INFLUENCE OF THE TYPE OF STEEL BAR TO CORROSION OF REINFORCED FLY ASH MORTAR MIXED WITH SEAWATER

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Abstract: At present, the global issue regarding the devastating effects of water scarcity can no longer be disregarded. This study delves on whether seawater, with partial fly ash replacement, is a significant alternative in constructing mortar, and is of substantial effect to the corrosion on different types of steel bars. Five types of steel bars, namely: prestressed, round corroded, round uncorroded, deformed corroded and deformed uncorroded, were tested every week in a span of 18 weeks in terms of corrosion potential (Ep), microcell current density (i_{corr}), and chloride content. The result shows that: 1) The i_{corr} and Ep reflect a boundary low corrosion for mixes with and without fly ash. 2) Both seawater and freshwater mixes have higher chloride content than the mix without fly ash. 3) Both seawater and fly ash mixes will increase the chloride content of the samples regardless of the type of steel bar used. This research would serve as vital information in the future on whether the use of seawater as an alternative to fresh water in reinforced concrete would provide significant effects on the structural properties and the overall life span of the structure. Although the seawater mix increased the chloride content of the samples and experienced a higher corrosion rate, the data shows that the corrosion on the steel was still minimal and relatively close to fresh water mix. The study also shows that seawater can still be a viable option for mixing in terms of corrosion in steel bars.

Key Words: fly ash; mortar; seawater; corrosion of steel bar; compressive strength

1. INTRODUCTION

At present, the issue on water scarcity can no longer be disregarded as the world is already experiencing its devastating effects. Therefore, it is important to address this issue and to conserve fresh water. This study aims to address the issue on water scarcity in the construction industry as it resorts to the use of seawater rather than conventional fresh water.

The objective of this study is to investigate the influence of the type of steel bar to the corrosion of reinforced fly ash mortar mixed with seawater. The corrosion of steel bars is detrimental as it is one of the most common causes of failure in reinforced concrete structures. Similarly, corrosion of concrete-covered steel can cause the concrete to break, resulting to severe structural problems.

This study analyzed the behavior of the type of steel bar exposed to seawater and the influence of corrosion formation so as to avoid structural failures. The study will also investigate if utilizing fly ash can prevent the occurrence of corrosion.

2. METHODOLOGY

This study is an experimental research. The corrosion behavior of steel bars was evaluated using the values obtained from the corrosion monitoring device (CT-7). Rectangular prisms of size 4 cm x 4 cm x 16 cm with ten millimeter diameter round steel bars suspended at a constant cover of 5 mm were used in order to accelerate the corrosion process. Five types of steel bars, namely: prestressed, round corroded, round uncorroded, deformed corroded and deformed uncorroded, were tested every week in a span of 18 weeks in terms of Ep, microcell i_{corr}, and chloride content. Chloride content was measured using the 'washing the bar method' (Odchimar and Otsuki, 2011).

The independent variables are the type of steel, freshwater and seawater mixes (with and without fly ash). The dependent variable is the corrosion of the steel bars when it is reinforced in mortar. Figure 2.1 presents the methodology for this research.

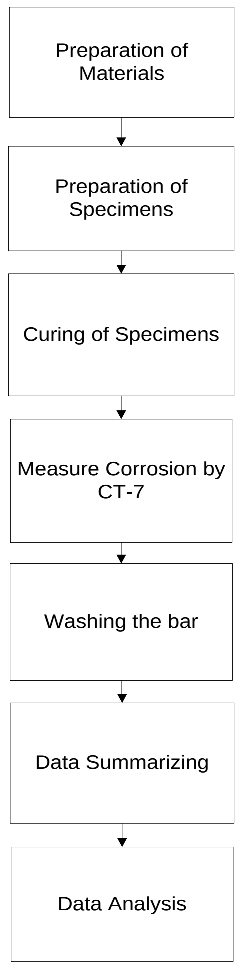

Figure 2.1: Research Procedure

Table 2.1: Specification of Test Specimens

Water to binder ratio	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Replacement Ratio	20%	20%	20%	20%	20%
Type of Steel Bar	Round	Deformed	Pre-stressed	Round (corroded)	Deformed (corroded)
(Control) Freshwater & OPC	4	4	4	4	4
Seawater & OPC	4	4	4	4	4
(Test) Freshwater & OPC with Fly ash	4	4	4	4	4
Seawater & OPC with Fly ash	4	4	4	4	4
Total no. of specimens	16	16	16	16	16
Total	80				

Table 2.2: Mix Design

Control				Test			
Material	**Total Weight (kg)**	**Material**	**Total Weight (kg)**	**Material**	**Total Weight (kg)**	**Material**	**Total Weight (kg)**
Cement	6	Cement	6	Cement	4.8	Cement	16.8
Sand	12	Sand	12	Sand	12	Sand	42
Freshwater	1.67	Seawater	3	Freshwater	1.93	Seawater	10.5
				Fly ash	1.2	Fly ash	4.2

Water – binder – sand ratio = 1:2:0.5

$$I_{micro} = \frac{K}{R_p S} \qquad \textbf{Eq. 2.1}$$

Where: K = 0.0209 V
R_p = Polarization Resistance
S = Surface Area
I_{micro} = Microcell Current

3. RESULTS AND DISCUSSION

This research investigated the effects of seawater as mixing agent to the corrosion of different types of steel in mortar specimens with 20% fly ash replacement and with cement:sand:water ratio of 1:2:0.5. The Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements (ASTM G 59-91) and ASTM C846-91 (Test Method for Half Cell Potentials of Uncoated Reinforcing Steel in Concrete) were used in this study.

Table 5.1 i_{corr} Boundaries

i_{corr}	Boundary
High corrosion rate	$x>1\mu A/cm^2$
High or middle corrosion rate	$0.5<x<1\mu A/cm^2$
Low or middle corrosion rate	$0.2<x<0.5\mu A/cm^2$
Passive or no corrosion	$x<0.2\mu A/cm^2$

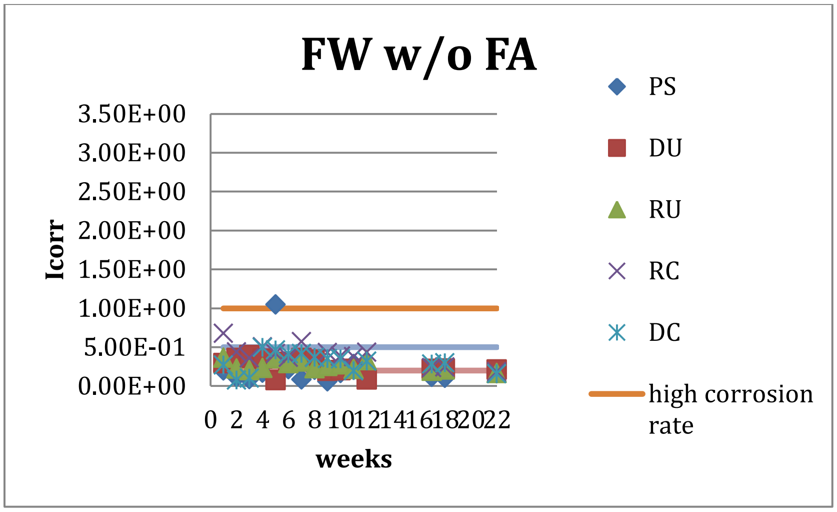

Figure 3.1 I_{corr} for specimens w/o fly ash and mixed w/ freshwater

From Figure 3.1, the i_{corr} for all the types of steel bars fall in the low corrosion rate boundary on the 22nd week. This means that the steel bars did not experience any corrosion at this point. In the early weeks of testing, the steel bars fell in the low or middle corrosion rate. The behavior of the PS in this mix is almost uniform that there is no significant difference with the other steel bars.

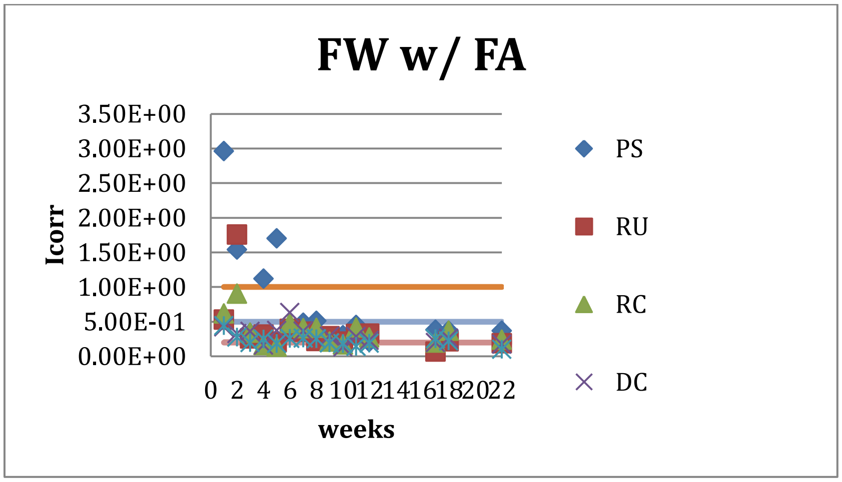

Figure 3.2 I_{corr} for specimens w/ fly ash and mixed w/ freshwater

From Figure 3.2, the steel bars fall in the low corrosion rate boundary on its 22nd week. This means that the steel bars did not experience any corrosion during this point. In the early weeks of testing however, the steel bars corrosion rate is in the middle and high corrosion rate boundaries for PS, RU and RC. DC and DU steel bars are in the low or middle corrosion rates. PS shows a high i_{corr} on the early weeks of testing compared to the other steel bars. The behavior of the PS in this mix is somewhat erratic at the early stages but became fairly uniform on the latter weeks of testing.

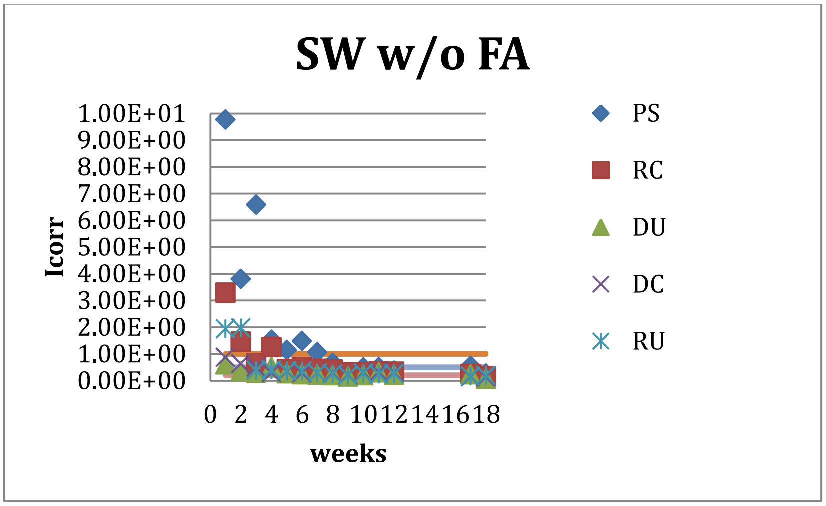

Figure 3.3 I_{corr} for specimens w/o fly ash and mixed w/ seawater

In Figure 3.3, the i_{corr} shows the corrosion rate of the steel bar within the rectangular prism. All of the bars resulted to a high corrosion rate for the first few weeks then gradually decreased towards the end. The i_{corr} shows that after 18 weeks there was no significant difference in the corrosion rate among the steel bars.

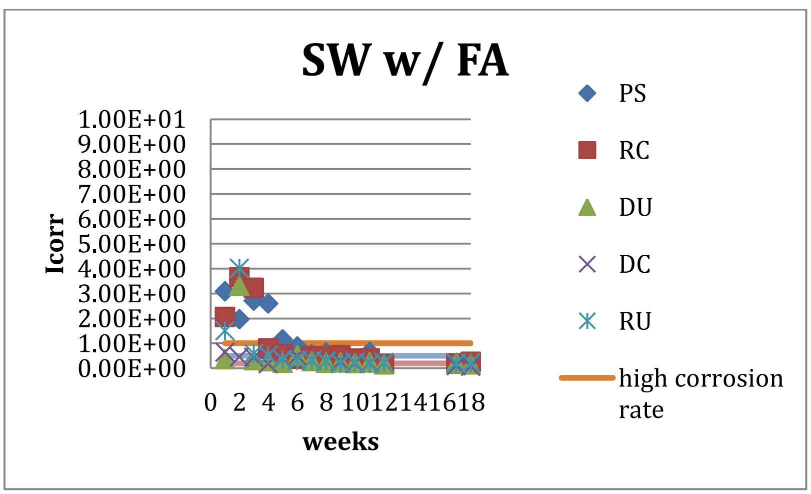

Figure 3.4 I_{corr} for specimens w/ fly ash and mixed w/ seawater

In Figure 3.4, the i_{corr} shows almost similar results, where all of the bars obtained a high corrosion rate for the first few weeks then gradually decreased towards the end. The i_{corr} also shows that there was no significant difference between the corrosion rates among the steel bars.

The high i_{corr} of the steel bars in the early weeks of testing in the freshwater mix can be due of hydration. During the hydration process, the reaction of cement, water and sand is ongoing that could have contributed to the high i_{corr}. On mixes with fly ash, the components of the fly ash react with the cement, water and sand during hydration which contributed to a higher i_{corr} on the steel bars when tested during the early weeks. In the seawater mix, the steel bars also had high i_{corr} but the mix with fly ash resulted to lower values. This can be attributed to hydration, i.e., the fly ash reduced the effects of the chloride in the seawater which made the i_{corr} lower compared to the seawater mix without fly ash. The high i_{corr} of PS may be caused by the voids in between the strands of bars twisted together.

Comparing the freshwater and seawater mix, the mix with the highest i_{corr} is the seawater mix. This is because seawater contains chloride which contributed to the high i_{corr} when it was used to mix the mortar on its early weeks. In the latter weeks of testing, the i_{corr} of both mixes is below the low corrosion rate boundary.

4. CONCLUSION

In the freshwater mix, it is evident that corrosion formation is relatively low, which indicates that freshwater used for mixing is recommended. From the specimens mixed with seawater, results showed that corrosion formation is higher during the first few weeks of testing. This is basically due to the hydration process in concrete for which the steels bars are exposed to. However, the values gradually decreased in the succeeding weeks of testing. Similar to that of the freshwater mix, the pre-stressed steel bars yielded the highest rate of corrosion from the five types of steel bars tested. In the first few weeks of testing, the deformed bars showed a greater resistance towards corrosion compared to that of the round bars, but this gradually changed in the succeeding weeks up to the 18th week of testing, since the results of the deformed bars and the round bars became eventually relatively close to one another. Results also show that in the seawater mix, it is ideal to incorporate fly ash for the reason that it decreases the corrosion rate in the steel bars. The mix with the greatest resistance to corrosion is that of the freshwater mix with fly ash. The mix that has a lesser resistance to corrosion, on the other hand, is that of the seawater mix without fly ash. For further study, one could use seawater for curing instead of freshwater to determine whether curing will have a different effect on the different types of steel bars. Also, in measuring the i_{corr}, the testing period can be prolonged to determine whether the i_{corr} will increase the corrosion over time while embedded in the mortar.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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