Corrosion Behaviour of Structural Steels Entrenched in Concrete

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Abstract.

This study evaluates the corrosion behaviours of two grades of construction steels, ST60Mn and RST37-2 steels embedded in concrete and exposed to ordinary water and high chlorine rich seawater environment .Samples of the steels were embedded in concrete with cement-sand-gravel ratio of 1:2:4,cured at different time and later immersed in the corroding media. Corrosion potentials were measured using $Cu/CuSO_4$ reference electrode and the voltmeter. The ST60Mn steel grade was found to be more corrosion resistant in both ordinary water and seawater environment. The corrosion potential of the steel in air is about twice that embedded in concrete. Long exposure of reinforced concrete structures to chlorine water might result to quick deterioration. Careful attention should therefore be paid to buildings, bridges, elevated highways, parking garages, offshore oil platforms, piers and tunnels, built on or over water.

Keywords: Curing-time, Embedded, Offshore, Passivity, Piers, corrosion potential.

1.0 Introduction

Corrosion is one of the major technological problems of modern society. It is one of the most destructive agents responsible for colossal loss of materials occurring everywhere [1-5]. Through a lot of scientific understanding of many phases of corrosion has been developed, but it is a very complex phenomenon as there are a large number of complex variables responsible for it [6-9].

In other words, corrosion is the wearing-away of metal due to a chemical reaction. One of such areas in recent years that have generated much concern is steel used as reinforcement in concrete. Concrete structures such as bridges, dams, buildings, tunnels, offshore oil platforms, packing garages, etc. all contain reinforcing steel [10, 12, 14, 16] . These steel are usually attacked by certain aggressive agents making them lose their integrity, thereby rendering them incapable of satisfactorily performing their intended functions [11, 13, 15, 17, 19].

Contrarily to common belief, concrete is a complex composite material; a mixture of coarse (stones or bricks chips) and fine (generally sand) aggregates with a binder material (usually Portland cement). When mixed with a small amount of water, the cement hydrates and form microscopically opaque crystal lattices encapsulating and locking the aggregates into a rigid structure. Typical concrete mixes have high resistance to comprehensive stresses (about 4,000 psi (28Mpa); however, any appreciable tension (e.g. due to bending) will break the microscopic rigid lattice, resulting in cracking and separation of the concrete [18, 20, 22]. And hence it is common practice to reinforce concrete with steel, for improved tensile mechanical properties. For this reason, typical non-reinforced concrete must be well supported to prevent the development of tension [19, 21]

The environment provided by good concrete to steel reinforcement is one of high alkalinity (pH 12-13) due to presence of the hydroxides of sodium, potassium, calcium produced during the hydration reactions. The bulk of surrounding concrete act as a physical barrier to many of the steel's aggressor, and in such an environment steels are passive and any small breaks in its protective oxide film are soon repaired. However, the principal cause of degradation of steel reinforced structures is corrosion damage to the rebar embedded in the concrete [23-25]. In addition, the failure strain of concrete in tension is so low that the reinforcement has to hold the cracked sections together.

The aim of this research work is to study the corrosion behaviour of steel grades: RST37-2 and ST60Mn in concrete and also determine the stability of RST37-2 and ST60Mn steels as reinforcements in buildings, bridges and other concrete structures.

2.0 Materials and Method

The materials used for this study are RST37-2 and ST60Mn steels locally produced in Nigeria and sourced from Universal Steel limited Ikeja, Lagos, Nigeria. The chemical composition of the steels is as given in Table 1. The seawater used was sourced from Lagoon around Victoria Island, Nigeria. Other materials used are The Burham Brand Portland cement, the composition is illustrated in Table 2. The aggregate used were obtained at Julius Berger Nigeria Plc. $Cu/CuSO_4$ reference electrode and the voltmeter was used to measure the corrosion of the samples.

Table 1: Chemical Analysis of Steel Samples.

	ELEMENT	C	Si	Mg	Ph	Su	Cu	Cr	Ni	Iron
STEELS	ST60Mn	0.35-0.42	0.20-0.30	0.90-1.20	0.04	0.25	0.10	0.10	0.10	Balance
	RST37-2	012-0.17	0.18-0.17	0.40-0.60	0.04	0.04	-	-	-	Balance

Table 2: Composition of Portland Cement.

Cement	Calcium oxide CaO	Silicon oxide SiO_2	Aluminum oxide Al_2O_3	Ferric oxide Fe_2O_2	Sulfate
CCN	C	S	A	F	S
Mass%	61-67%	19.23%	2.5-6%	0-6%	1.5-4.5%

2.1 Material Preparation

A concrete mix was made which comprised Burham Brand Portland cement, sand as fine aggregate, gravel as coarse aggregate and water. Then cement-sand-gravel ratio used was 1:2:4. Eight steel embedded concrete cubes were cast with four each for RST37-32 and ST60Mn steel samples respectively. The steel specimen each with 7 mm width and length of 20 cm were pickled in hot dilute hydrochloric acid solution for 10 min at 60^0 C. The steel samples were rinsed in water and dried before insertion. Only about 15 cm of the steel samples was embedded while the remaining 5 cm protruded out at one end of the cube to facilitate electrical connection during the taking of reading. The concrete cubes have uniform dimensions of 15x15x15 cm. After remoulding, the concrete cubes were cured in water for 21 and 28 days to reduce porosity and permeability.

To obtain readings, a copper sulphate reference electrode was placed on the concrete cube. The circuit was completed by connecting an insulated flexible cable of a half-cell to a

voltmeter and another cable to a hole drilled on the exposed end of the steel specimen. Readings were taken on both sides of each cube and the average potential calculated.

3.0 Results and Discussion

Table 1 indicates that ST60Mn contain about 0.35-0.42% Carbon content while RST37-2 has between 0.12 and 0.17%Carbon. Hence the former is a medium carbon steel while the latter is a low carbon steel. Table 2 also revealed that Portland cement is rich in slaked lime (CaO) about 61-67 % and contain appreciable sulfate (1.5-4.5%) content. These are potential corrodant of the embedded steel in a reinforced concrete.

Figures 1 and 2 showed that the corrosion potentials of both steels embedded in concrete are higher in sea water than in ordinary water. This may be as a result of chloride ion in sea water. Structures such as bridges in sea must be given better protection against this aggressive environment. From figure 3 the corrosion potential of RST 37-2 steel is higher for 28 days curing time in sea water than those concrete cured at 21 days. This behavior is reversed for ST 60 Mn steel as shown in Figure 4. Figure 5 showed that corrosion potential of ST 60 Mn steel cured in concrete for 3 weeks is higher than RST 37-2 steel in sea water. While in figure 6, RST 37-2 steel has higher corrosion potential when immersed in sea water for 10 days, thereafter ST60Mn steel corrodes at higher rate. Figure 7 showed that both steels have higher corrosion potentials when exposed directly to seawater without concrete casing.
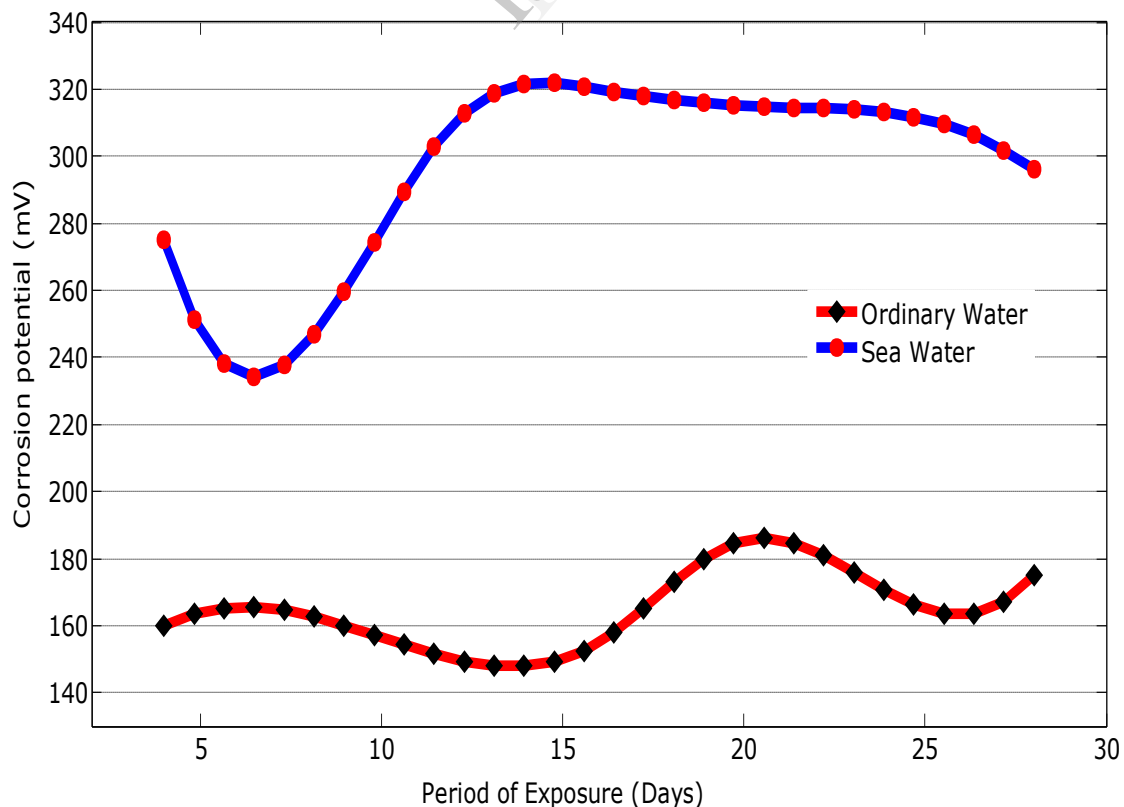

Figure 1:   Variation of corrosion potential against exposure period for RST37-2 exposed in seawater for three and four weeks of curing
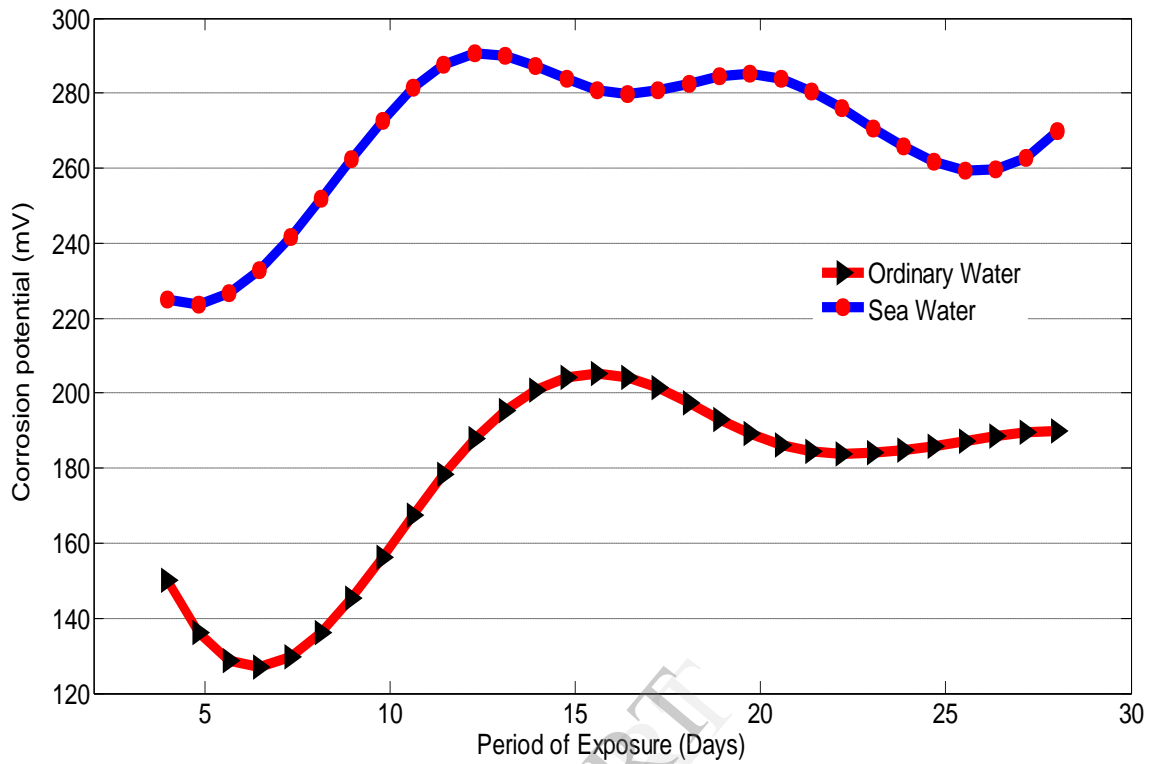
Figure 2: Variation of corrosion potential against exposure period for ST60Mn exposed in Seawater for three and four weeks of curing
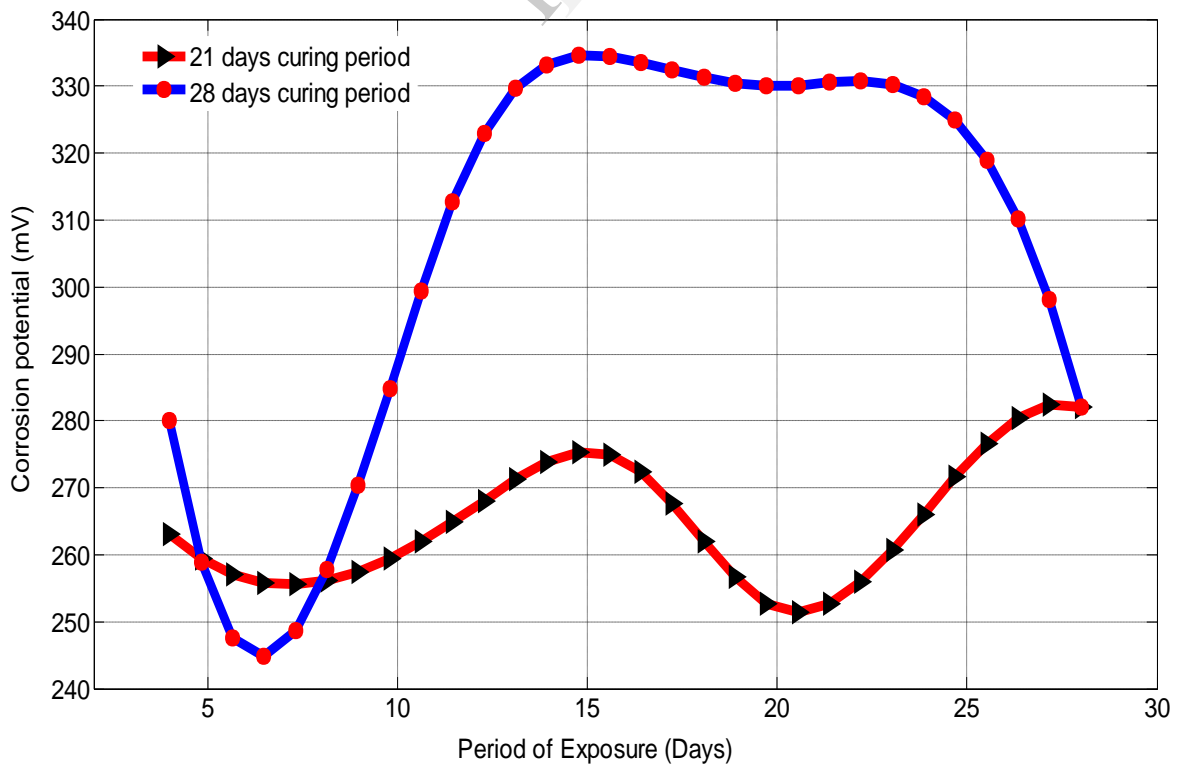

Figure 3: Variation of corrosion potential against exposure period for RST37-2 exposed in seawater for three and four weeks of curing
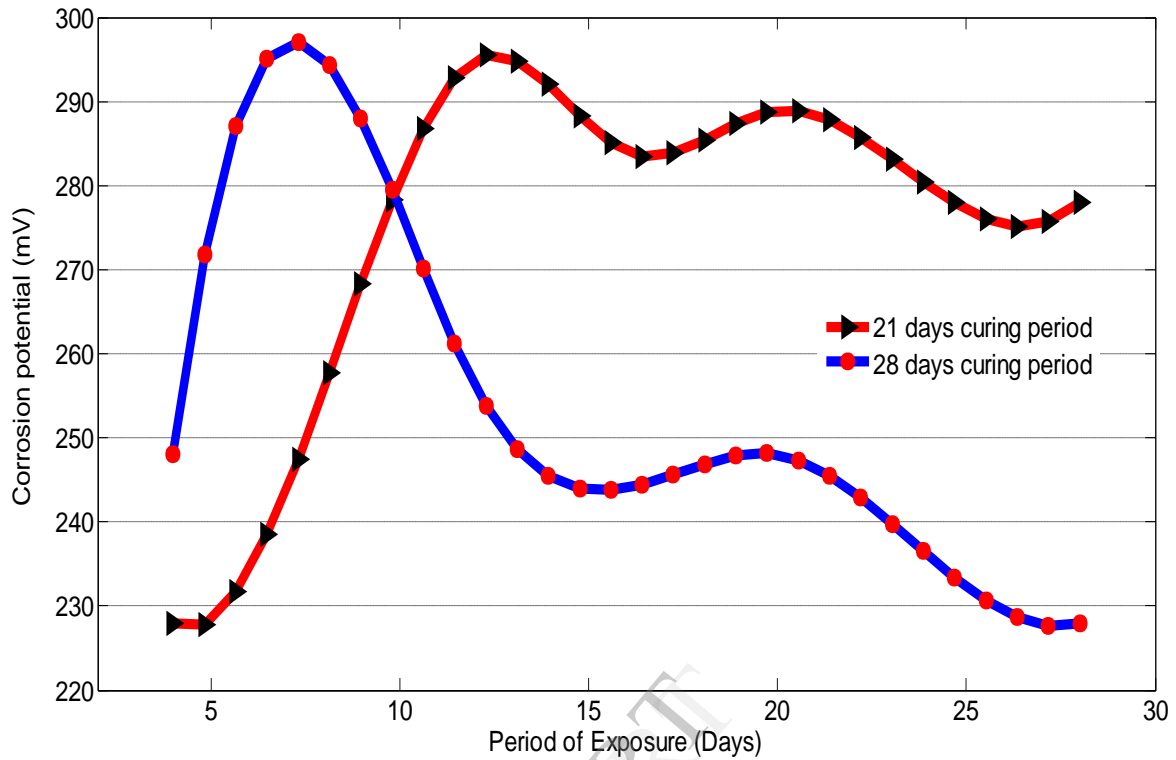
Figure 4:   Variation of corrosion potential against exposure period for ST60Mn exposed in seawater for three and four weeks of curing
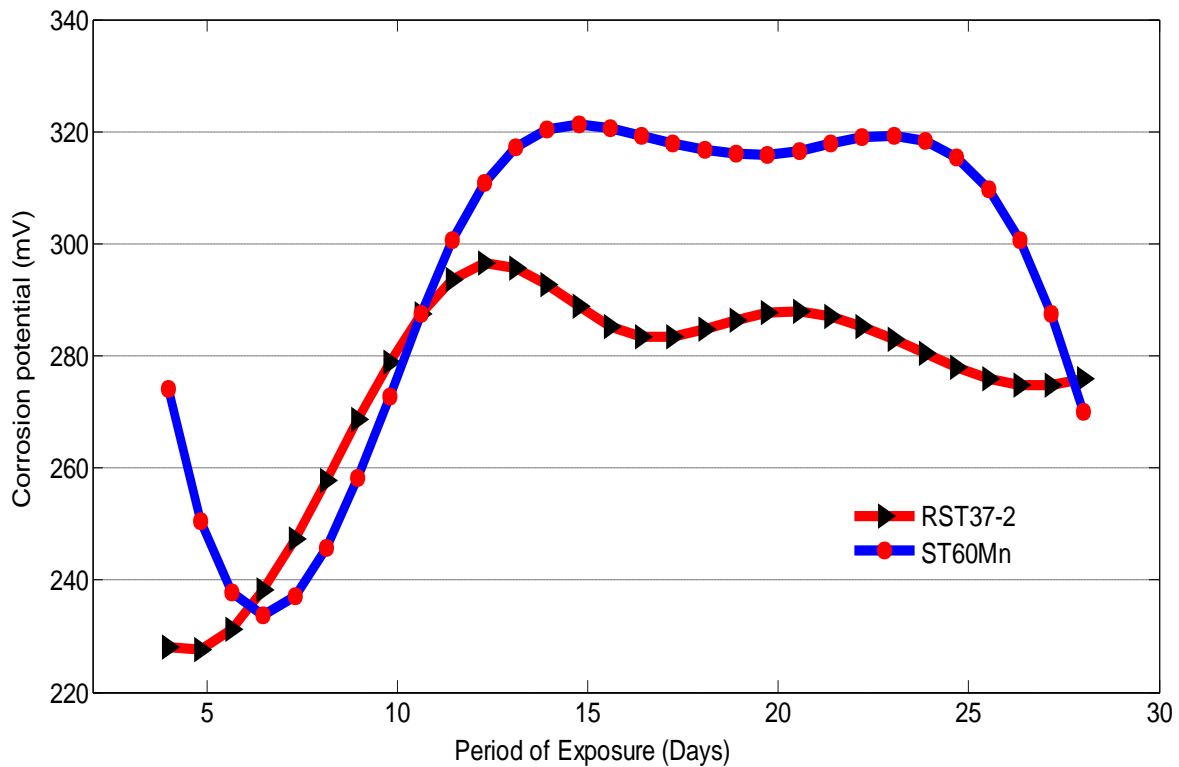

Figure 5:   Variation of corrosion potential against exposure period for RST37-2 and ST60Mn exposed to seawater for three weeks of curing
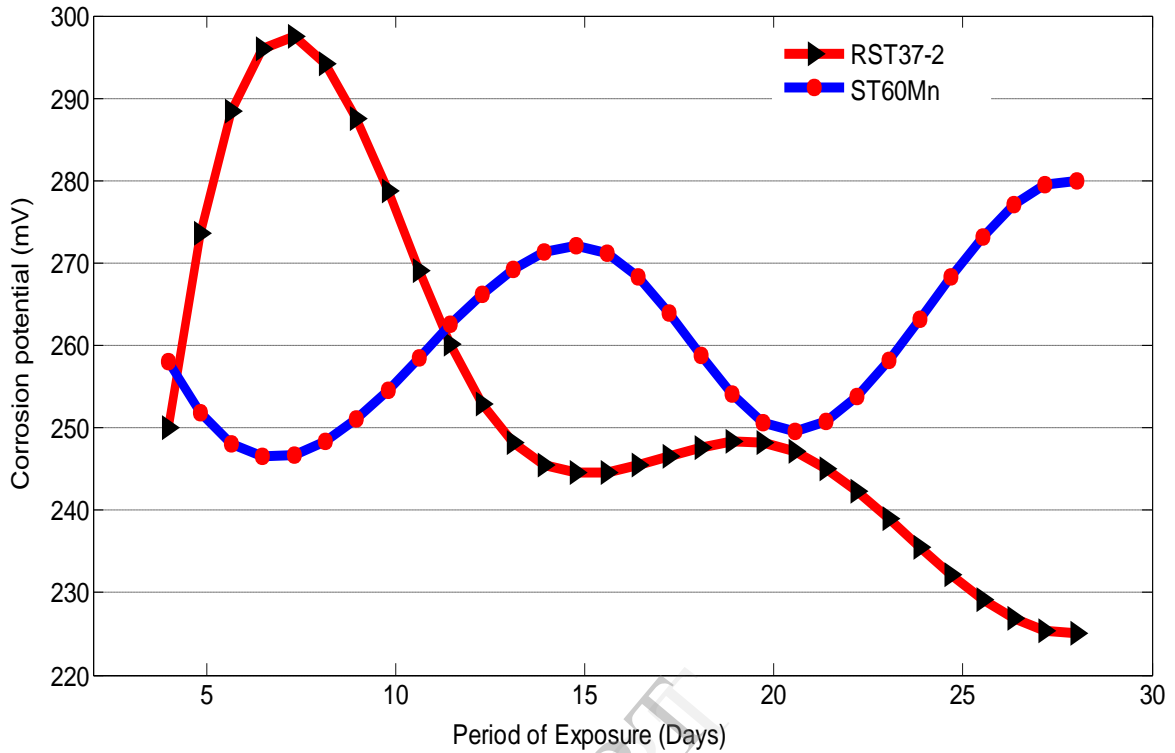
Figure 6:   Variation of corrosion potential against exposure period for RST37-2 and ST60Mn exposed to seawater for four weeks of curing
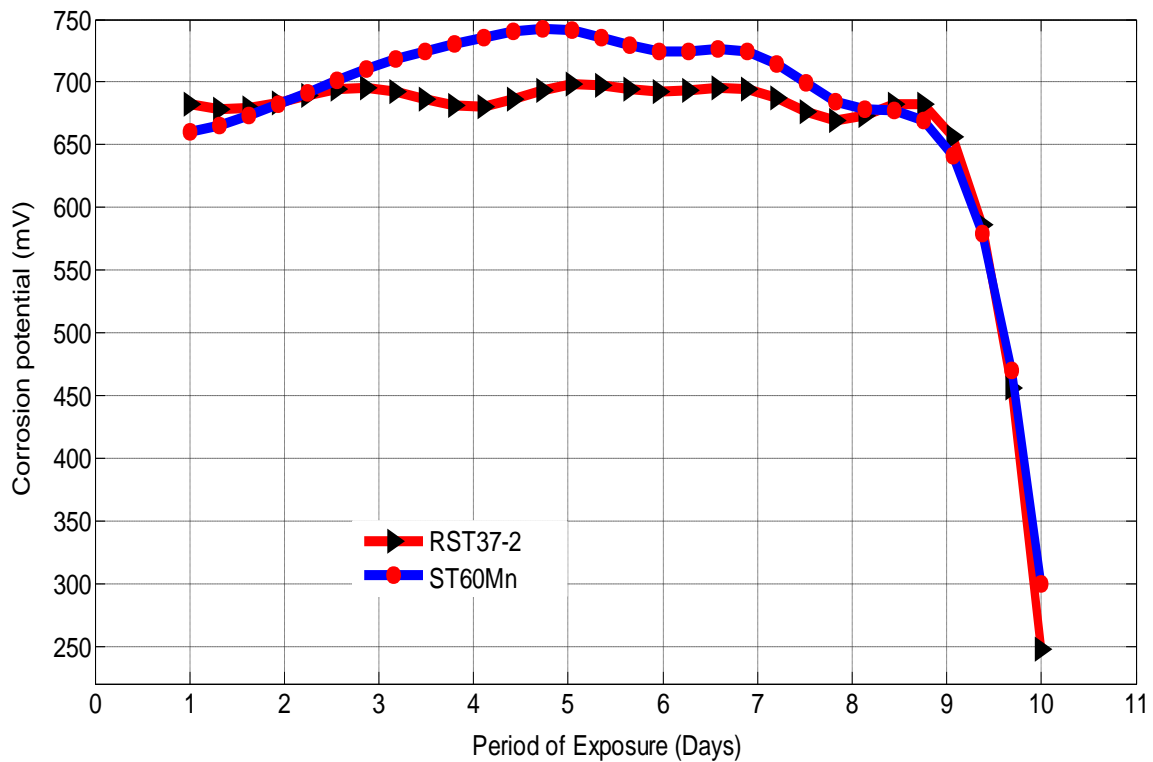

Figure 7:   Variation of corrosion potential against exposure period for RST37-2 and ST60Mn directly exposed to seawater

4.0 Conclusion

❖ It is deduced from the result of this research that the corrosion rate of RST37-2 Steel is higher than those of ST60Mn.

❖ Both steels have higher corrosion potentials when exposed directly to seawater without concrete casing.

❖ Corrosion potential of ST 60 Mn steel cured in concrete for 3 weeks is higher than RST 37-2 steel in seawater.

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