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CHARACTERIZATION AND GAUSSIAN DISTRIBUTION OF TENSILE STRENGTH OF SOME REBARS PRODUCED FROM SECONDARY SOURCE

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ABSTRACT

In this work, the chemical, physical and mechanical characterization of two rebars produced locally in some areas in Nigeria were investigated. The chemical composition, phases and microstructure of the rebars were determined using optical emission spectrometry (OES), X-ray diffraction (XRD), optical microscopy/scanning electron microscopy (SEM). The mechanical characterization was determined using hardness, and tensile strength. The tensile strength data of the rebars were subjected to Gaussian distribution. From the results, it shows that the steels have carbon content in the range 0.444-0.864 wt% C. The XRD result shows the presence of ferrite and sharp peaks of cementite. The optical micro-scope shows the presence of large amount of cementite in the ferrite matrix. The SEM analysis shows the presence of defects in the microstructure. The Gaussian distribution shows wide variability in the tensile strength data of the rebars. From the chemical, physical and mechanical characterization results, it shows that the rebars are below the standard quality.
Keywords: Rebars: microstructure; gaussian distribution; ferrite; cementite

1. INTRODUCTION

Recently, reinforcement bars from secondary sources are manufactured for building construction industry in Nigeria. The sources of such steels may be from different sources, which lead to the rebars produced to lack the quality and properties expected of rebars. Researchers have studied the characterization and mechanical properties of rebars produced locally in Nigeria. Therefore, some of the rebars presents variability in their tensile strength data. The ideal tensile strength and carbon content of rebars should be within the range of 600-650 MPa and 0.15-0.25% C respectively (BS4449, 1997).

However, some researchers have employed the use of statistical tools to model the variability in mechanical properties of steels from multiple tensile test data. For example, Tatsuo et al. (1996) conducted research using a normal distribution to analyze the tensile strength of rebars structural steels used in the construction industry. A mean and standard deviation value in the range 442.8-656.2Mpa and 21.8-33.8Mpa respectively were reported. Several years later, Rafi *et al.* (2014) carried out a study using log normal distribution to predict the reliability of flexural strength and yield strength of some steel rebars manufactured in Pakistan. The correlation coefficient value of the flexural strength comes out to be 0.80 less than the value recommended by ACI code (0.91) and the standard deviation of the yield strength was found to be in the range 60-75 Mpa. (Ukamaka and Muhammad, 2015). Lazar and Bejinariu (2017), investigated the variability of mechanical properties of reinforcing bar produced in Saudi Arabia from 60 samples from different manufacturers. The results show that a mean and standard deviation of the tensile strength data are 675.99 MPa and 21.927 MPa respectively.

There is lack in literature on the characterization and study of the variability in tensile strength data produced from secondary sources in Nigeria. The objective of this study is to characterize some rebars using optical emission spectrometry (OES), X-ray diffraction (XRD), optical microscopy/scanning electron microscopy (SEM). In addition the Gaussian distribution of the tensile strength will be studied due to the variability in tensile strength of the same steel as tensile strength is one of the important parameter in steel development and quality control (ASTM E8/E8M-09, 2010).

2. MATERIALS AND METHODS

The rebars used in this research were obtained from two different companies manufacturing rebars. The samples were labeled A and B. The elemental composition of the rebars was determined using optical emission spectroscopy (OES) Shimadzu PDA-700. The phases present in the rebars were recorded using XRD PROTO machine. The rebars were cut and were mechanically ground on grades of SIC (Silicon Carbide) of 240, 320, 400, 600 and 800 grits respectively using water as the lubricant. Polishing was carried out using 5µm, 3µm and 1µm size alumina polishing powder suspended in distilled water respectively. Final polishing was achieved using 0.05µm alumina powder suspended in distilled water. The etching of the polished samples was done using NITAL (2% nitric acid) to reveal the phases. The micrographs were obtained photographically using an optical metallurgical microscope Model no.NJF-120A with an inbuilt camera. Secondary image of the rebars was recorded using scanning electron microscopy (SEM) to reveal the types of defects present in the rebars.

The tensile strength of the rebars (22 each) were determined after preparing the samples according to (ASTM E8/E8M-09, 2010) using universal testing machine P503. The tensile strength data was subjected to Gaussian distribution to determine the mean and standard deviation according to the equation (Rafi et al., 2014).

$$p(x)\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{x-\mu}{2\sigma^2}} \quad (1)$$

where p(x) is the probability density function, σ is standard deviation and μ is the mean.

3. RESULTS AND DISCUSSION

The result of the chemical composition of the rebars used in this research is shown in Table 1. From the table, it shows that rebar A has a carbon content of 0.441% while rebar B has a carbon content of 0.863%. From the results, it shows all the rebars have carbon content above that is required of structural steels (0.15-0.25%) as reported by Tarsuro et al. (2001) and established in (BS 4449-2005).

The phases present in the rebars A and B are shown in Fig. 1. From the figure, it shows a sharp peak of ferrite and pearlite in rebars A and B at 2θ angle of 45.01 and 66.84° respectively. The pearlite peak of rebar B are more pronounced compared to rebar A. This can be attributed the carbon content. This can be attributed to the carbon content of the steel, which is closer to the euctectoid point of steels. At the eutectic point, a structure called pearlite is formed, which is a lamellae structure consisting of ferrite and cementite. In addition, high cementite content in steels makes them very brittle.

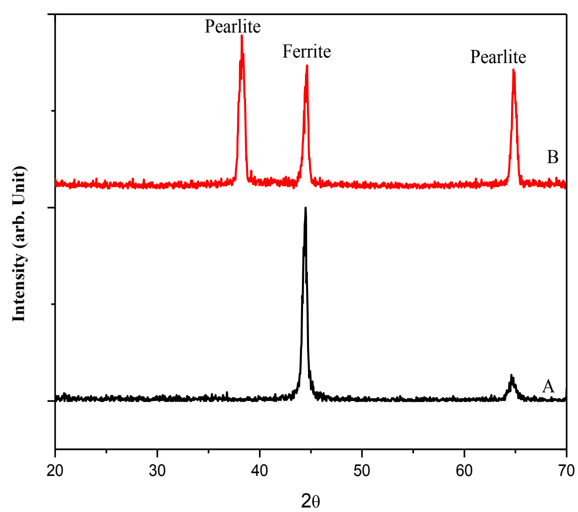

Fig. 1 XRD peaks of rebar A and B

Table 1: Chemical composition of rebar A and B (Muazu and Ibrahim, 2023).

Category (Rebars)	Percentage of elements (wt. %)													
	C	Mn	Si	P	S	Ni	Cr	Mo	Cu	Ti	Sn	Al	Pb	W	Va
A	0.441	0.785	0.217	0.005	0.016	0.119	0.098	0.056	0.052	0.02	-	-	-	-	-
B	0.863	0.853	0.433	0.008	0.028	0.158	0.176	0.089	-	0.008	0.01	0.027	0.022	0.151	0.01

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3.1 Microstructure

Figure 2 shows the microstructure of the steels recorded by optical microscopy. From the figure, it shows rebar A has higher amount of ferrite than cementite. However, rebar B has almost equal amounts of ferrite and pearlite in its microstructure. This can be attributed to its high carbon content, which shows an increase in carbon content results in the increase in pearlite (dark phase). All the phases present in the rebars are not in conformity with what has been reported in ASTM (1997).

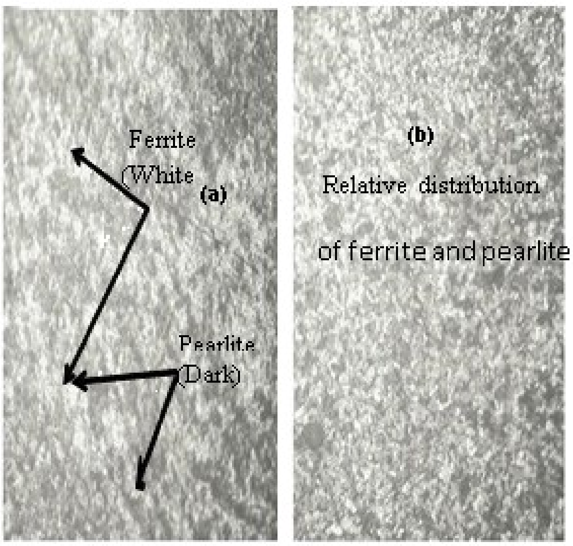

Fig.2 Optical microscope of rebar (a)A and (b)B (×200)

3.2 SEM

The SEM (secondary image) is shown in Figure 3. From the figure, it shows the rebars have defects in the form of pores and cracks. These defects will have a great influence on the tensile strength as postulated by Irwin; flaws such as cracks and pores influence the tensile strength property of materials (Anderson, 1995). For rebar A, it shows the presence of cracks in the SEM micrograph. While, rebar B shows crack, which is less than that of rebar A. The presence of defects such as pores in some of the steels may arise due to the presence of nonmetallic inclusions such as paints, silicates and oxides present in the scrap.

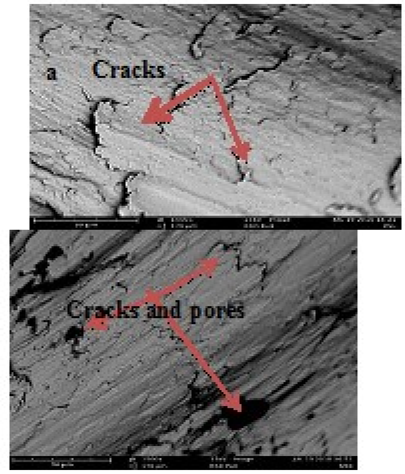

Fig. 3 SEM image of rebar (a) A and (b) (x1500)

Table 2 Summarizes the Minimum, the Maximum, the Mean and the Standard deviation of the tensile strength. From the Table 2, it can be observed that, the mean value of rebar B is the natures of flaws found in rebar A (cracks and pores) as shown in Figure 3. However, the nature of flaws in rebar B is cracks only. Also, from the table, it shows the standard deviation of rebar A is lower than that of rebar B. This is due to less variability in the tensile strength data of rebar A.

Fig. 4 shows the Gaussian probability density function of rebar A and B. From the figure, its shows that rebar A has a higher probability density with narrower tensile strength distribution than rebar B. This can be attributed to the higher value of standard deviation of rebar B than rebar A. This further show that the tensile strength data of rebar A is more uniform than that of rebars B.

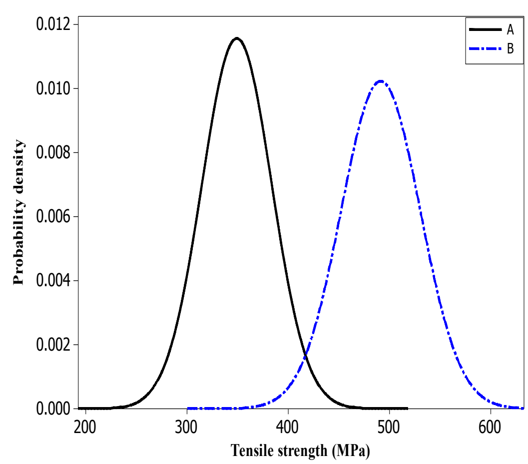

Fig.4 Probability density function of rebar A and B

Table2: Summary Minimum, Maximum, Mean and Standard deviation of the tensile strength

Rebar	(N)	Mean (MPa)	St Deviation (MPa)	Minimum (MPa)	Maximum (MPa)
A	22	349.23	34.51	294.41	386.83
B	22	491.33	39.01	399.29	540.72

4. CONCLUSION

Research on rebars produced from scraps was conducted. From the work it shows higher percentage of carbon than that found in rebars for construction industry. Also, the mean tensile strength of the rebars tested were below the tensile strength of rebars (ASTM, 2007).

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