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Investigation into the Mechanical Properties and Microstructure of a Local and an Imported Reinforcement Bar

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Abstract: *This study investigates the mechanical properties and microstructure of locally manufactured and imported steel reinforcement bars, which are used in industrial and wastewater settings. Imported Steel (Brazilian steel) and local steel (Land craft industrial Steel) were used for the experiment. Tensile, hardness and impact tests were done and Optical microscope was employed to examine the microstructure of the steels before and after corrosion when immersed in 1 molar of sulphuric acid solution. Ultimate tensile strength for land craft industrial steel was 708.30 MPa, the yield strength 520 MPa while the % elongation was 25.64. However, for the Brazilian steel, ultimate tensile strength was 538.51 MPa, yield strength 525 MPa and % elongation was 16.32. The average hardness value for land craft industrial steel was 194.80 HV, while for Brazilian steel; the average hardness value was 182.38 HV. The impact result for land craft industrial steel and Brazilian steel were 41.03 J and 35.68 J respectively., the Brazilian steel depicted pitting corrosion that is wide, elliptical, and whitish, suggesting that the corrosion has a noticeable elongation in one direction while Local craft industrial steel was observed to have open and deep pits suggesting a localized form of corrosion.*

Keywords: *Reinforcement bars, Brazilian Steel, Land Craft Industrial Steel, Mechanical Properties, Microstructure, Corrosion*

1. INTRODUCTION

Steels are generally utilized in the construction sector on account of its high tensile strength as well as affordable cost [1]. Steel-reinforced concrete forms the backbone of today's infrastructure, with steel bars giving concrete the tensile strength it needs to match its ability to withstand compression. Steel corrosion in acidic conditions is a complex electrochemical process that depends on a number of variables, including steel's chemical makeup and microstructure as well as the surrounding environment. In addition, the presence of sulphur and phosphorus impurities in steel may also accelerate corrosion and lead to brittleness as well as lower mechanical performance [2]. Reinforcement bars, also known as rebars, are crucial parts of reinforced concrete structures because they raise their tensile strength. In addition, the physical properties of corroded rebars change a lot when they are exposed to harsh environments for a long time. Research shows that corrosion makes rebars weaker less stretchy, and more likely to break. This puts the strength of reinforced concrete structures at risk [3]. But in harsh settings, like those with sulfuric acid (H_2SO_4), these structures can take a hit as the steel inside starts to rust. When steel reinforcement rusts in acidic environments, it gets thinner, weaker, and might even cause the whole structure to fail [4]. Leon and Jeon [5] showed that what is in the rebar especially how much sulphur it contains makes a big difference in how well it resists rust. The way steel rebars are built on the inside also has a lot to do with how they handle rust. When rebars are exposed to corrosive environments, their impact strength drastically reduces, as demonstrated by Nwankwo and Abubakar [6]. These problems are worse in rebars that already have flaws in their microstructure or were made using poor methods [3], [7]. Welds, corrosion, and surface imperfections all drastically shorten fatigue life, according to studies like those by Kalfat and Al-Mahaidi [8]. According to Fang *et al.* [9], brittle failures could result from even low levels of corrosion reducing yield strength and elongation. This degradation is frequently studied using accelerated corrosion tests in conjunction with tensile tests. The attributes of rebars are considered with respect to their ultimate tensile strength, percentage elongation and yield strength As a result, sufficient quality control need to be done on the mechanical properties of rebars to monitor regulatory standards in order to prevent failure of structures [10]. Locally made rebars from scrap metal are growing in popularity in Nigeria and throughout Africa. In Nigeria and throughout Africa generally, locally produced rebars made are fast becoming increasingly popular. Thus, particular focus needs to be placed on the quality of the high yield grade reinforcement steel that is produced and utilized in Nigeria's construction sector [11].

2. RELATED WORKS

Katiyar *et al.* [7] proved that different internal structures like ferrite-pearlite, martensite, and tempered martensite do not all rust at the same rate when they're surrounded by concrete. The research concluded that smaller microstructures provide improved resistance to corrosion. This happens because of the even spread of phases and fewer galvanic cells [12]. Katiyar *et al.* [7], Shuaib and Mohammed [13] tested local rebars and found that inadequate heat treatment caused re-bend test failures, indicating a noncompliance with production standards. In areas where rebar bending is necessary during installation, these problems have a direct effect on rebar performance. The mechanical performance of rebars is typically evaluated using standardized tests since it is essential for both safety and structural integrity. These tests, which assess attributes like toughness, ductility, yield strength, and tensile strength, include impact testing, fatigue analysis, bend testing, and tensile testing [14]. According Akinyele *et al.* [14], buildings in seismic zones are more vulnerable because the ductility of rebars obtained from West African informal markets frequently falls short of standard elongation requirements. Ettu *et al.* [15] examined the mechanical characteristics of steel rebars from Nigerian markets and discovered notable variations in yield and tensile strength, indicating the need for improved quality control. [16], investigated fatigue performance and came to the conclusion that irregularities in tensile properties could result in unexpected structural behavior, expressed similar worries. In addition to decreasing cross-sectional area, corrosion also alters mechanical characteristics.

Sy *et al.* [17] conducted an analysis of the physical characteristics, chemical composition and linear mass variations of some of steels—both locally produced and imported—used in Senegal's construction industry. The chemical analyses of the steels was done using combustion, reductive fusion for nitrogen, infrared detection for carbon and sulphur, and optical emission spectrometer for all other elements. The chemical analysis showed that steel type 3 exceeded the limit value for the proportion of carbon by 29.16%. The limit values outlined in the French standard NF EN 10,080 were not exceeded for the other kinds, 1, 2, and 4. Regarding the relative mass variations, the findings showed that 33% of steels with diameters of 8 mm and all specimens of rods with diameters of 10 and 12 mm did not meet the requirements for locally produced steels. According to the data, type 4 steels also satisfied the requirements for chemical composition and relative linear mass variations.

The chemical composition and degree of adherence to conventional concrete reinforcement steel rods rolled in Nigeria were also compared by Leramo *et al.* [18]. From Nigeria's six geographical zones, thirty selected rebar brands were collected, and their degree of conformance to five distinct standards (SON, BSI, ASTM, AISI, and ISO) was assessed. The test for the chemical composition was conducted utilizing optical light spectrometric methods. To ascertain if there are significant differences in the mean chemical composition of the steel rods, a one-way ANOVA (ANOVA) test was conducted using SPSS version 20. The compliance level and chemical composition of the various steel rods differ significantly ($P < 0.05$) according to statistical analysis. It was observed that, with exception of Brand 16's regular steel bar with value above the CEV's defined bounds, the brands were completely compliant with the utmost ranges allowed by local, international, and foreign standards.

Ahmed *et al.* [19] produced industrial rebars of two B400B-R and B500B grades using a Tempcore process. To enhance its mechanical properties B500B grade's normal chemical composition was further alloyed with 0.067 wt.% V. Two diameters D20 (Ø 20 mm) and D32 (Ø 32 mm) were manufactured under a series of ideal processing parameters. The relationships between microstructure and mechanical properties were evaluated by tensile testing, hardness testing, and optical and scanning electron microscopy. Additionally, using a definition of the thermal cycle evolution during cooling in the quenching & tempering box (QTB), a thermal model was developed to replicate the V(C, N) precipitation kinetics. The microstructure studies showed a conventional graded microstructure consisting of an outer tempered martensite ring and a ferrite-pearlite core for both grades of both diameters. The optimized processing parameters for B400B-R of D32, in comparison to D20, resulted in tempered martensite surface (from 220 to 200 HV10) and core softening (from 160 to 135 HV10), as well as a decrease in yield strength (from 455 to 413 MPa) and tensile strength (from 580 to 559 MPa). Contrarily, for B500B grade D32, the yield strength increased from 510 to 537 MPa at nearly the same level of tensile strength of 624–626 MPa, the hardness of the core increased from 165 to 175 HV10, and the hardness of the outside tempered martensite increases from 240 to 270 HV10 when compared with D20.

A thorough study of the deformation behavior and microstructural development of a new ultra-low carbon Cr-Mo alloyed dual-phase steel rebar meant for marine uses was reported by [20]. The reported that the rebar matrix consisted of the lamellar ferrite/bainite dual phases with the lamellar interfaces along the rolling direction and the soft ferrite phase was made up of larger grains with a reduced dislocation density, while the hard bainite phase was made up of finer grains with a greater dislocation density. The chemical and mechanical quality of reinforcing bars on the Lubumbashi market—including those imported from South Africa (FA), Zambia (FZ), and those made domestically (FC) by the sole steel plant in the former Katanga province, the iron processing company, were assessed by [21]. The chemical identification revealed that save three chemical components such as Mo, Ni and Cu the three natures of the reinforcing bars are comparable with all the elements in the ISO 9001 standards, namely Fe, Mn, Cu, Si, C, Cr, Ni, Mo, P, S, Nb, Co, Ti, V and Al. This discrepancy is, though, lessened by the same carbon content. Mechanical characterization revealed that every material under investigation satisfies the ISO 6898 criteria. The FC samples (436 N/mm^2); FA (450 N/mm^2); FC (475 N/mm^2) respectively exhibit the high values of the elastic limit resistances of 16, 12, and 10mm diameter. These habits were seen as well in the plastic stage.

Studying the metallurgy of various rebars arbitrarily acquired in Ghana, Annan *et al.* [22] hoped to assess their suitability for building projects. The research involved identifying the chemical composition of the different diameters of rebars, examining microstructure and mechanical characteristics of the rebars, and comparing the found data to values of the Ghana Standards Authority (GSA). They said that the diameters measured provided average values near those of the standard values and that the chemical compositions of the rebars were excellent as they were all within the mild steel range but a few noteworthy differences were noticed in the chemical composition. With 545.11 MPa average tensile strength and 453.55 MPa average yield strength, the samples exceeded the GSA criteria of 400 MPa and 300 MPa minimum, respectively. As requirements for both elongation and area reduction were surpassed, the rebars were extremely ductile. They demonstrated that the chosen rebars adhered to GSA specifications.

Fente *et al.* [23] evaluated the performance of locally produced rebar in relation to the Compulsory Ethiopian Standard (CES) in order to foster confidence in contractors and consultants of various projects. They experimented with rebar of grades B400BWR and B500BWR with different diameters that were sourced from four different manufacturing locations. The collected samples were analyzed using the following criteria: yield strength, ultimate tensile strength, elongation, hardness, chemical composition, and microstructure formation. Using the tension test results obtained from the 2000 KN Universal Testing Machine (UTM), the yield strength, ultimate tensile strength, and elongation of the rebar were assessed. The Spark Emission Spectrometer Analyzer was used to analyze the chemical composition. At a 0.5 mm cross-sectional gap the Vickers Hardness Tester with 3 kgf and 15-s dwell duration was utilized for the micro-hardness testing. Five high strength steels from various suppliers (three DP980 and two CP980) were mechanically and microstructurally examined by Fente *et al.* [23] to obtain mechanical variances, tensile tests were conducted, to measure grain size, microstructural examinations were also conducted. Scanning electron microscopy (SEM) and optical microscopy with the cross-section of the rebar was examined. One of the tested samples, B400BWR, was unable to meet the CES 101, 2017 minimum yield strength requirement of 400 MPa. Even though the B500BWR samples exceeded the minimum requirement by 41%, they still met all the standards' requirements.

Muñiz *et al.* [24] mechanically and microstructurally analysed five different high strength steels (three DP980 and two CP980). Through microstructural analysis, grain size and volume fractions of martensite and ferrite in the case of DP980, and ferrite, bainite, and retained austenite in the case of CP980 were obtained, while mechanical variances were measured using tensile tests. Much differences were shown by the mean grain size, hardening exponent and elongation. To investigate their variance in an industrial process, bending angle and U-bending experiments were conducted following the measurement of springback. For the steels and press strokes, 250 pieces in total were bent. For the same press stroke, differences of up to 1.25° in bending angle were found among the different batches. A correlation test was conducted to estimate the effects of the various factors on the bending angle, and the results showed that sheet thickness and tensile strength were two of the most important factors.

3. METHODOLOGY

Brazilian and Land craft industrial steels both imported and local were sourced from the local market and were used for this experimental work The chemical analysis of the steels is shown in Table 1

Table 1: Chemical composition of low carbon steels used in the study

Steel Sample	C%	Si%	S%	P%	Mn%	Ni%	Cr%	Mo%	V%	Cu%	Fe%
Brazilian Steel	0.114	0.215	0.014	0.0097	0.93	0.019	0.021	0.0001	0.0009	0.013	98.6
Land Craft Industrial steel	0.172	0.257	0.056	0.106	0.71	0.100	0.237	0.014	0.012	0.253	98.0

3.1 Sample Preparation

Five (5) samples with diameter 16 mm and length 60 mm to 75 mm were cut out from the parent metals of both local (Land craft industrial) and imported steel (Brazilian) for hardness, impact, tensile, and metallography processes respectively. The standard method of getting good microstructure was adhered to by cutting some samples out followed by grinding the surface of the metal with silicon carbide in order of 220, 320, 400 and 600 emery papers. After polishing the surfaces, they were etched with 2% NITAL (2% Nitric Acid and 98% Ethyl Alcohol) and then placed in a desiccator.

3.2 Tensile Strength Test

The steels were subjected to tensile strength test in accordance with [25]. Three identical specimens were tested at room temperature with a strain/loading rate of 5 mm/mm. An X-Y recorder was used to obtain load displacement plots, from which the ultimate tensile strength, percentage elongation and yield strength values were computed.

3.3 Impact Test

The specimens were subjected to impact test in accordance with [26]. The section thickness of these test specimens was examined. On a Hounds field impact-testing machine, the tests were conducted utilizing the Izod impact testing method. The specimen was notched from a 28 mm end length of 75 mm at a 45º angle. The machine's calibrated scale was used to measure the impact strength in Joules (J) that the specimen imbibed.

3.4 Hardness Test

Hardness test of the reinforcement steel bars sample was performed according [27]. To determine the Vickers hardness, the specimen was loaded through a diamond pyramid indenter. The diagonals of the indentation in were measured mm.

To Calculate average diagonal: $D = \frac{(D1+D2)}{2}$ (1)

To calculate Vickers Hardness (HV): $HV = \frac{(1.85\ X\ F)}{D^2}$ (2)

Where F is load in kg and D is average diagonal in mm.

3.5 Microstructural Examination

Optical Microscope was utilized to study the Microstructure of the steels before and after corrosion after immersion in 1 Molar of Sulphuric acid solution.

Figure 1: LaboQuip XTJ103i Optical microscope

4. RESULTS AND DISCUSSIONS

The results and discussions are presented in this section

4.1 Tensile Test

The provided data in Table 2 presents a comparative analysis of tensile test results for 16 mm steel samples. It shows values for ultimate tensile strength, yield strength, modulus of elasticity, standard deviation of ultimate tensile strength, tensile stress at break, tensile strain at break, and percentage elongation for both steel types.

The ultimate tensile strength of the Land craft industrial steel (708.30 MPa) is significantly higher (approximately 31.5%) than that of the Brazilian steel (538.51 MPa). This indicates that the local steel can withstand a considerably greater maximum tensile stress before it starts to fracture compared to the Brazilian steel.

The yield strength of the Land craft industrial steel (520 MPa) is (approximately 22.4%) higher than that of the Brazilian steel (425 MPa). This indicates that the Land craft industrial steel can withstand a greater amount of stress before it begins to deform permanently compared to the Brazilian steel.

The modulus of elasticity for the Land craft industrial steel (17586.68 MPa) is (approximately 63.5%) higher than that of the Brazilian Steel (10756.46 MPa). The Land craft industrial steel exhibits a much higher modulus of elasticity compared to the Brazilian steel, indicating that the Land craft industrial steel is significantly stiffer and more resistant to elastic deformation under tensile stress in these 16 mm samples

The standard deviation of the ultimate tensile strength for the Brazilian steel (25.68 MPa) is higher than that of the Land craft industrial steel (20.12 MPa). The standard deviation ultimate tensile strength values show that the Brazilian steel exhibits a higher degree of variability in its ultimate tensile strength compared to the Land craft industrial steel.

Table 2: Tensile test result for 16 mm Steels

Steel Sample	Ultimate Tensile Strength (MPa)	Yield strength (MPa)	Modulus of Elasticity (MPa)	Standard deviation Ultimate Tensile Strength (MPa)	Tensile Stress at break (MPa)	Tensile strain at break (mm/mm)	Percentage Elongation
Brazilian steel	538.51	425	10756.46	25.68	363.94	0.20614	16.32
Land craft industrial steel	708.30	520	17586.68	20.12	507.04	0.21843	25.64

Figures 2 and 3 shows the stress-strain responses of the Brazilian and Land craft industrial steels for three specimens, the y-axis shows the tensile stress (in MPa) against tensile strain (in mm/mm) on the x-axis. Both steels exhibit strain hardening, where the stress increases again after the initial yielding as the material undergoes further plastic deformation. Observing the graphs, we can note the following differences in the overall stress-strain behaviours:

i. Yield strength: It appears that the Land craft industrial steel (Figure 3) exhibits a higher yield strength compared to the Brazilian steel (Figure 2). The stress at which the curve deviates significantly from the initial linear elastic region seems to occur at a higher tensile stress level for the Land craft industrial steel across all three specimens. The Brazil steel, while showing some variation between specimens, generally yields at a lower tensile stress.

ii. Ultimate tensile strength: Similarly, the ultimate tensile strength (the peak stress reached on the curve) appears to be higher for the Land craft industrial steel (Figure 3) compared to the Brazil steel (Figure 2). The maximum tensile stress attained by the Land craft industrial steel specimens is seen to be greater than that of the Brazilian steel specimens.

iii. Ductility: The Brazilian steel (Figure 2) seem to exhibit greater ductility than the Land craft industrial steel (Figure 3). The stress-strain curves for the Brazil steel extend to significantly higher tensile strain values before the apparent drop indicating fracture, suggesting a larger capacity for plastic deformation. The Land craft industrial steel curves, on the other hand, appear to reach their peak stress and then decrease at lower strain values compared to the Brazilian steel.

4.2 Hardness Test

Table 3 gives the result for the hardness test of the two 16 mm steel samples: Brazilian steel and Land craft industrial steel. Four hardness measurements were taken for each type, yielding varying vickers hardness (HV) values. The data allows for a comparison of the relative hardness between the two materials. The Brazilian steel samples exhibited the following hardness vickers (HV) values: 170.57 HV, 192.42 HV, 191.25 HV, and 175.28 HV. The Land craft industrial steel samples gave the following Hardness Vickers (HV) values: 193.72 HV, 187.73 HV, 191.93 HV, and 205.83 HV. Both steels exhibited vickers hardness values within a similar range, indicating that they possess comparable resistance to indentation under a defined force. However, Land craft industrial steel samples generally showed higher hardness values compared to the Brazilian steel samples across the measurements. Also, there is some degree of overlap in the individual measurements, indicating that some samples of each type can exhibit similar hardness and the Brazilian steel samples show a slightly wider range of hardness values within the tested set. The average hardness values for Land craft industrial steel was 194.80 HV, while for Brazilian steel the average values were 182.38 HV.

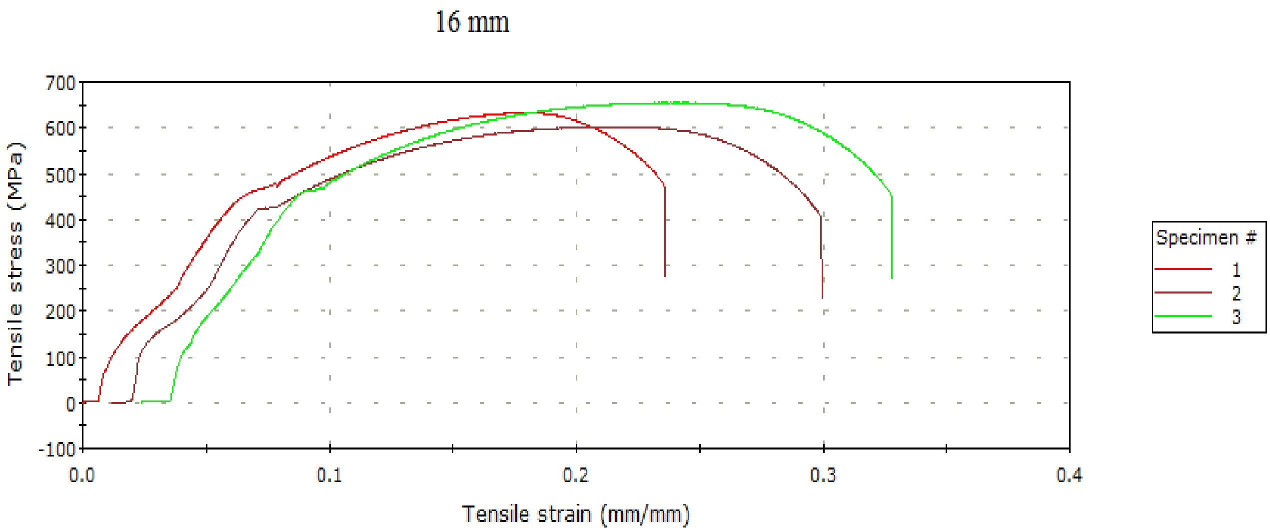

Figure 2: Stress - Strain curve for 16 mm Brazilian steel

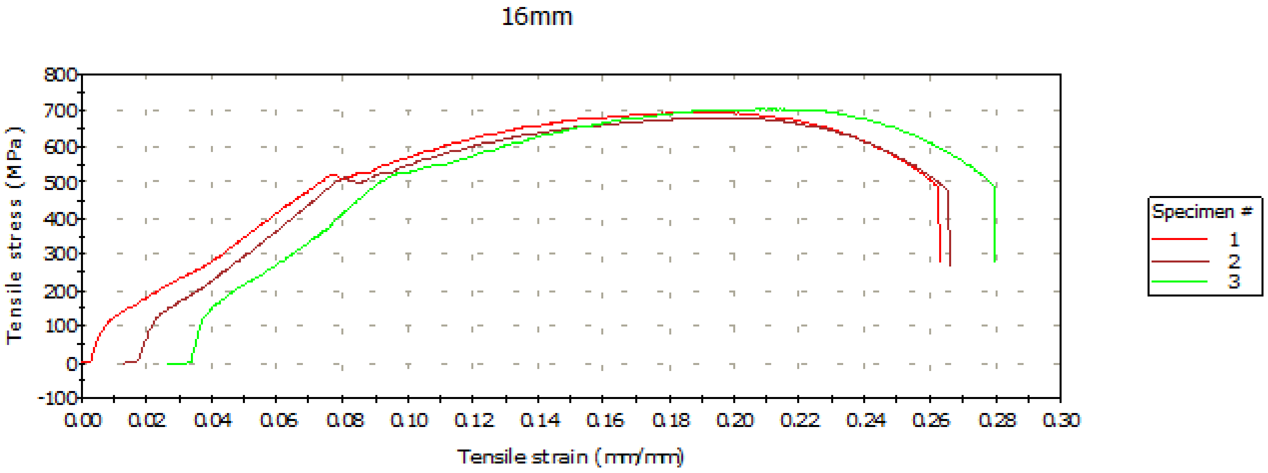

Figure 3: Stress - Strain curve for 16 mm local craft industrial steel

Table 3: Results for hardness vicker test.

Steel Sample	Hardness vicker (HV)	Hardness vicker (HV)	Hardness vicker (HV)	Hardness vicker (HV)	Average (HV)
Brazilian steel	170.57	192.42	191.25	175.28	182.38
Land craft industrial steel	193.72	187.73	191.93	205.83	194.80

4.3 Impact test

The provided data in Table 3 presents impact test results for the two distinct 16 mm steel samples: Brazilian steel and Land craft industrial steel. The table offers two impact measurements in Joules for each material. Land craft industrial steel demonstrates higher impact resistance: The individual impact test results for the Land craft industrial steel samples (41.82 J and 40.23 J) were consistently higher than those for the Brazilian steel samples (35.02 J and 36.34 J). The average impact resistance is significantly different: The average impact result for the Land craft industrial steel was 41.03 J, while the average impact result for the Brazilian steel was 35.68 J. The data suggest that under the conditions of the impact test, the Land craft industrial steel was more capable of withstanding sudden and forceful loads without fracturing compared to the Brazilian steel. This implies that the Land craft Industrial steel can be a more suitable material for applications where impact resistance is a critical factor and possesses a greater capacity to absorb energy during an impact without fracturing compared to the tested Brazilian steel sample. These are at par with the work of Alo *et al.* [28]

Table 4: Results for impact test

Steel Sample	Impact (Joules)	Impact (Joules)	Average (Joules)
Brazilian steel	35.02	36.34	35.68
Land craft industrial steel	41.82	40.23	41.03

4.4 Microstructural test

Figure 4 shows a heterogeneous microstructure typical of low to medium carbon steel, which depicts locally made or hand-forged steel. It shows a non-uniform distribution of pearlite (dark regions), a lamellar mixture of cementite (Fe_3C) and ferrite (light regions), which is the soft and ductile phase of iron, contributes to hardness and strength. The appearance is mottled or grainy, which is common for steels with different micro constituents.

Figure 5 shows a typical ferrite-pearlite microstructure, found in mild to medium carbon steel reinforcement bars. Compared to the local craft steel, it shows a more consistent and refined microstructure. The grain sizes and distribution are consistent with industrial rebar manufacturing processes, indicating hot rolling. The darker areas represent the pearlite regions, which are the tougher and more durable phase formed by the eutectoid transformation of austenite. On the other hand, the lighter areas indicate the ferrite regions, which are the soft and ductile phase. Because it balances strength and toughness, the ferrite-pearlite structure is suitable for structural applications. The microstructure's elongated grains are indicative of either directional deformation or solidification. The irregular and interconnected grain of the steel indicates that it has undergone thermomechanical processing.

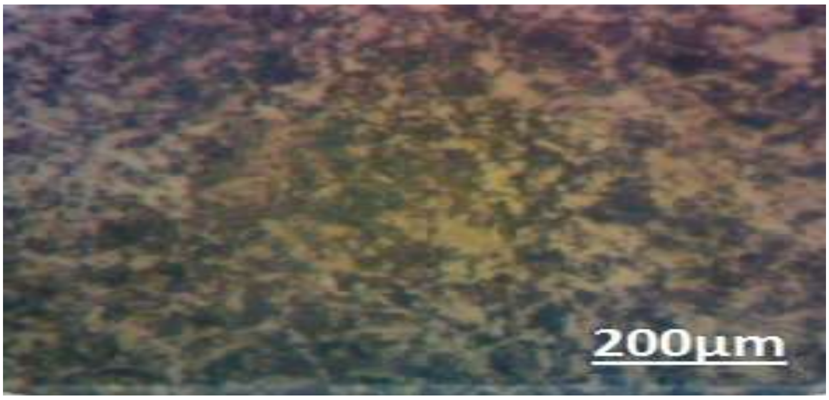

Figure 4: Optical microscopy of land craft industrial steel

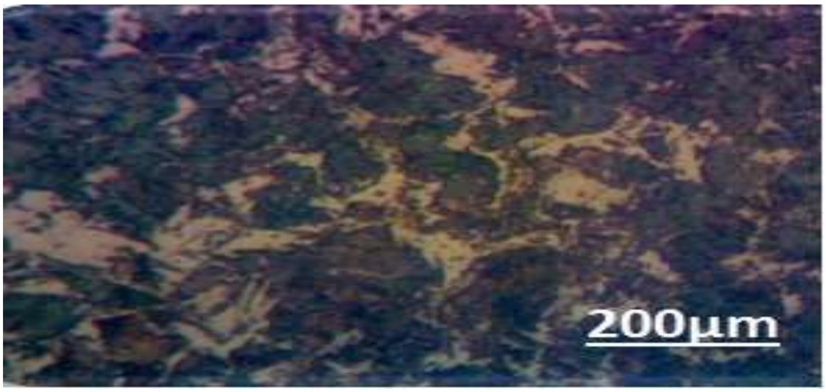

Figure 5: Optical microscopy of Brazilian steel

Figure 6 shows the Brazilian steel sample after corrosion in 1 Molar of sulphuric medium, viewed with an optical microscope, it depicts pitting corrosion that is wide, elliptical, and whitish, suggesting that the corrosion is not perfectly circular and has a noticeable elongation in one direction. The elliptical shape of the pits suggest that the corrosion propagated preferentially along certain directions on the steel surface. This is indicative of the direction of a corrosive flow, stress, or the microstructure of the material being corroded. Factors such as grain orientation, presence of elongated inclusions or anisotropic conditions at the steel-sulphuric acid interface influenced the direction and rate of pit growth, leading to a wide and elliptical form. The whitish color of the corrosion products within the pits indicates the formation of specific compounds due to the interaction between the Brazilian steel and the acidic medium.

Figure 6: Optical microscopy of Brazilian steel after corrosion

Figure 7 shows Land craft industrial steel sample after corrosion in a 1 Molar of sulphuric acid, viewed with an optical microscope, it has a general localized corrosion pits, where pits were open, deep, and black corrosion products were observed. were open, deep and black corrosion products were observed [29]. The observation of open and deep pits suggests a localized form of corrosion, often referred to as pitting corrosion. This kind of corrosion is subtle with very harmful effects and even failure while leaving much of the surface relatively unaffected. The depth of the pits indicates that the corrosion process has progressed considerably at these locations.

Figure 7: Optical microscopy of land craft industrial steel after corrosion

5. CONCLUSION

Based on the tests carried out on the Brazilian steel and the Land craft industrial steel, the following results were gotten: Ultimate tensile strength for Land craft industrial steel was 708.30 MPa, the yield strength was 520 MPa while the % elongation was 25.64 but for the Brazil steel, the Ultimate tensile strength was 538.51 MPa, Yield strength was 525 MPa and the % elongation was 16.32, based on the provided stress-strain curves, the 16mm steel from Land craft Industrial steel appears to be stronger, exhibiting higher yield strength and ultimate tensile strength compared to the 16mm steel from Brazilian steel. Conversely, the 16mm steel from Brazil demonstrates greater ductility, being able to undergo more plastic deformation before failure. The average hardness values for Land craft industrial steel was 194.80 HV, while for the Brazilian steel, the average values were 182.38 HV. Therefore, Land craft industrial steel samples generally showed higher hardness values compared to the Brazilian steel samples. The Impact result for Land craft industrial steel was 41.03 J, while for Brazil steel impact was 35.68 J, this also implies that the Land craft industrial steel might be a more suitable material for applications where impact resistance is a critical factor and possesses a greater capacity to absorb energy during an impact without fracturing compared to the tested Brazilian steel sample. Brazilian steel sample after corrosion in 1 Molar of sulphuric acid medium, viewed with an optical microscope, depicts pitting corrosion that is wide, elliptical, and whitish, suggesting that the corrosion is not perfectly circular and has a noticeable elongation in one direction while the Local craft industrial steel was observed to have open and deep pits suggesting a localized form of corrosion, often referred to as pitting corrosion. This kind of corrosion is subtle with very harmful effects and even failure while leaving most of the surface relatively unaffected. The depth of the pits indicates that the corrosion process has progressed considerably at these locations. These suggests that the Brazilian steel has a reduced corrosion effect than the Local craft steel. In summary, where strength high is desirable, the 16mm local craft steel is recommendable but where ductility is utmost, then the 16mm Brazilian steel should be used.

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