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# Inhibition effect of cow bone soot on low carbon steel corrosion in artificial concrete pore environment

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**Abstract.** The corrosion inhibition of cow bone soot (BAS) at 5%, 10%, 15% and 20% weight on low carbon steel (LCS) in artificial concrete pore solution was evaluated with potentiodynamic polarization and current-time displacement. BAS visibly decreased the corrosion rate of LCS from  $7.31 \times 10^2$  mm/y at 0% BAS to  $1.45 \times 10^2$  mm/y at 20% BAS concentration. Maximum inhibition performance of 80.18% was obtained at 20% BAS concentration. The inhibition mechanism of BAS was determined to be anodic type. Cathodic reduction of the polarization plot was significant due to decrease in  $O_2$  adsorption. Plot of current versus time shows BAS reduces the thermodynamic tendency of LCS to corrode.

## 1. Introduction

Replacement of cement content in concrete with biodegradable waste disposals is the objective of current scientific investigations into improvement of concrete technology. According to statistica [1] Industrial production of cement globally totaled 4.1 billion metric tons in 2017. This has adverse effect on environmental safety. The most applicable and reliable building material in construction is reinforced concrete due to its relatively low cost, strength and resilience. Environmental pollution resulting from the production of cement is the focus of research to reduce global warming. According to Malhotra and Mehta [2], mining of raw material and eventual conversion to cement in industry contributes 7% of the overall greenhouse released to the planet. Cement has extensive application in building and construction being the most widely used substance behind  $H_2O$  globally [3]. Research into improvement of concrete technology aims at the use non-toxic partial additives to concrete such as agro-industrial wastes which improves environmental sustainability and possibly increase the strength of concrete [4, 5]. Tons of cow bones from abattoirs are disposed yearly in Nigeria, though most are incinerated and contributes to environmental pollution [6, 7]. Reinforced steel in concrete corrodes due to the alkaline nature of concrete pores leading to decreased lifespan of reinforced concrete [8, 9]. Due to alteration of the chemical environment of reinforced concrete as a result of the partial replacement of the cement admixed, further study is required to understand the resulting effect of reinforce steel in concrete to corrosion [10]. Hence, this research focuses on the influence of cow bone soot on corrosion behaviour of mild steel in simulated concrete pore environment.

## 2. Experimental procedures

Low carbon steel (LCS) samples purchased in Lagos, Nigeria has cylindrical dimension (12 mm diameter). The samples were machined, sectioned and subsequently embedded in Versocit resin mounts. The visible surface of LCS was grinded with silicon carbide paper of various grits before



polishing with diamond paste at 6  $\mu\text{m}$ . Cow bone soot (BAS) was produced from waste cow bones secured from an abattoir in Lagos, Nigeria. The bones were subsequently cleaned to remove unwanted materials due to its effect on their chemical constituent [11]. They were incinerated at 900°C and crushed. Portland lime stone cement and fine aggregate sand (NIS 444-1:2003 and NIS 13:1974 standard) were used in the study in addition to portable H<sub>2</sub>O for the batching of concrete [12]. BAS powder was added in wt. % (0%, 5%, 10%, 15%, 20% and 25% BAS) with respect to cement weight. The H<sub>2</sub>O/cement ratio at 0.88 was used [13]. Table 1 present the concrete mix blueprint. Potentiodynamic polarization test was executed using a ternary electrode workpiece (embedded LCS terminal, Ag/AgCl reference terminal and Pt counter terminal) within a container filled with the pore electrolyte at specific concentrations of BAS. The electrode system was linked to Digi-Ivy potentiostat/computer system. Potentiodynamic polarization curves were plotted at sweep rate of 0.0015 V/s (-1 V and +1.75 V). Current versus time curves was plotted for 5000s with Digi-Ivy potentiostat/computer system to assess the tendency of LCS to corrode.

**Table 1.** Mix blueprint of concrete aggregates, cement, BAS and H<sub>2</sub>O.

Cement Substitution (%)	Rough Cluster (Kg)	Powdery Cluster (Kg)	Complete Weight (Kg)	Cement (Kg)	CBA (Kg)	H <sub>2</sub> O/Cement Proportion
0	80	40	120	20	0	0.88
95	80	40	120	19	1	0.88
90	80	40	120	18	2	0.88
85	80	40	120	17	3	0.88
80	80	40	120	16	4	0.88

### 3. Results and discussion

#### 3.1. Potentiodynamic polarization studies

Fig. 1(a) depict the potentiodynamic polarization curves of LCS corrosion at 0%, 5%, 10%, 15% and 20% BAS in artificial concrete pore solution. Outputs for the electrochemical parameters are laid out in Table 2. BAS substantially decreased the corrosion of LCS in the pore solution. The corrosion rate of LCS at 0% BAS is  $7.31 \times 10^{-2}$  mm/y due to oxidation of LCS surface and the resulting surface degradation of the steel. BAS passivates the steel surface in the alkaline pore environment. The cathodic polarization curve in Fig. 1(b) depict reduction in slope at specific BAS concentration compared to the slope at 0% BAS. This results from stifling the O<sub>2</sub> reduction reactions and possibly H<sub>2</sub> evolution reactions also. The incline decrease shows the presence of BAS results in selective precipitation of BAS components on LCS surface resulting in suppression of the active sites on the steel responsible for corrosion. Anodic shift in corrosion potential with respect to BAS concentration shows BAS substantially suppresses the oxidation reaction responsible for corrosion. The corrosion rate of BAS at 5% BAS is  $2.96 \times 10^{-2}$  mm/y. The corresponding inhibition efficiency is 59.52%. At 20% BAS, the corrosion rate has decreased to  $1.45 \times 10^{-2}$  mm/y with inhibition efficiency of 80.18%. This result ensures the viability of reinforcing LCS in concrete environment.

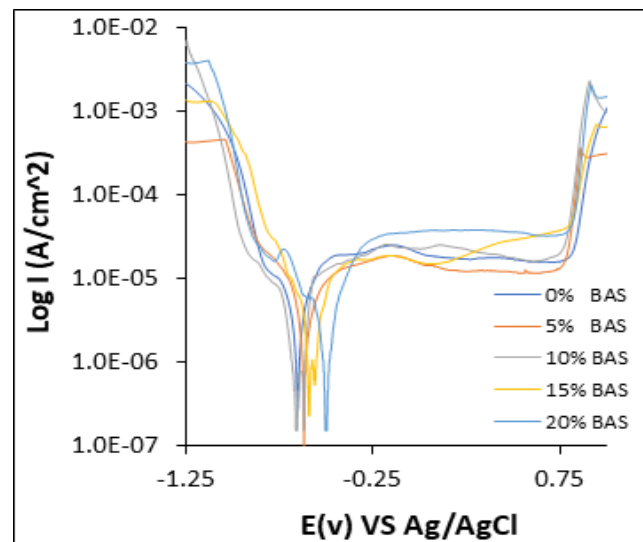
#### 3.2. Current-time measurement

Plot of LCS corrosion current versus exposure time at 0% to 20% BAS is depicted in Fig. 2(a) and (b). The active passive behaviour of the plot at 0% BAS results from anodic oxidation of the steel. However, the oxide formed is porous. Hence the resulting current value is relatively higher than obtained at specific BAS concentration. Observation of the current plot at 5% - 20% BAS shows anodic degradation is limited compared to the plot at 0% BAS [14]. This is due to the inhibition effect of BAS which selectively precipitates on the steel and influence the oxide film formed on LCS. The plot at 0% BAS shows LCS is thermodynamically unstable and has a higher tendency to corrode [15]. The magnified image of the corrosion current-time plot at 5% - 20% BAS shows that at 5% BAS, the

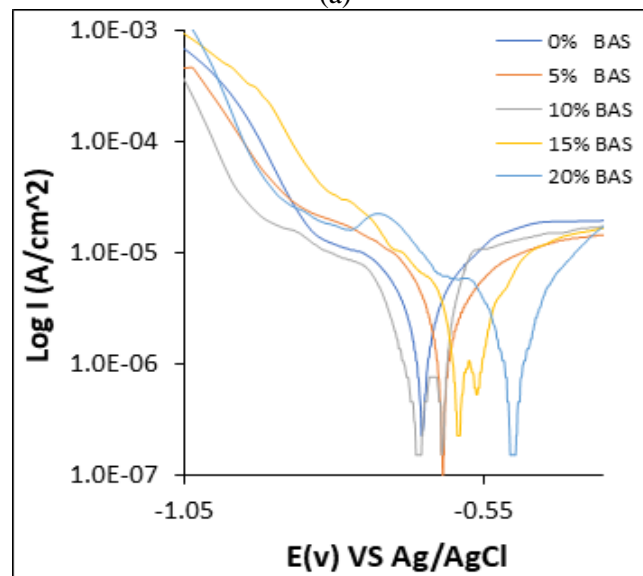
plot is more thermodynamically stable than the plot at 0% BAS. Subsequent increase in BAS concentration increases the thermodynamic stability of LCS in the concrete pore solution.

**Table 2.** Results for potentiodynamic polarization parameters on LCS corrosion

Sample	CBA Conc. (%)	MS Corrosion Rate, $C_r$ (mm/y)	Inhibition Efficiency, $E$ (%)	Corrosion Current, $C_i$ (A)	Corrosion			Polarization Resistance, $R_p$ ( $\Omega$ )	Cathodic Tafel Slope, $B_c$ (V/dec)	Anodic Tafel Slope, $B_a$ (V/dec)
					Density, $C_a$ (A/cm <sup>2</sup> )	Potential, $C_p$ (V)	Current, $C_i$ (A)			
A	0	7.31E-02	0	7.12E-06	6.30E-06	-0.652	3609.00	-5.414	5.412	
B	5	2.96E-02	59.52	2.88E-06	2.55E-06	-0.618	8935.00	-5.500	6.970	
C	10	2.91E-02	60.19	2.84E-06	2.51E-06	-0.572	9107.00	-5.510	5.349	
D	15	2.50E-02	65.83	2.43E-06	2.15E-06	-0.592	10560.00	-6.012	7.951	
E	20	1.45E-02	80.18	2.91E-05	1.25E-06	-0.501	20570.00	-2.070	7.023	

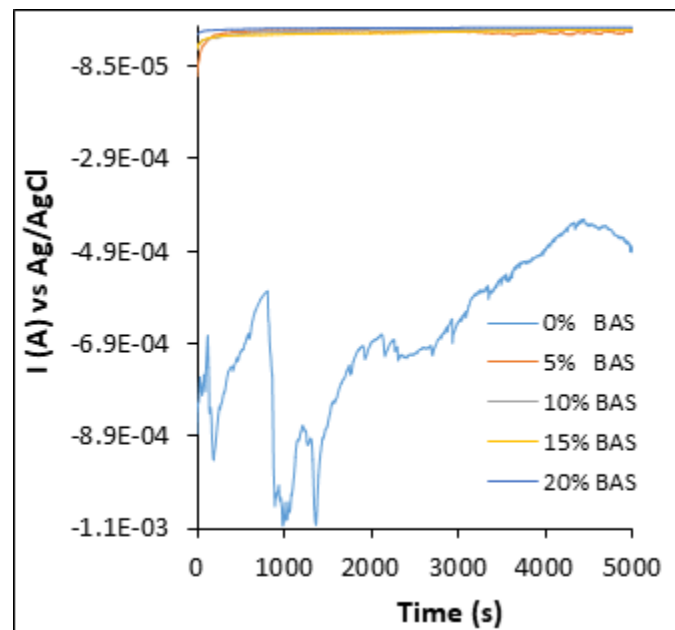


(a)

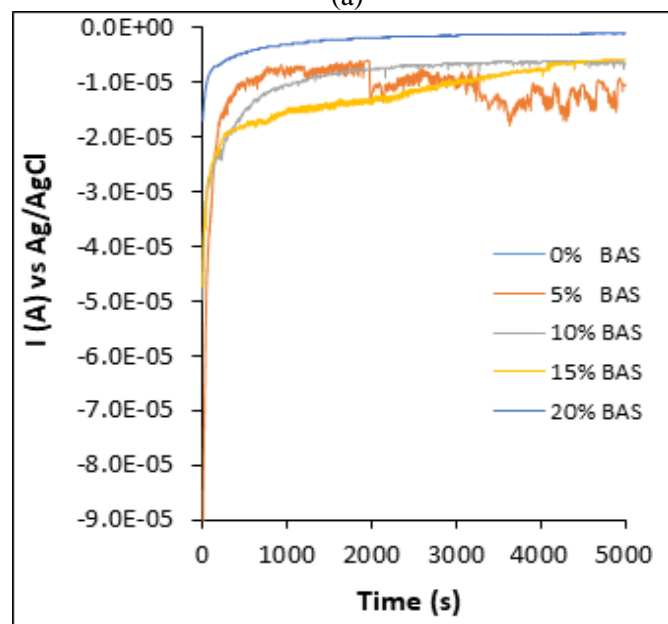


(b)

**Figure 1.** (a) Potentiodynamic polarization curve for LCS artificial pore electrolyte (0% - 20% BAS) and (b) Cathodic polarization curves for LCS in artificial pore electrolyte (0% - 20% BAS)



(a)



(b)

**Figure 2.** (a) Plot of corrosion current versus exposure time LCS corrosion in artificial pore solution (0% - 20% BAS) (b) Expanded view of corrosion current versus exposure time at 5% - 20% BAS wt. content.

#### 4. Conclusion

The presence of cow bone soot in reinforced concrete pore solution significantly decreased the vulnerability of low carbon steel to corrosion with respect to concentration of the soot. Results show the presence of the soot suppressed the reduction reactions coupled with significant anodic potential variation due to inhibition of carbon steel corrosion and passivation of the steel surface. Corrosion current versus exposure time plot shows cow bone soot significantly decreases its thermodynamic tendency to corrode and passivates the steel surface.

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