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An Assessment of Imported and Local Constructional Steel in Nigeria: Analysis by One-Way ANOVA

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Abstract This study reports an assessment of imported and local constructional steel in Nigeria. The analysis was carried out using one-way ANOVA. The result showed that, Federated steel has the highest hardness value of 126.3 HV and Impact value of 149 HV among all the sizes of the iron rod followed by Land Craft Industrial with 190 HV. Ukraine has the least hardness of 130 HV. While Brazil has the least Impact value of 35.02 J. Federated steel has Ultimate Tensile strength (UTS) of 799.49MPa, Land Craft Industrial steel has 708.30 MPa, Brazil steel has 538.51MPa followed by Ukraine with 544.81 MPa. The yield strength for the Federated steel is 660MPa, Land Craft Industrial steel is 510 MPa, and Brazil has 440 MPa. Ukraine Steel with 420 MPa. ANOVA test confirmed the results at 95% confidence and further showed that there was significant difference between the four samples. There existed significance difference between land craft and Ukraine, as well as between land craft and Brazil (mean differences = 326. and 512. respectively, at $p<0.05$) Further analysis on the interaction effect within the locations revealed that significant difference existed between Federated and Ukraine as well as between Federated and Brazil (mean differences = 340. and 526. respectively, at $p<0.05$).

Keywords Mechanical, Properties, ANOVA, Steel and Strength

1. Introduction

Steels are the major components of machineries used in the industries. Mild steel is one the major construction materials, which is extensively used in chemical and allied industries for the handing of acid, alkali and salt solution [1]. Steel is an alloy of iron and carbon with iron being the major constituent. The various grades of steel produced in the country and currently used for construction works are largely structural steels (Mild steels).

Over 500 million tonnes of low carbon steels are produced yearly around the world; they are used for most of the engineering applications. Low carbon steels are utilised to produce cars body panels, tubes, domestic appliance side panels and other engineering applications because they are readily available, workable and weldable [2].

In addition, the mechanical properties of low carbon steel such as strength formability, ductility, fatigue strength and surface hardness, amongst others enhances its performance in service. Studies have also shown that failure of carbon steels can result from production methods, use of substandard material, poor design, manufacturing errors due to poor machining, or failure from a phenomenon called fatigue [3, 4]. Steel exhibits a wide range of mechanical characteristics of which the strength factor is the dominant property. Engineering strength is however, evaluated in terms of yield strength, ultimate tensile strength (UTS), modulus of elasticity (E), percentage elongation and impact strength. Any increase in the strength characteristics of steel will enhance the reliability and durability of the structure/machine in which it is used [5]. Conversely, low strength characteristics often result in short life span of structures, warpage, undesirable deflection and even failure/collapse. Mild steel mostly used for structural purposes contain 0.15-0.30 percent carbon [6], the quality of molten steel depends on the charge characteristics. These include levels of deoxidation, inclusions, slag composition and cleanliness. Sulphur and phosphorus are the two major deleterious elements that must be controlled [7].

It has been identified that the use of inferior and substandard steel rod are among the causes of construction collapse and failures [8]. Therefore, the production of the steel bars to meet service requirements and estimation of the mechanical properties are very imperative [9, 10].

Since the rate of building is on increase since early 90s, many researches have been conducted on the reinforcement steels in the constructional building. [11] Investigated the yield strength of steel reinforcing bars used in Nigerian concrete structures and concluded that the test results of 12mm and 16mm reinforcing bars adopted for structural purposes within Lagos State environment which have

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experienced the most cases of building collapse in Nigeria. A total of 433 samples from sites located in 10 Local Government Areas of Lagos State were analysed with statistical tools. About 42% of the 12mm bars and 46% of 16mm bars failed to meet the BS code prescription of 460N/mm yield strength and about 28 % and 33% of 12mm and 16mm bars, respectively, failed to meet the Nigerian's professional's prescription of 410N/mm.

2. Experimental Procedures

The experimental procedures were carried out as follows:

2.1. Materials and Sample Preparation

The steels were commercially obtained and the chemical compositions of the steels were analyzed at Nigerian Foundries Limited, Ilupeju, Lagos State, Nigeria. The result of the analysis is shown in Table 1.

The mild steels were sectioned into 30 mm × 20 mm × 5.0 mm with Buehler Isomet 4000 linear precision saw and were successively grinded on Buehler Automatic polisher with series of SiC abrasive papers (240, 320, 600 and 800). Tensile strength testing of all specimens were conducted as per ASTME 8 standard [12]. Three identical tests specimen for each section thickness per sample were tested at room temperature with a strain/ loading rate of 5 mm/mm using a computerized Instron Testing Machine (model 3369). Load displacement plots were obtained on an X – Y recorder and ultimate tensile strength, yield strength and percentage elongation values were calculated from this load displacement diagrams. For the Hardness testing, the cut sample from different steel manufacturing company were subjected to the microhardness Vicker tester, model FM-800, serial no: FMS 8033 according to ASTM/A29M-15 [13]. The Impact testing for all the specimens was done based on ASTM E23 [14]. These test specimens were tested for section thickness. The tests were carried out using Izod Impact Testing method on Hounsfield Impact Testing Machine. Specimen was notched at an angle of 45° from 28 mm end length of 75 mm. The amount of Impact energy absorbed by the specimen was read off on the calibrated scale attached to the machine as a measure of impact strength in Joules.

The Universal Testing Machine (UTM) was used to determine the mechanical properties of the specimens. Each specimen was subjected to tension in accordance with the BS4449:1997 [15] ASTME8 standard provisions, and after fracture, the average Yield Strength (YS), average Ultimate Tensile Strength (UTS) and the Percentage Elongation (%E) were obtained according to the Expressions:

Yield Strength (N/mm^2) = Yield Force / Original Cross Sectional Area (1)

Ultimate Tensile Strength (N/mm^2) = Maximum Force the Specimen can withstand / Original Cross Sectional Area (2)

Percentage Elongation (%) = (Final Length – Original Length) / Original Length (3)

Steel serves as a suitable reinforcement material because its coefficient of thermal expansion (5.8 x 10^{-6} to 6.4 x 10^{-6}) is nearly the same as that of concrete (5 x 10^{-6} to 7 x 10^{-6}). This means that there will be no relative movement between embedded bars and concrete in the reinforced concrete work due to temperature changes [16]. [17], in her work on assessment of the Microstructure and Mechanical Properties of 0.26% Low Carbon Steel under Different Cooling Media via one-way ANOVA confirmed the results at 90% confidence. Many authors had used Anova for statistical analysis like [18-20].

3. Result and Discussions

From Figure 1, it could be seen that Federated, Land craft industrial steel, Ukraine and Brazil steels are in the same range with the standard, only Ife iron steel has a very low Brinell hardness value. The reason may be due to the low carbon contents and this is in agreement with the work of Valeria [21].

The summary result for 16 mm steel is presented in Table 2. Federated steel has Ultimate Tensile strength (UTS) of 799.49MPa, land craft industrial steel has 708.30MPa, Brazil steel has 538.51MPa followed by Ukraine with 544.81MPa. The yield strength for the Federated steel is 660MPa, Land Craft Industrial steel is 510MPa, and Brazil has 440MPa. Ukraine Steel with 420 M Pa. The stress-strain graphs for 16 mm steel are shown in Figure 2.

In Figure 3, Federated steel has the highest hardness value of 126.3 HV and Impact value of 149 HV amongst all the sizes of the iron rod followed by Land Craft Industrial with 190 HV. Ukraine has the least hardness of 130 HV. While Brazil has the least Impact value of 35.02 J.

Table 1. Elemental Composition of Steel Used (Mass fraction, wt. %)

	C%	Si%	S%	P%	Mn%	Ni%	Cr%	Mo%	V%	Cu%	Fe%
Federated Steel	0.266	0.164	0.018	0.018	0.637	0.026	0.025	0.502	0.001	0.220	98.123
Brazil	0.114	0.215	0.014	0.0097	0.93	0.019	0.021	0.0001	0.0009	0.013	98.6
LCI	0.172	0.257	0.056	0.106	0.71	0.100	0.237	0.014	0.012	0.253	98.0
Ife Iron	0.320	0.203	0.038	0.003	0.514	0.093	0.215	0.0001	0.0001	0.307	98.255
Ukraine	0.195	0.075	0.025	0.009	0.56	0.013	0.022	0.0001	0.0001	0.018	99.083

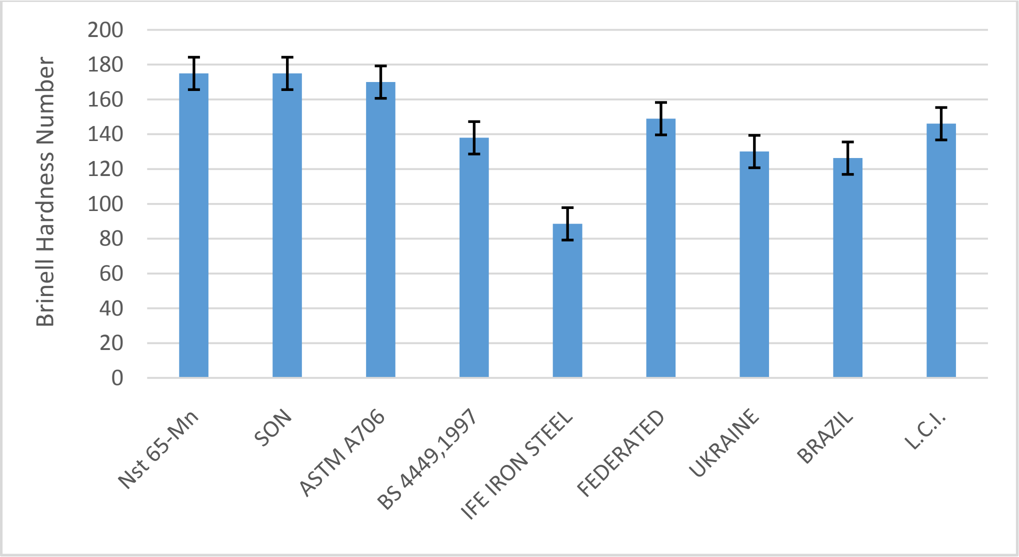


Figure 1. Comparison of Brinell Hardness Number of Ife Iron steel, Federated steel, land Craft industrial steel, Ukraine steel and Brazil steel compared with enable standards

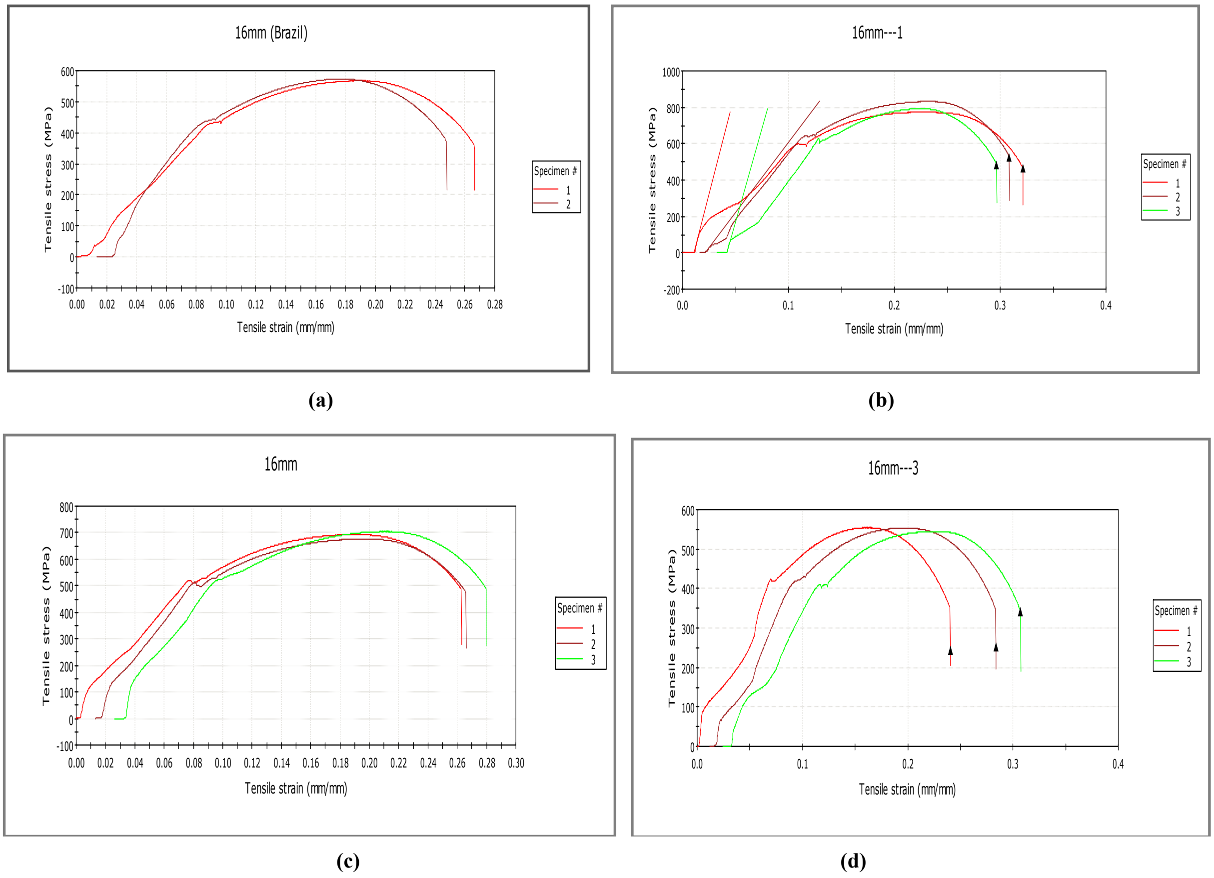


Figure 2. Stress Strain Result for 16mm Steel (a) Brazil, (b) Federated, (c) Land Craft Industrial and (d) Ukraine

Table 2. Stress Strain Result for 16mm Steel

Sample 16mm	Ultimate Tensile Strength (MPA) $UTS = \frac{Pmax}{Ao}$	Yield Strenght (MPA) $Yield\ Strenght = \frac{Yl}{Ao}$	Modulus of elasticity (MPA) E=STRESS/STRAIN	Standard Deviation of UTS	Tensile Stress at Break (MPA)	Tensile Strain at Break (mm/mm)	Percentage Elongation $\frac{Lf - Lo}{Lo}$
Federated	799.49	640	17028.65	30.12	490.19	0.2644	29.29
L.C.I	708.30	520	17586.68	20.13	507.04	0.21843	25.64
Ukraine	544.81	420	20933.91	66.56	278.94	0.18279	25.64
Brazil	538.51	425	10756.46	25.677	363.94	0.17991	25.04

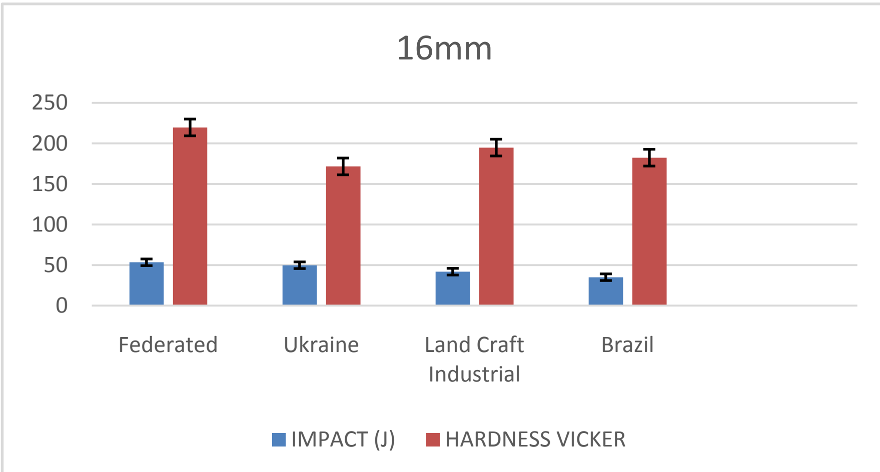


Figure 3. Comparison of Impact and Micro hardness Values of different of Steel

3.1. Statistical Analysis

Stress Total for Four Different Locations

Analysis of variance (ANOVA) was carried out to consider the effect of location on the stressTOTAL, it was discovered that location had statistically significant effect on the stressTOTAL (f = 11.311 @ $p<0.05$) (Table 3), this implied that stress MTOTAL for the 4 locations were not the same, this can be confirmed from their mean values which ranged between 1360 and 834 (Table 3). Federated has the highest mean value (1360) followed by land craft (1346), Ukraine (1020) with the lowest being Brazil (834).

If the decision rule is the higher the stress TOTAL, the higher the performance, this result therefore implied that the stress TOTAL from the location with the highest mean has the highest performance. Hence stress TOTAL from Federated will perform best followed by land craft, Ukraine and Brazil with the lowest performance.

Further analysis on the interaction effect within the locations revealed that significance difference existed between Federated and Ukraine as well as between Federated and Brazil (mean differences = 340 and 526. respectively, at $p<0.05$) (Table 4) whereas no significance difference existed between Federated and Land Craft (mean difference = 14 at $p<0.05$).

It was also shown from the Table that mean stress TOTAL for the Federated was higher than that of Ukraine, Land Craft and Brazil (mean differences being positive); mean difference between Federated and Ukraine and that of Brazil were large which implied that their means would not be close and confirmed significance difference in their means.

In the same vein, there existed significance difference between Land Craft and Ukraine, as well as between Land Craft and Brazil (mean differences = 326. and 512. respectively, at $p<0.05$). It was also shown from the Table that mean stress TOTAL for Land Craft was higher than that of Ukraine and Brazil, also mean stress TOTAL for Ukraine was higher than that of Brazil (mean differences being positive). It is worth noting that no statistically significance difference existed between Ukraine and Brazil (mean difference = 186 at $p<0.05$) with Ukraine having higher mean stress TOTAL than Brazil.

The result of Tukey (HSD) test (Table 5) also revealed that Brazil and Ukraine belong to subset 1 while, land craft and Federated shared subset 2; this is an indication that the effect of locations within the same subset on MTOTAL was not statistically significant whereas effect of the locations sharing different subsets on MTOTAL was significant. This is an indication that samples from brazil and Ukraine will behave the same way while samples from land craft and Federated will behave the same way but different from the previously listed locations.

The profile plot of steel samples (Figure 4) showed that stress TOTAL for Federated and Land Craft were very close while a very wide divergent occurs in stress TOTAL for Brazil compared with others which also confirm the above result.

Table 3. ANOVA result with the mean values for stresstotal

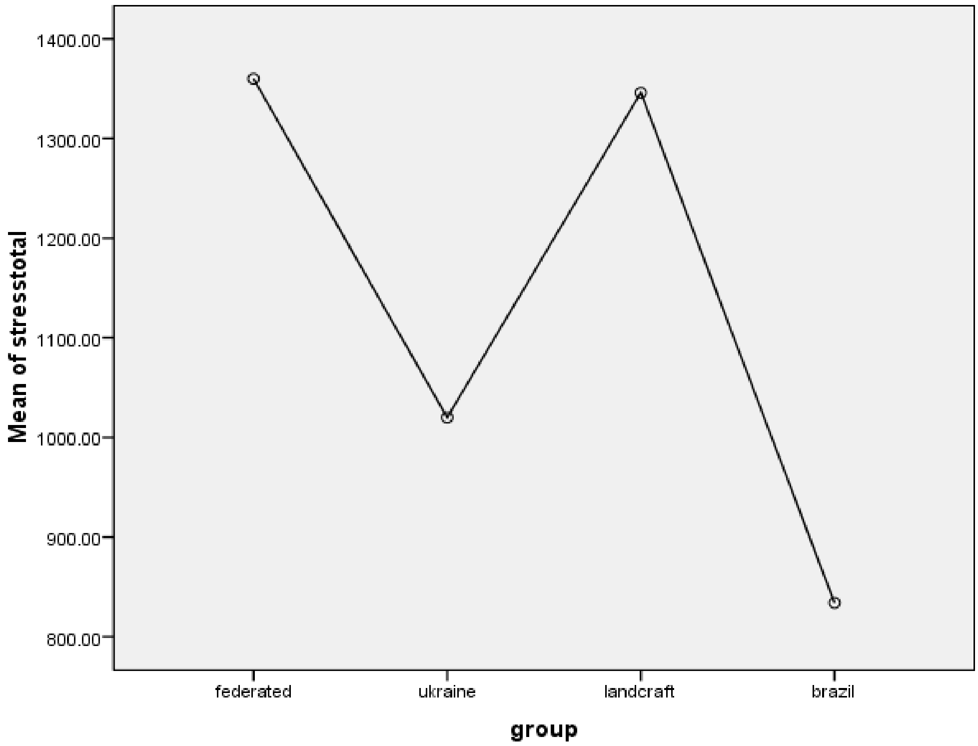
Descriptive						
Stress total						
					95% Confidence Interval for Mean	
	N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**
Federated	6	1360.00	55.14	22.51	1302.14	1417.86
Ukraine	5	1020.00	204.08	91.27	766.60	1273.40
Land craft	5	1346.00	238.39	106.61	1050.00	1642.00
Brazil	5	834.00	167.42	74.87	626.12	1041.88
Total	21	1150.47	279.44	60.98	1023.28	1277.67
F= 11.311; sig = .000						

Table 4. Result of Tukey HSD Test for the 4 locations for stresstotal

Multiple Comparisons						
stress total **Tukey HSD**						
(I) group	**(J) group**				**95% Confidence Interval**	
		Mean Difference (I-J)	**Std. Error**	**Sig.**	**Lower Bound**	**Upper Bound**
Federated	**Ukraine**	340.00000*	106.03033	.024	38.6026	641.3974
	Land craft	14.00000	106.03033	.999	-287.3974	315.3974
	Brazil	526.00000*	106.03033	.001	224.6026	827.3974
Ukraine	**Federated**	-340.00000*	106.03033	.024	-641.3974	-38.6026
	Land craft	-326.00000*	110.74507	.041	-640.7993	-11.2007
	Brazil	186.00000	110.74507	.364	-128.7993	500.7993
Land craft	**Federated**	-14.00000	106.03033	.999	-315.3974	287.3974
	Ukraine	326.00000*	110.74507	.041	11.2007	640.7993
	Brazil	512.00000*	110.74507	.001	197.2007	826.7993
Brazil	**Federated**	-526.00000*	106.03033	.001	-827.3974	-224.6026
	Ukraine	-186.00000	110.74507	.364	-500.7993	128.7993
	Land craft	-512.00000*	110.74507	.001	-826.7993	-197.2007
The mean difference is significant at the 0.05 level.						

Table 5. Tukey Hsd test Result for Stress Total

Tukey HSD[a,b]			
Group		**Subset for alpha = 0.05**	
	N	**1**	**2**
Brazil	5	834.0000	
Ukraine	5	1020.0000	
Land craft	5		1346.0000
Federated	6		1360.0000
Sig.		.346	.999
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 5.217.			
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.			



Figures 4. Profile Plots for Stress Mtotal

4. Conclusions

This study shows that Federated steel has the highest hardness value of 126.3 HV and Impact value of 149 HV among all the sizes of the iron rod followed by Land Craft Industrial with 190 HV. Ukraine has the least hardness of 130 HV. While Brazil has the least Impact value of 35.02J Federated steel has Ultimate Tensile strength (UTS) of 799.49MPa, Land Craft Industrial steel has 708.30MPa, Brazil steel has 538.51MPa followed by Ukraine with 544.81MPa. The yield strength for the Federated steel is 660MPa, Land Craft Industrial steel is 510MPa, and Brazil has 440MPa. Ukraine Steel with 420MPa. ANOVA test confirmed the results at 95% confidence and further showed that there was significant difference between the four samples. There existed significance difference between land craft and Ukraine, as well as between land craft and Brazil (mean differences = 326. and 512. respectively, at $p<0.05$).

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