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ELECTROCHEMICAL CORROSION BEHAVIOUR OF CONCRETES WITH IRON ORE TAILINGS

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ABSTRACT: Concrete reinforcement corrosion is one of the most important causes of premature failure of reinforced concrete structure worldwide and generates a great concern due to its effects on global economy. To assess the influence of concrete incorporating IOT on the electrochemical corrosion behaviour, 50% and 100% IOT replacement levels by the total weight of the river sand were assigned in concrete production. The corrosion behaviours of reinforcing bars embedded in concretes were monitored through accelerated corrosion test, corrosion current density (icorr) and the corresponding corrosion rate by linear polarization technique (LPR). Moreover, the electrochemical impedance spectroscopy (EIS) and electrical resistivity of concrete were measured.

Keyword: Concrete, IOT, Linear polarization resistance, electrochemical impedance spectroscopy

INTRODUCTION

Presently, achieving an environmentally friendly community through effective waste recycling and sustainability in construction are key issues across the world. Thus far, utilization of some categories of industrial by-products in concrete production seems to be providing satisfactory solution to these concerns. IOT is a waste generated in enormous quantity during the production of iron ore. Corrosion is defined as the destructive and unwanted attacked on a metal by electrochemical, which mostly initiated from the surface of the metal or grain boundary depending upon the types of corrosion (1).

Corrosion of reinforcing steel embedded in concrete is an electrochemical process that requires an anode, a cathode, an electrolyte, and an electrical connection between the anode and cathode for the transfer of electrons. Coupled anodic and cathodic reactions take place on the surface of the reinforcing steel.

The oxidation and reduction reactions were take place at the anode and cathode. The products of these reactions in concrete combine together and build a stable film that passivates and protects the reinforcing steel from corrosion (2). The passive film protecting the reinforcement steel can be disrupted by two mechanisms: carbonation and chloride induced corrosion (3, 4). Disruption of passive film initiates corrosion of reinforcing steel, initiating corrosion.

The objective of this study was to determine the effect of IOT on corrosion behaviour of concretes at 50% and 100% of natural fine aggregate replacement with w/c ratio of 0.60 and 0.45. Control mix (0% IOT) having 0.60 W/C ratio was designated as T-1 while T-3 and T-5 were designated for 50% and 100% IOT respectively. Similarly control mix (0% IOT), having 0.45 W/C ratios was designated as T-6 and mixes with IOT 50% and 100% were designated as T-8 and T-10 respectively

An accelerated corrosion testing technique was used to compare the corrosion performance of control specimen and IOT concretes. The corrosion process was initiated by impressing a constant DC voltage between the steel bar (as anode) and steel plate (as cathode) and the variation of current with time was recorded. Samples' degradation measurements were conducted by using two methods; linear polarization resistance (LPR) and electrochemical impedance spectroscopy (EIS).

RESULTS AND DISCUSSION

Table 1: Results of LPR

Sample	icorr	CR	w/c ratio
T-1	1.9	0.02	
T-3	2.4	0.03	0.60
T-5	3.2	0.04	
T-6	1.1	0.01	
T-8	1.6	0.02	0.45
T-10	2.3	0.03	

Table 2: Results of Concrete resistivity

Sample	Concrete resistivity (KΩcm)			w/c ratio
	7days	28days	90days	
T-1	9.1	10.0	10.0	
T-3	7.6	8.1	9.0	0.60
T-5	5.1	6.2	6.9	
T-6	13.4	14.3	15.2	
T-8	12.7	13.9	15.0	0.40
T-10	9.8	12.4	12.6	

Table 2: Simulated corrosion results obtained from the EIS equivalent circuit

Properties	Simulated EIS results					
	T-1	T-3	T-5	T-6	T-8	T-10
Resistance, R_p (ohm)	127	104.7	100.4	194.6	151.9	123.4
Capacitance (Cdl)	6.53E-05	1.546E-03	2.64E-09	7.22E-05	3.81E-04	1.45E-04
Resistance, R_c (ohm)	6.026	4.36	4.807	5.101	3.019	4.929

The results of LPR presented in Table 1 indicate that the Corrosion current density (Icorr) was lower for concrete mix with lower w/c ratios (0.45) compared to higher w/c ratios (0.60). This behaviours is not surprising and is in agreement with that reported by other authors (5, 6). Corrosion current density (Icorr) represents instantaneous rate of corrosion at the particular time of voltage measurement, and changes frequently over time for specimen (7).

The EIS analysis shown in Table 2 indicates the formation of good polarization resistance oxide film on the IOT concrete at 50% replacement to sand in both w/c ratios that impeded the corrosion process. The R_t value of the T-3 and T-8 were much higher than that of the other samples. It has been established previously that, corrosion resistance increases when its charge transfers resistance (R_t) increases (8).

CONCLUSION

The corrosion current density values obtained for 50% concretes with both w/c ratios were close to those of control samples. Corrosion rates of the concretes seemed to have similar trends with the aforementioned findings. The highest corrosion rate was measured as 0.04 mm/yr in 100% replacement to sand at 0.60 w/c ratio. The results of the EIS showed that concrete at 50% IOT replacement of river sand has close trend in terms of double layer capacitance (Cdl), concrete resistivity and polarization resistance (Rp).

REFERENCES

1. S. Izman , Mohammed Rafiq Abdul-Kadir, Mahmood Anwar, E. M. Nazim, R.Rosliza ASaMAH. Surface Modification Techniques for Biomedical Grade of Titanium Alloys: Oxidation, Carburization and Ion Implantation Processes Book Chapter. Croatia: Intech Publisher; 2012. p. 201-28.
2. Montemor MF, Simões AMP, Ferreira MGS. Chloride-induced corrosion on reinforcing steel: from the fundamentals to the monitoring techniques. Cement and Concrete Composites. 2003;25(4–5):491-502.
3. Abosrra L, Ashour AF, Youseffi M. Corrosion of steel reinforcement in concrete of different compressive strengths. Construction and Building Materials. 2011;25(10):3915-25.
4. Ismail M, Siti Fatimah AR, Muhammad B, Noor NM, Bakhtiar H. Embedded Sensor for Detecting Corrosion of Reinforcement in Concrete. Advanced Materials Research. 2011;250-253:1118-23.
5. Vedalakshmi R, Manoharan SP, Song H-W, Palaniswamy N. Application of harmonic analysis in measuring the corrosion rate of rebar in concrete. Corrosion Science. 2009;51(11):2777-89.
6. Dhouibi L, Triki E, Raharinaivo A. The application of electrochemical impedance spectroscopy to determine the long-term effectiveness of corrosion inhibitors for steel in concrete. Cement and Concrete Composites. 2002;24(1):35-43.
7. El-Hacha R, Mirmiran A, Cook A, Rizkalla S. Effectiveness of Surface-Applied Corrosion Inhibitors for Concrete Bridges. Journal of Materials in Civil Engineering. 2011;23(3):271-80.
8. G. Rondelli, P. Torricelli, M. Fini, Giardino R. In vitro corrosion study by EIS of a nickel-free stainless steel for orthopaedic applications. . Biomaterials. 2005;26:739-44.