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Studying Corrosion Resistance of Different Roofing Sheets in Ghana

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ABSTRACT

There is a great request for housing in Ghana and as a result, the selection of durable roofing sheets has become very significant as roofing plays a vital role in building construction. This investigation aimed to see how corrosive compounds affected the most predominant roofing sheets on the Ghanaian market. One-star galvanised Japan [G1*Jap], galvanised coated [GC], Aluzinc three-star galvanised [AlZn3*], one-star galvanised Indi [G1*Ind], and aluminium [Al] were the most common on the market and were used. The corrosion experiments were carried out by putting various samples in five jars containing various chemicals for varying amounts of time. A computer-interfaced optical microscope (Leica DM 2500M) was employed to study the surface microstructures of the corroded surfaces, with the corrosion rates per day being determined. Average corrosion rates for one-star galvanised Japan [G1*Jap] roofing sheets were the most corrosive resistant whilst [AlZn3*] roofing sheets were the least resistant to corrosion. Generally, G1*Jap roofing sheet stood out as the best roofing sheet in terms of corrosion resistance. These numbers led to the conclusion that G1*Jap roofing sheets were the most corrosion-resistant when compared to the other roofing sheets. The most corroded roofing sheets were Aluzinc three-star galvanised [AlZn3*] roofing sheets.

1. Introduction

Throughout history, man has used various natural resources and technical means to produce ecologically safe, functional roofing, including wood, mud, straw, tiles, shingles and other building materials. Given that roofing is simply as excellent as the resources accessible, each civilisation used different methods, tools, and materials to construct its roofs. The completed product and the resources needed to make it is a true reflection of how technologically progressive and innovative the world has become. Although most of the expansion in the roofing sector occurred in the previous 200 years, the history of roofing dates back further [1]. Different roofing types were initially experimented with by the Greeks and Romans [2].

Meanwhile, local resources are still used to create roofing styles today. However, a wider choice of more expansive materials is now accessible in various marketplaces worldwide. Metal sheets, slate and felt are among the commonly used roofing materials today. Nevertheless, it is difficult to forecast the roofing industry's future and what technologies will impact it, the only certainty with roofing is that it will continue to change indefinitely while it has drastically evolved over the years [3].

Currently, there are numerous types of roofing in use, with metal roofing [4, 5] and non-metal roofing [6, 7] being the two most prominent. Roofs can also be classified as

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sloping [8] or flat [9]. Corrosion science has existed for a very long period as a result of the early usage of metals in society. Consequently, corrosion science has been formed as a scientific subject which aimed to understand the rates of corrosion of materials in various situations to develop more lasting metallic materials [10].

Considering that it negatively impacts the economies of both rich and developing nations, corrosion is a global issue that has to be tackled by the educational and industrial sectors [11–13]. It is an intrinsic feature of pure metals except for silver, gold and platinum, and the pace at which it occurs is greatly influenced by the environment [14–16]. The nature of the surrounding environment will determine the nature of the pollutant causing the corrosion. For instance, in an industrial location, corrosion might be caused by acid rain as a result of the toxic chemical available, meanwhile, in a coastal area, the probable cause of corrosion will be seawater.

Fatukasi et al. modelled the impact of HNO3 (acid raid) on weight loss because of corrosion on some selected roofing sheets comprising of stone coated, zinc corrugate, embossed aluminium, Aluzinc corrugated and so on. In the end, it was concluded that the embossed aluminium was the least corroded. This is because the embossed aluminium has finer grains which reduced inter-granular corrosion. The zinc corrugated roofing sheet had the worst level of corrosion. The embossed aluminium roofing sheet has the minimum loss of weight and corrosion level among the selected roofing sheets in an acidic medium [17].

Similarly, Akuma et al. modelled corrosion of roofing sheets in acid rain using four different molar concentrations of H_2SO_4 and HNO_3 on aluminium, zinc, Aluzinc, galvanised steel and stone-coated roofing sheets [18]. In the end, it confirmed Fatukasi et al’s works that a high percentage of aluminium-based roofing sheets are the best in preventing corrosion caused by acid rain, with the reason being that the rate of corrosion of the roofing sheet is effectively decreased by the establishment of a passivation layer on aluminium-coated items.

Pawar et al. also showed that even though aluminium-based materials are the best, installation and maintenance are essential for the roofing sheets to fully benefit from the outstanding corrosion resistance and extended life offered. [19]. For instance, in aluminium smelting plants where there is the release of fluorine fumes, corrosion can be mitigated by coating with epoxy.

The two researchers also agree that the level of corrosion caused by acid rain is dependent on several other factors such as the concentration level of the pollutant, exposure time and so on. Such that in Akuma et al’s case the H_2SO_4 solution showed more aggression than the HNO_3 solution.

Therefore, this research aims to examine the impact of corrosion on various locally manufactured and imported roofing sheets in the Ghanaian construction sector. Corrosion is a naturally occurring process that tries to restore metals to their initial, steady state [19]. As a consequence of the various types of roofing sheets available in the country, these tests are carried out to determine the strength of these metal sheets. These characteristics will be used to pick a roofing material with a long-life cycle. This is because the amount and severity of corrosion are determined by the material used in the roofing sheet [20–23] as well as the environment in which the roofing sheet is located [19, 24–30].

There is a strong demand for housing in Ghana, and the selection of a long-lasting roofing sheet as well as the site where a certain type of roofing sheet will be utilised is critical given that roofing plays a significant role in building construction.

2. Methodology

Herein, roofing sheets were cut into 5 cm x 2 cm dimensions for corrosion testing, with holes drilled at one end, as illustrated in Figure 1, and hung in each solution by a nylon thread. For the corrosion experiments, the samples were placed in six jars containing seawater, rainwater, hydrochloric acid, sodium hydroxide (NaOH) and acetic acid (CH_3COOH) for 6, 54 and 90 days.

Each roofing sheet's initial mass was measured and recorded as m (t0). The 0.5 M NaOH solution, 0.2 M HCl solution, 0.5 M CH_3COOH solution, seawater and rainwater were all kept in 25 glass jars.

The pH of each solution was measured at the beginning of the experiment, and each glass jar was closed with a lid to stop the fluid from evaporating over time. After 6, 16, 25, 54, 60, 75, 90 and 101 days, the corrosion specimens were removed from each glass jar to assess the alteration in shape, colour and mass [m(t)]. Then, at every stage, a specimen was taken from the solution where it was cleaned and rinsed in distilled water and ethanol to halt the reaction. Subsequently, the specimen was dried and weighed to find the mass loss.

Surface metallographic examinations were performed on the roofing samples using a Leica DM 2500M optical reflection microscope. Gravimetric analysis was used to estimate the mass loss m (g) relative to the beginning and ending mass after each defined period before the corrosion testing.

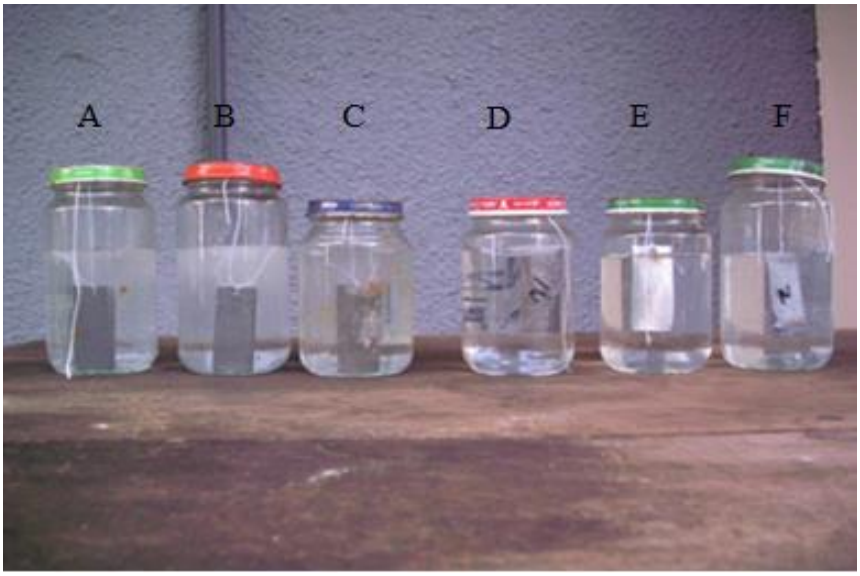


Figure 1. Specimen suspended in (a) rain water (b) sea water (c) 0.5 M NaOH (d) 0.5 M CH3COOH (e) 0.2 M HCl solution for corrosion test (f) Distilled water

2.1 Preparation of sampling containers

Procedures were used to remove or reduce any contamination of the samples to achieve reliable results. After soaking in HNO_3 overnight, the sample containers were cleaned with distilled water and then dried. Afterwards, the pH of several of the dry containers was measured after they were filled with distilled water; if the pH was 6 or 7, the sample container was ready to use; if not, the sample container was cleaned and the pH was rereviewed. Finally, test containers were labelled for easy identification.

2.2 Surface microstructure of corroded samples

The deteriorating roofing samples were placed on a plasticine slide one by one, levelled and studied under a microscope. One of the objective pieces was chosen for magnification (5X). The focusing ring was manipulated by peering into the eyepiece lens until proper sharpness was achieved. Surface microstructural tests were carried out on each roofing sample before and after they were immersed in the different solutions for 6, 54 and 90 days, as shown in Figure 2.

3. Results and discussion

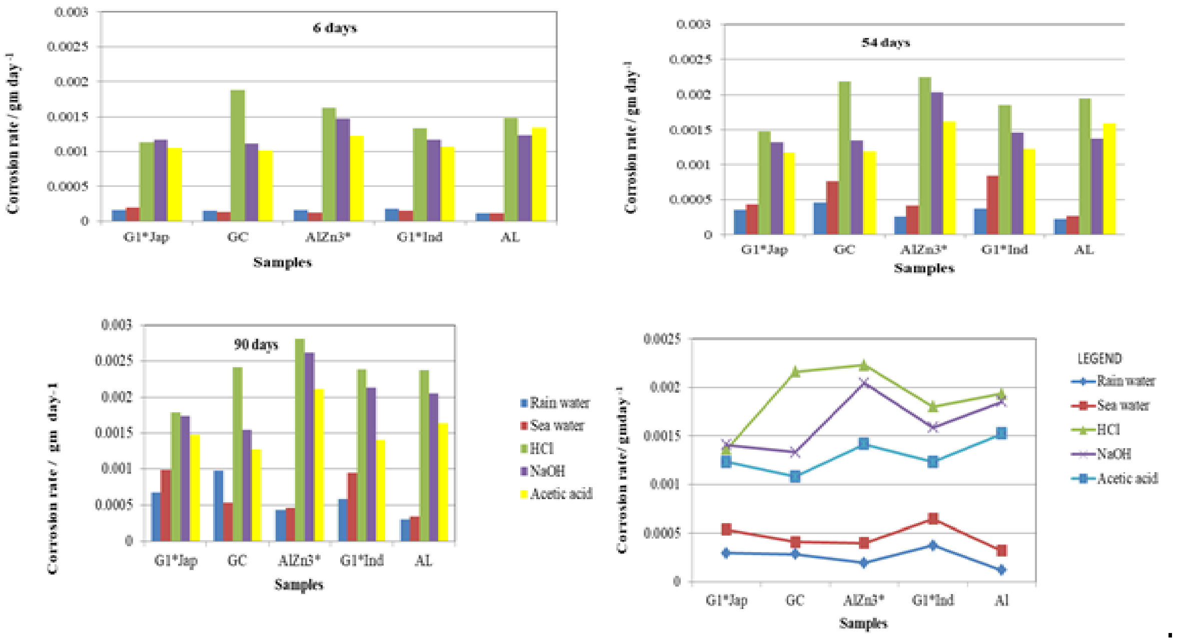


Figure 2. Corrosion rates (gm/day) for various samples for 6, 54 and 90 days

The corrosion per day for the various samples is shown in Figure 2 for three different periods (6, 54 and 90 days). When can be observed, the rate of corrosion for each sample rises as it is immersed in the various compounds for longer periods? This is to be expected because of the extended exposure durations. Consequently, the longer the exposure time the more the sample will corrode up to a point beyond which it will start to decline and eventually reach a nearly constant level [21].

On GC, HCl caused the most corrosion (0.001877 gm/day), closely followed by AlZn3* (0.001633 gm/day) and G1*Jap (0.001133 gm/day). During the same period, AlZn3* (0.001476 gm/day) was the most corroded by NaOH solution, whereas GC (0.00116 gm/day) was the least. CH3COOH corrosion was greatest on Al (0.001345 gm/day), followed by AlZn3* (0.001224 gm/day) and G1*Jap (0.000547 gm/day). In addition, Al was the least influenced by rain and seawater (0.000111 gm/day and 0.0001164 gm/day, respectively).

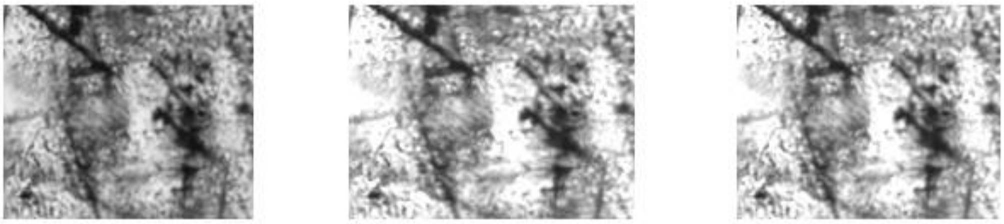
This is because when a scratch occurs on Al's surface, it can produce an oxide. Sea water had the greatest impact on G1*Jap (0.0001933 gm/day), whereas rain water and sea water had the greatest impact on G1*Ind. Consequently, the HCl acid solution corroded the most during 6 days, followed by NaOH and rainwater corroded the least.

HCl corrosion was highest on AlZn3* (0.001855 gm/day) over 54 days, followed by Al (0.001953 gm/day) and GC (0.002189 gm/day) had the lowest value. During the same period, NaOH caused the most corrosion on G1*Ind (0.001459 gm/day), followed by Al (0.001593 gm/day) and AlZn3* (0.002935 gm/day). The bar charts in Figure 3 (c) depict the effect of various solutions on each roofing sample over the course of 90 days.

As shown in Figure 2 (d), the mean corrosion per day for solutions with great acidity rose during the course of the research, thereby indicating that the metal dissolution was expedited. This outcome is predicted because the acidic component of the HCl acid solution increases both H+ and Cl- ion concentrations. In HCl solutions, the H+ ion is more important than the Cl- ion for iron dissolution.

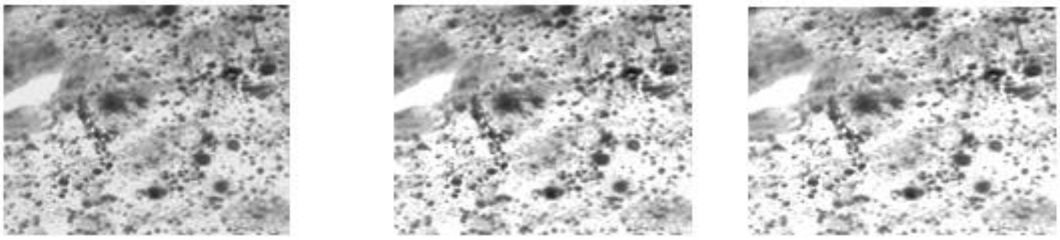
The equation depicts the evolution of hydrogen gas and the mass loss that occurs.

$$Fe\ (solid) + 2\ H^+ == Fe^{2+} + H_2\ (gas)$$



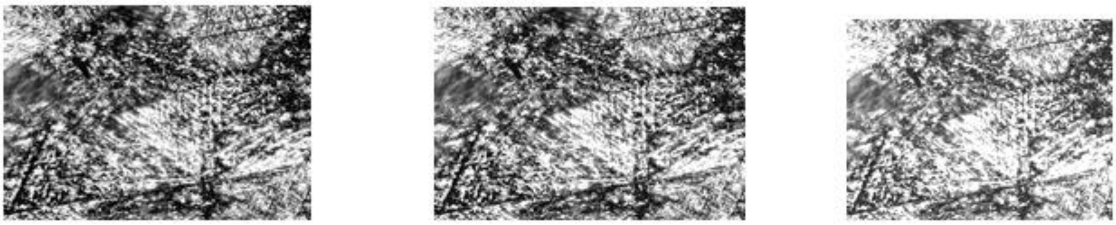
(a) (b) (c)

Figure 3. G1*Jap roofing sheets' microstructures after being submerged in 0.2 M HCl for (a) 6 days, (b) 54 days, and (c) 90 days.



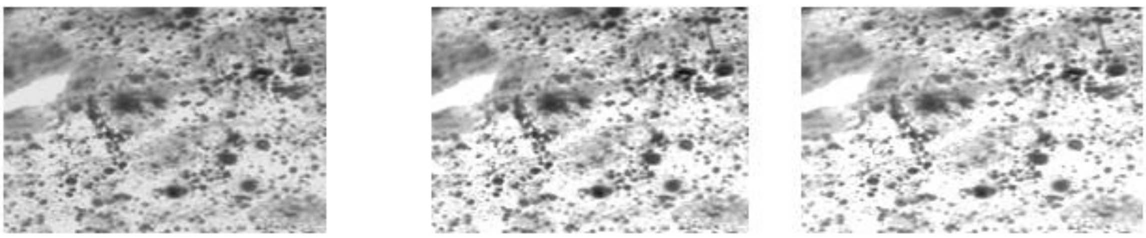
(b) (b) (c)

Figure 4. GC roofing sheets' microstructures after being submerged in 0.2 M HCl for (a) six days, (b) 54 days, and (c) 90 days.



(a) (b) (c)

Figure 5. $AlZn^{3}$* roofing sheets' microstructures after being submerged in 0.2 M HCl for (a) six days, (b) 54 days, and (c) 90 days.



(a) (b) (c)

Figure 6. G1*In roofing sheets' microstructures after being submerged in 0.2 M HCl for (a) six days, (b) 54 days, and (c) 90 days.

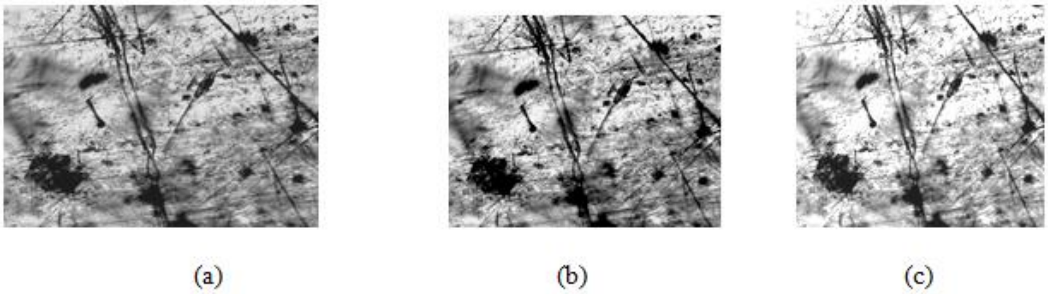


Figure 7. Al roofing sheets' microstructures after being submerged in 0.2 M HCl for (a) six days, (b) 54 days, and (c) 90 days

Table 1: Daily corrosion rates for submerged samples in diverse sample solutions for 6 days

Sample	**G1*Jap**	**GC**	**AlZn^{3*}**	**G1*Ind**	**Al**	**Total (gm day^{-1})**
HCl	0.001133	0.001877	0.001633	0.001333	0.001484	*0.0075*
NaOH	0.001167	0.001116	0.001476	0.001167	0.001237	*0.0063*
CH3COOH	0.001047	0.001012	0.001224	0.001067	0.0011345	*0.0058*
Sea Water	0.0001933	0.0001333	0.0001243	0.0001467	0.0001164	*0.0006*
Rain Water	0.0001633	0.0001466	0.0001567	0.0001767	0.000111	*0.0008*
Total	0.0037	0.00428	0.00461	0.00389	0.00408	*0.02058*

Table 2: Daily corrosion rates for submerged samples in diverse sample solutions for 54 days

Sample	G1*Jap	GC	AlZn^{3*}	G1*Ind	Al	Total (gm day^{-1})
HCl	0.001477	0.002191	0.00225	0.001857	0.001954	*0.0096*
NaOH	0.001325	0.001345	0.002036	0.001469	0.001375	*0.0073*
CH3COOH	0.001178	0.001192	0.001622	0.001223	0.001594	*0.0069*
Sea Water	0.0004358	0.000769	0.0004122	0.0008425	0.0002704	*0.0023*
Rain Water	0.0003556	0.000463	0.0002567	0.0003704	0.0002255	*0.0014*
Total	0.00477	0.00596	0.00658	0.00576	0.00542	*0.02849*

Table 3: Daily corrosion rates for submerged samples in diverse sample solutions for 90 days

Sample	**G1*Jap**	**GC**	**AlZn^{3*}**	**G1*Ind**	**Al**	**Total (gm day^{-1})**
HCl	0.001786	0.002422	0.0028125	0.0023811	0.002375	*0.0112*
NaOH	0.001732	0.00154	0.002619	0.002135	0.002054	*0.0099*
CH3COOH	0.0014692	0.001271	0.002111	0.001403	0.001632	*0.0079*
Sea Water	0.0009841	0.000529	0.0004556	0.0009431	0.0003422	*0.0032*
Rain Water	0.0006704	0.000976	0.000433	0.000578	0.0002975	*0.0031*
Total	0.00664	0.00674	0.00843	0.00744	0.0067	*0.03595*

4. Conclusions

G1*Jap roofing sheets were the most corrosion-resistant when compared to others. They were also the most effective in acidic or extremely hazardous settings with the possibility for acid rain, such as high-industrial places like the Tema industrial area in Ghana.

The most corroded roofing sheets were found to be Aluzinc three-star galvanised [AlZn3*] roofing sheets. However, in coastal places where there is a risk of exposure to seawater, such as Cape Coast, Elmina, and other coastal areas of Ghana, aluminium-based roofing sheets are the best given that they corrode the least when exposed to seawater.

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