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Comparison of Mechanical Properties of Locally Made and Imported Carbon Steel Reinforcement Rods (ASTM: A36)

Ofuyekpone Okiemute[1], Utu Ochuko G[2]., Okonji Patrick O[3] and Philip N Atanmo[4]

[1]Metallurgical Engineering Department. Delta State Polytechnic, Ogwashi-Uku.
[2,3]Welding and Fabrication Engineering Department. Delta State Polytechnic, Ogwashi-Uku.
[4]Mechanical Engineering Department. Chukwuemeka Odumegwu Ojukwu University, Uli.

Abstract

Investigation of the mechanical properties (ultimate tensile strength, yield strength, hardness, impact strength and % elongation) of locally made and imported carbon steel reinforcement rods (ASTM: A36) was carried out. Steel samples were obtained from Rathisteel Mill and Power Ltd, India (Sample A), Eastern Metals (Nig.) Ltd. Asaba (Sample B), PUKKIT (Nig.) Ltd, Lagos (Sample C) and SANKYO (Nig.) Ltd, Lagos (Sample D) and were prepared into mechanical test specimens. Thereafter the mechanical properties of the samples were evaluated. The results showed that locally produced steel products showed better mechanical properties when compared to the imported steel products. The ultimate tensile strength values are705N/mm^2 for Sample A, 602N/mm^2 for Sample B, 614N/mm^2 and 693N/mm^2 for Samples C and D respectively.The yield strength values 520N/mm^2 for Sample A, 482N/mm^2 for Sample B, 496N/mm^2 for Sample C and 508N/mm^2 for Sample D.The % elongation values samples are 18.33% for Samples A, 30.00% for Sample B, 25.00% for Sample C and 21.67% for Sample D. The charpy impact test values are 57J for Sample A, 192J for Sample B, 162J and 66J for Samples C and D respectively. While the hardness numbers values are 49.00BHN for Sample A, 34.75BHN for Sample B, 38.25BHN for Sample C and 41.50BHN for Samples D respectively. Thus, the steel product, sample B appeared to be the best steel sample since it showed better mechanical properties when compared to the other steel products during period of investigation.

Keywords: Strength, Hardness, Carbon Steel rods (ASTM: A36), Energy Absorbed, % Elongation

Nomenclature:

UTS	=Ultimate tensile strength
YS	=Yield Strength.
%EL	= Percentage Elongation.
IT	=Impact Test (joules).
BHN	=Brinell hardness Tester
ASTM	= American Society of Testing and Materials

1.0 Introduction

Most Engineering failures are frequently caused by misuse of materials. When a plastic tea spoon buckles as it is being used, when a building collapses or when an aircraft is grounded because cracks have appeared in the tail plane, it is likely the engineer who designed them used the wrong materials or did not understand the properties of those materials used [1].There are more than 50,000 materials available to the engineer. In addition, hundreds of new materials appear on the market each month. Each of these materials has its characteristics, applications, advantages, limitations and cost. Thus, the task of knowing the properties and behaviour of types of available materials becomes enormous and challenging [2].

Adequate knowledge, therefore, of materials and their properties will no doubt help engineers and designers to avoid mistakes that may lead to engineering failures. Admittedly, some materials are not used widely because of availability, initial properties, cost or service performance. Others, like iron and steel, paper, concrete, wood (timber) etc., find extensive uses.

Corresponding author: Ofuyekpone Okiemute, E-mail: okedickbest@yahoo.com, Tel.: +2348034119210

Often, materials are reinforced to make them stronger when improved strength is the major goal. The reinforcing components must have a large aspect ratio. This means that its length-diameter ratio must be high so that the load is transferred across potential points of fracture. This is why steel rods are placed in concrete structures as reinforcing components [2].Unreinforced concrete, although has great compressive strength, is very weak in tension. It is this lack of tensile strength that leads to the necessity for reinforcement, which carries the tensile forces present in the structure. Although, a variety of materials such as glass fibres and plastic filaments have been used as reinforcement, most concrete members are reinforced with steel in the form of bars, wire mesh and strands because of their high strength, ductility and stiffness. Steel reinforcement imparts great strength and toughness to concrete. Reinforcement also reduces creep and minimizes the width of cracks [2]. Steel serves as a suitable reinforcement material because its coefficient of thermal expansion (5.8 x $10^{-60}C^{-1}$ to 6.4 x$10^{-60}C^{-1}$) is nearly the same as that of concrete (5 x $10^{-60}C^{-1}$to 7 x $10^{-60}C^{-1}$).

Plain carbon steel is by far the most widely used kind of steel. The properties of carbon steel depend primarily on the amount of carbon it contains. Most carbon steel has a carbon content of less than 1%. Carbon steel is made into a wide range of products, including structural beams, car bodies, kitchen appliances and cans. The three types of plain carbon steel are low carbon steel, medium carbon steel, high carbon steel, and as their names suggest, all these types of plain carbon steel differs in the amount of carbon they contain [3]. Plain carbon steel is a type of steel having a maximum carbon content of 1.5% along with small percentages of silica, sulphur, phosphorus and manganese[4]. Generally, with an increase in the carbon content from 0.01 to 1.5% in the alloy, its strength and hardness increase but still such an increase beyond 1.5% causes appreciable reduction in the ductility and malleability of the steel.

It is evident that hardness, brittleness and ductility are very important properties as they determine the way these different carbon content steels are used. The microstructure of slowly cooled mild steel, for instance, with 0.2% carbon. Consists of about 75% of proeutectoid ferrite that forms above the eutectoid temperature and about 25% of pearlite (pearlite and ferrite being microstructure components of steel). When the carbon content in the steel is increased, the amount of pearlite increases until the fully pearlitic structure of a composition of 0.8% carbon is obtained Beyond 0.8%, high carbon steel contains proeutectoid cementite in addition to pearlite [5].However, in slowly cooled carbon steels, the overall hardness and ductility of the steel are determined by the relative proportions of the soft, ductile ferrite and the hard cementite. The cementite content increases with increasing carbon content, resulting in an increase of hardness and a decrease of ductility, on transition from low carbon to high carbon steels [5].

Different materials possess different properties in varying degree and therefore behave in different ways under given conditions. These properties includes; mechanical properties, electrical properties, thermal properties, chemical properties, magnetic properties and physical properties [6, 7].

A design engineer is interested in the behaviour of materials under load which is mechanical in nature, for the design of machines and structures. Any material subjected to a load either deforms, yields, or breaks, depending upon the magnitude of the load. Engineers are basically interested in knowing how a particular material will behave under applied load, i.e. the mechanical properties[8].

Before choosing the materials of construction for an off-shore structure, ship, submersible, ocean-floor installation, buildings, bridges, rail ways or instrument package, many factors must be considered. Among these are the initial costs of the materials, their efficiency in the intended design, and the predicted lifetime of the materials. Many materials when fabricated into a system deteriorate in service in unexpected manners, unlike their predicted behaviour established in laboratory saline solutions [9].

In recent time, cases of collapsed buildings, bridges, rail ways, telecommunication mask etc have increased tremendously. Some of those failures are due to lack of proper material selection, not using the right dimension and number of steel samples for reinforcement, imbalance ratio of cement to sand to water, cement to water to gravel to sand ratios, lack of proper soil analysis to ascertain the load (weight) bearing capacity of the sand, use of sub-standard materials, engaging the services of quacks and so on. Consequently, the need for proper selection of material to withstand each peculiar environment, service conditions and type of structures is imperative. This has necessitated the investigation of the mechanical properties of locally made and imported carbon steel reinforcement rods (ASTM: A36).

2.0 Materials and Methods

Test Materials: The materials used for this investigation were medium carbon steel 18mm diameter reinforced steel bars. These samples were obtained from two major sources, namely: locally produced steel bars and imported product. The locally produced steel bars were obtained from three steel industries in Nigeria: Eastern Metals (Nig.) Ltd. Asaba (Sample B), PUKKIT (Nig.) Ltd. Lagos (Sample C) and SANKYO (Nig.) Lagos (Sample D). The imported steel, Rathi Steel Mill and Power Ltd, India (sample A) was purchased from Eastern Metals, Nig. Ltd. Asaba, Delta State. The chemical composition of each of the steel is shown in Table 1

Table 1: Chemical Composition (Wt %) of the Medium Carbon Steel for the Four Companies

No.	Alloy Elements	Company A	Company B	Company C	Company D
1.	C	0.387	0.254	0.275	0.313
2.	Fe	97.760	98.000	98.090	96.754
3.	Si	0.244	0.212	0.252	0.224
4.	Mn	0.827	0.555	0.732	0.991
5.	S	0.040	0.020	0.049	0.038
6.	P	0.041	0.015	0.064	0.036
7.	Cr	0.771	0.374	0.209	0.104
8.	Ni	0.673	0.350	0.102	0.111
9.	Mo	0.077	0.026	0.0001	0.0001
10.	Cu	0.224	0.183	0.231	0.311
11.	Al	0.008	0.014	0.031	0.032
12.	V	0.009	0.090	0.0001	0.0001
13.	Sn	0.019	0.082	NIL	0.0060
14.	Ti	Nil	Nil	0.005	Nil
15.	Co	Nil	0.012	Nil	Nil
16.	W	Nil	0.016	0.0001	0.0001
17.	B	Nil	0.008	0.0001	0.0001
18.	Nb	Nil	0.001	0.0001	0.0001

3.0 Test Procedure:

Tensile Test: The samples were cut to size (230 ×18mm) using power hacksaw in accordance with the standard of the American Society for testing and materials [10].The tensile test carried out according to ASTM E8 standard. The initial lengths and area of the specimens were measured. The specimens were loaded into the universal testing machine and load was gradually increased at a steady rate until the specimens fractured. The broken pieces were placed together and the final length was measured to determine the % elongation. The ultimate tensile strength and the yield strength were read off from the dial[10].

Hardness Test: The specimens were cut into 10 ×10mm size using hacksaw. The surface was ground, polished to ensure that the surface was flat, smooth and clean. The specimens' preparation and test procedure for the hardness test were in accordance with ASTM E18 standard. The hardness test was done using digital Brinell Hardness (BHN) tester. The hardness measurement was taken in four (4) different locations for each sample and the average values of the results were considered [11].

Charpy V-Notch Impact Test: The purpose of the impact test was to measure the toughness, or energy absorption capacity of the materials prior to fracture. The test was performed in accordance with ASTM E23. The specimen was cut to 55 × 10mm cross section and a V-shaped notch, 2mm deep, was cut atangle of 45^0 angle and 0.25mm radius cut on the larger face. The specimens were placed on the anvil of the machine and properly secured. The pendulum was set in raised position and the pointer on the dial set on the upper limit of the scale. The pendulum was released and impacted the specimen immediately behind the notch, breaking the specimen. The absorbed energy was read off from the dial. The sample is shown in Figure 1.

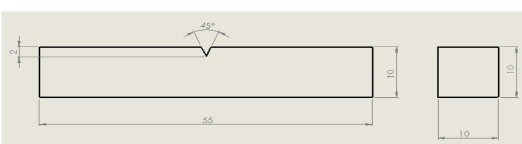

Figure 1: Charpy Impact test sample

4.0 Results

Table 2: Shows the result of the tensile tests for the different steel samples

Sample	Yield Strength (YS) N/mm^2	Ultimate Tensile Strength (UTS) N/mm^2	% Elongation
A	520	705	18.33
B	482	602	30.00
C	496	614	25.00
D	508	693	21.67

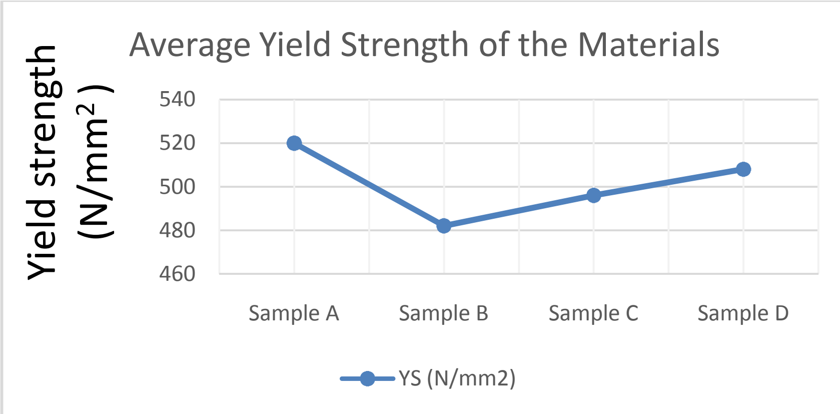

Figure 2: Plot of the yield strength (N/mm^2) Vs steel sample

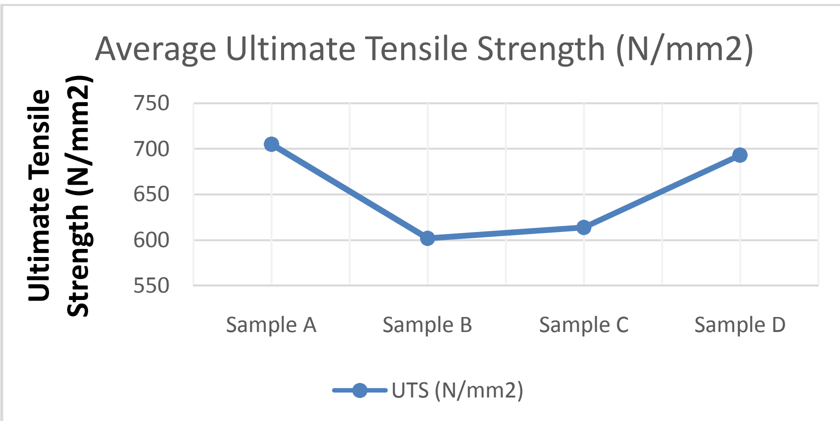

Figure 3: Plot of the Ultimate Tensile strength (N/mm^2) Vs steel samples

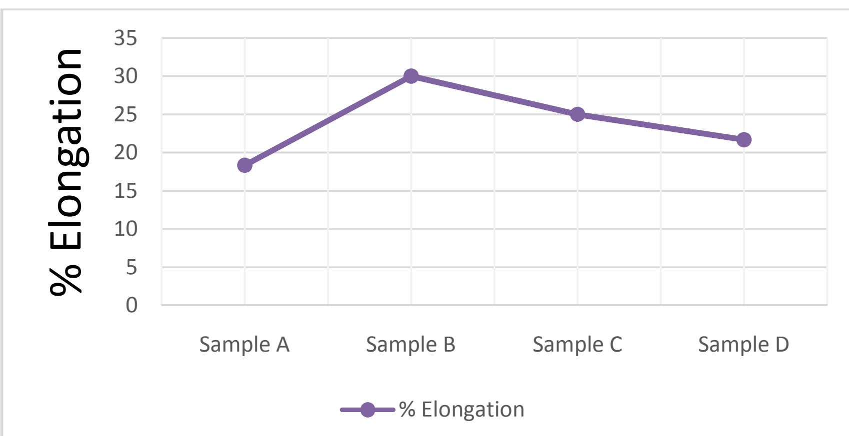

Figure 4: Plot of the Percentage (%) Elongation Vs steel sample

Table 3 shows the result obtained from the Impact Test for the various steel samples investigated.

Table 3: Impact Test Result

Sample	Test 1	Test 2	Test 3	Test 4	Average Result
A	56	60	55	58	57
B	193	191	194	190	192
C	160	164	161	163	162
D	68	65	67	64	66

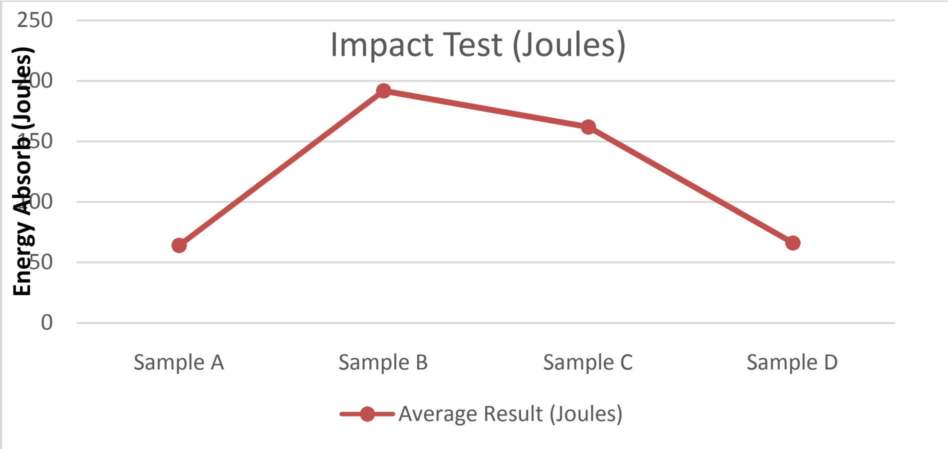

Figure 5: Plot of the Energy absorb (Joules) Vs steel samples

Table 4 shows the result obtained from the Hardness Test recorded for the various steel samples analysed.

Table 4: Hardness Test Result (BHN)

Sample	Test 1	Test 2	Test 3	Test 4	Average Result
A	47	50	51	48	49.00
B	33	37	34	35	34.75
C	40	38	36	39	38.25
D	43	41	42	40	41.50

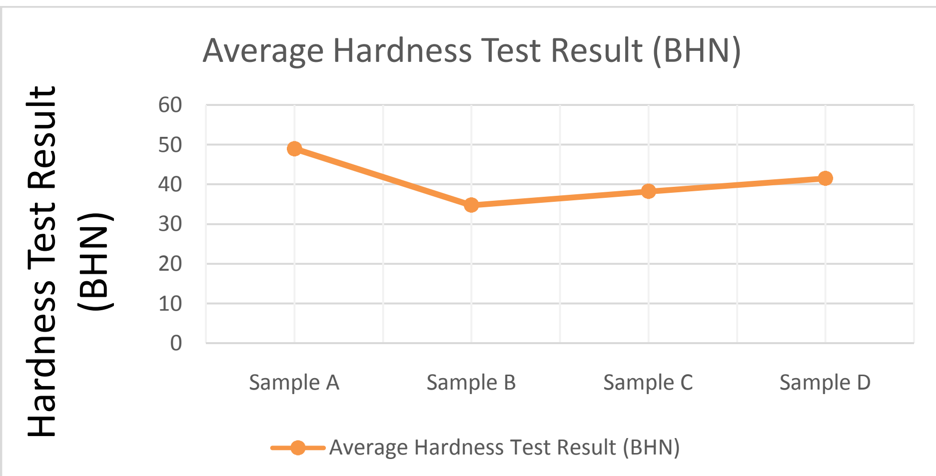

Figure 6: Plot of the Hardness Test Values (BHN) Vs steel samples

5.0 Discussion

The Figure 2 shows the plot of yield strength against the steel samples investigated. The plot reveals that sample A has the highest yield strength followed by samples D, E and B.

The Figure 3 shows the plot of ultimate tensile strength against the steel samples investigated. The plot reveals that sample A has the highest ultimate tensile strength followed by samples D, E and B.

The Figure 4 shows the plot of % Elongation against the steel samples investigated. The plot reveals that sample B has the highest % Elongation followed by samples C, D and A.

The Figure 5 shows the plot of Energy absorbed against the various steel samples investigated. The plot reveals that sample B has the highest value of energy absorbed followed by samples C, D and A

The Figure 6 shows the plot of Hardness test values against the analyzed steel samples. The plot reveals that sample A has the highest hardness value followed by samples D, C and B.

Carbon is the cheapest and one of the most effective alloying elements for hardening iron. The higher the carbon content the greater the hardenability, the strength and hardness of the steel. However, ductility, weldability and toughness are reduced with increasing carbon content [12]. This trend was observed in the result of the tensile test in Figure 1. The values of all the yield strengths which range from 482N/mm^2 for steel sample B to 520N/mm^2 for steel sample (A). The yield strength of Samples (C) and (D) are 496 N/mm^2 and 508N/mm^2 respectively, with steel sample (A)giving the highest yield stress.
Similarly, the values of the ultimate tensile strength for the local steel samples are 693N/mm^2 for (D), 614 N/mm^2 for (C), and, 602 N/mm^2 for (B), which showed smaller value of ultimate tensile strengths compared to the imported steel sample which gives a higher UTS (705N/mm^2 for A). This can be attributed to the carbon content in the steel.
Also, the results showed that as the carbon content increases the hardness value increased proportionately with Sample (A) showing the highest carbon content of 0.387%C and a hardness value of 49.00BHN, this is followed by Sample 'D' (0.313%C) with hardness value of 41.50BHN; Sample 'C' (0.275%C) with hardness value of 38.25 BHN and Sample 'B' (0.254%C) with hardness value of 34.75BHN.
The Figure 3 shows that %EL decreased as the carbon content increases (Sample (A) with the highest carbon content of 0.387%C has the lowest %EL of 18.33%, this is followed by Sample 'D' (0.313%C) with elongation of 21%; Sample 'C' (0.275%C) with elongation of 25% and Sample 'B' (0.254%C) with elongation of 30%. This reasonable elongation exhibited by sample B may be attributed to the small carbon content when compared with the carbon content of the other samples, and also, due to the presence of some alloying elements such as Ni, Mnetc. in the steel samples in proportions that favour ductility[13].
In the same vein, the energy absorbed increased as the carbon content decreases with sample B having the highest impact value of 192J. This is followed by sample C with impact value of 162J, and sample D having a value of 66J, while sample A recorded the least energy absorbed with a value of 57J. Thus, the higher the %El the more the energy absorbed.

6.0 Conclusion

The results showed thatSample B, a local steel sample, proved to be the best steel sample, since they show reasonable mechanical properties.

7.0 References

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