliberately as top surface is exposed to more corrosive environment than the bottom surface during service.

In general the response of metal towards corrosion is different in different environments [2]. Here the responses of two galvanized CI sheets towards corrosion in three different environments i.e. fresh water, brine (3.5%NaCl) & sea water with respect to exposure time are shown in figure 2. In all three cases scattered corrosion rate with exposure time is observed but in different environments their responses are different. In the following paragraphs, the corrosion behavior of galvanized CI sheets of different thickness in various environments is discussed separately.

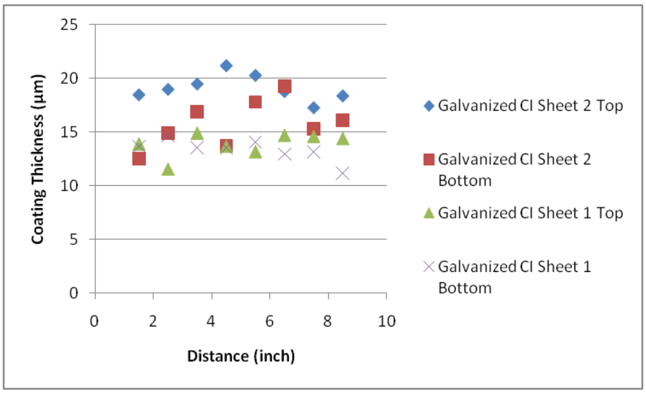

Figure 1. Comparison between the thicknesses of two galvanized CI sheets.

A. *Corrosive Environment: Fresh Water*

Galvanized CI sheets exposed in fresh water in a salt spray bath show decreasing corrosion rate with increasing exposure time [Figure 2(a)]. Here the water was collected from the tap of the laboratory. So, it contains some amount of chlorine and it might collect some oxygen from atmosphere during its falling [American Galvanizers Association]. Initially these reactants are high in the environment and as zinc is susceptible to corrosion because of the presence of these reactants, corrosion rate is high at the beginning. But with increasing time, the inhibition of corrosion rate results as the amount of reactants in the environment decreases [2].

B. *Corrosive Environment: Brine*

Galvanized CI sheets are exposed in the 3.5% NaCl solution in the same salt spray bath under the same temperature and pressure. This environment contains very high amount of chlorine and as chlorine is severely corrosive to zinc, initially corrosion rate is very high [6]. As most of the zinc corrodes early, decreasing Chloride concentration with time inevitably occurs and as a result corrosion rate also decreases. From the figure 2, it can also be observed that corrosion rate in brine (3.5% NaCl) is higher than the fresh water environment and the reason for that is more corrosive environment due to the higher chlorine content than the fresh water.

C. *Corrosive Environment: Sea Water*

Sea water is good electrolyte and it contains very high salt in the form of chlorides and detrimental sulfides. Corrosion rate in sea water is also affected by temperature, oxygen content, biological organisms and carbonates [American Galvanizers Association]. That is why corrosion rate with respect to exposure time in sea water is much different than the other two. Corrosion behavior in this case shows increasing trend but the rate is not higher than 3.5% NaCl environment [figure 2]. Initially corrosion rate is very low because sea water contains high amount of magnesium and calcium and they form protective film of carbonates on zinc surface. With increasing time, Ca and Mg ions become low in content and the surface of the sample get exposed to the environment and in effect corrosion rate also increases [American Galvanizers Association].

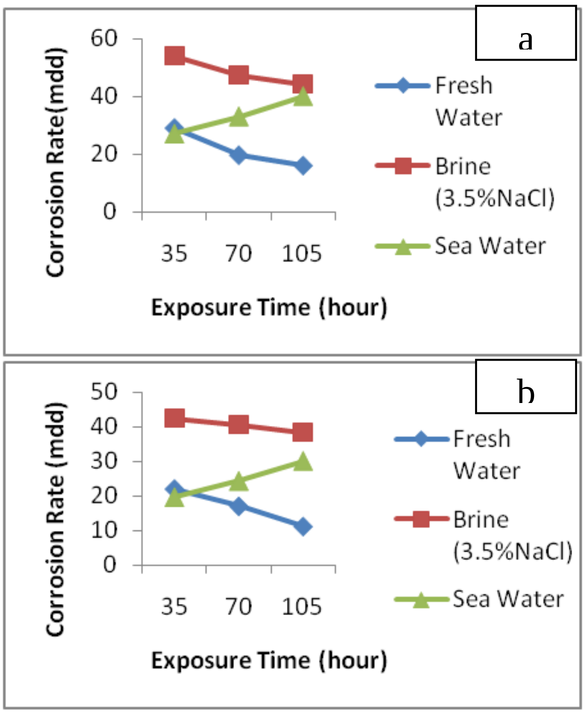

Figure 2. Corrosion rate with exposure time in three different environments. (a) Galvanized CI sheet 1 (b) Galvanized CI sheet 2.

The responses of the specimens towards corrosion in three different environments under same condition can be seen from the figure 3.

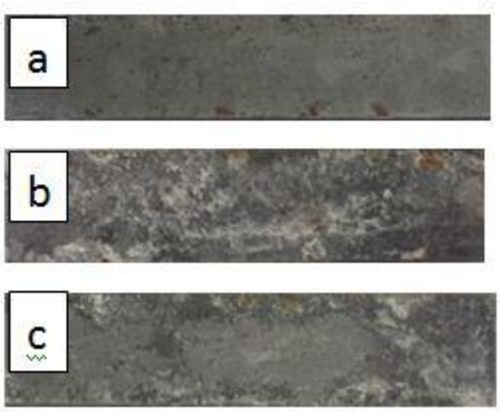

Figure 3. Samples after salt spray test in three different environments for an exposure time of 70 hours. (a) Fresh Water (b) 3.5% NaCl (c) Sea Water.

D. Coating Thickness & Corrosion

Corrosion rate (mdd) of galvanized corrugated iron sheets of different zinc coating thickness after exposure in three different environments for 70 hours is shown in figure 4. The figure depicts that corrosion rate decreases with increasing coating thickness. That is galvanized CI sheet containing thicker zinc coating is less susceptible to corrosion than the thinner one. So it concludes that zinc coating acts as a protective barrier against corrosion.

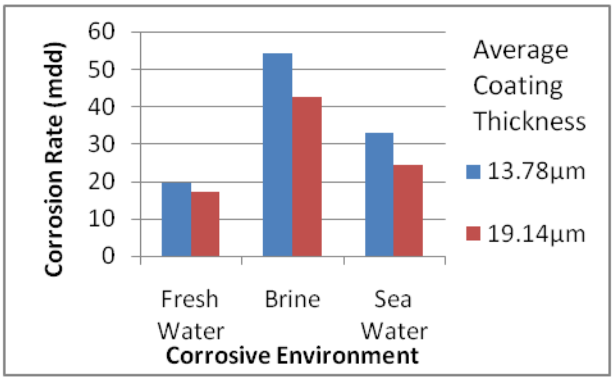

Figure 4. Effect of Coating Thickness on the Corrosion rate of galvanized CI sheets after being exposed in three different environments for 70hours.

IV. CONCLUSION

The corrosion of galvanized corrugated iron sheets with different coating thickness were investigated in different corrosive environments using salt spray bath. Weight loss technique was used to calculate corrosion rate. Based on the experimental results and analysis the following conclusions have been drawn:

- Galvanized corrugated iron sheets having thicker zinc coating are less susceptible to corrosion in all environments.
- In the case of fresh water and brine (3.5%NaCl), corrosion rate decreases with increasing exposure time. Whereas the opposite happens in case of sea water.
- Among the three environments brine is more corrosive than fresh water and sea water. But the result also depicts that, in the long run sea water can occur more damages than the other two in case of galvanized corrugated iron sheet.

V. ACKNOWLEDGMENT

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