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INVESTIGATING THE VIABILITY OF AS-ROLLED STEEL VIA RECYCLING OF STEEL SCRAP FOR CONSTRUCTION IN NIGERIA

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Abstract: A sustainable iron and steel sector has for a long time been the objective of the Nigerian government, but since the failure in the complete installation of the Ajaokuta steel complex, Nigeria has had to opt for steel recycled from scrap. In an endeavour to ascertain the viability of steels produced locally in Nigeria, six 12 mm diameter steel bars designated for construction were gotten from the market, each from different company in Nigeria. The steels gotten were analysed for chemical composition, microstructure, tensile strength, ductility and hardness and the result produced were benchmarked against the specification of the Standard Organisation of Nigeria (SON). The result produced shows that steel from neither company A,B,C and E was qualified to be in Nigeria market, as steel from company A, C and E failed because it had a yield strength of 386 Mpa, 410.77 MPa and 391.27 MPa respectively as against the 420 Mpa stipulated by SON and steel from company B was completely brittle. While steel from company D and F was fit to be in the market as it met the minimum yield strength requirement by possessing 582.88 MPa and 457.26 MPa respectively.
Keywords: Steel, Yield strength, Building Collapse, Scrap steels, Chemical compositions, Mechanical Properties.

1. INTRODUCTION

Steel is said to be the world's most "advanced" material because of its versatility, attractive properties and economical cost of mass production. Steels are ferrous alloys which contain by mass more iron than any other single element, having less than 2% wt. Carbon and containing other elements (Keehan, 2004).

The impact of iron and steel in an economy cannot be over emphasised because its production and consumption are used as a parameter for measuring the rate and level of industrialisation in an economy. Nigeria has been gifted with all the resources needed for the production of iron and steel with over three billion tonnes of iron ore (Adebimpe, 2011), three billion tonnes of coal (Agbu, 2007) and limestone as high as 700 million tonnes (Council, 2001). Meanwhile the yearly approximation of per capita consumption for the country has increased from 5 kg in 1968 (Adedeji, 1984) to 130 kg in 2012 (Uzondu, 2012). Despite the huge investment in the iron and steel sector, Nigeria has failed to actualise her aspirations in making the iron and steel sector one of the most industrialised sector in the country (Ohimain, 2013), this has crippled development and industrialisation in Nigeria and in turn gave investors edge on recycling of scrap to produce steel for the ever increase in the countries demand for steel.

Since the clampdown of Ajaokuta steel mill project which was to utilise 2.2 x 10^6 Tonnes of iron ore per year (Obikwelu and Nebo, 2012), mills have been built by private establishment and they depend 100% on scrap steel which is gotten from municipal solid waste (MSW) (Ohimain 2013).

Steel can be obtained from two diverse manufacturing routes. One of these is centered predominantly on the reduction and smelting of iron ore mined from the earth crust in a blast furnace after which the products of the blast furnace is processed in to steel.

The second route is centered on re-melting steel scrap in an electric arc furnace (EAF) or Induction furnace (IF). Scrap steel is a source of iron in both cases but the proportion of the charge varies up to 100% in the EAF (Senfuka, 2011).

Scrap steel are usually acquired from three different sources namely;

1. Home scrap or steel scrap. This is obtained from steel mills during production of steel. They are pure and are of known chemical composition
2. Process scrap or Prompt scrap. They are obtained from remnant during fabrication of products made from steel.
3. Obsolete scrap or Capital scrap. Discarded iron and steel products falls into this category. They are often mixed or coated with other materials which increase its level of impurity. (Janke *et al.* 2000).

Bulk of scrap steels obtained in Nigeria is usually from scavengers and knocked down vehicle spare parts (Ohimain 2013) which contain lots of impurities such as Cu, Zn and Sn which were initially used to coat steel. These impurities exist as tramp elements and can be harmful to the steel if available in large portions such as loss to ductility, decrease in drawing properties, surface defects and scaling. Tramp elements such as Sn, Sb and Bi cause reduction of the steel's grain cohesion and induce brittleness in the steel (Janke *et al*. 2000).

The news and media has given reports of collapse of buildings which might be attributed to the integrity of steel reinforcement, as Nigeria is not known to be a primary producer of steel, most of the steel produced are recycled scrap iron whose integrity cannot be guaranteed moreover, overloading, sudden stress and prolonged use causes deterioration of steels especially the untreated ones which can be lethal to lives and properties of the occupants and can in turn lead to a bad reputation for the construction company and the nation at large. Some of the failures attuned to the steels produced from scrap iron are the fact that there seems to be irregularities in the chemical composition of the elements and as is it known that chemical composition is the building block of steel which determines the mechanical properties of steel. These properties are compromised when impurities are contained in the steel composition. It is therefore necessary to test as produced steels in Nigeria and benchmark the result obtained against the specification of the standard organization of Nigeria (SON) to certify if they meet the specified requirements and are fit for construction.

2. MATERIALS AND METHOD

6 samples of 12 mm steel bars specified for construction purpose were obtained from the market. The samples were selected from different manufacturers each who have their names crested on the steel bar. The samples were then labeled from A to F.

The chemical compositions of the samples were obtained using *SPECTROMAXx LMX07* in accordance to Optical Emission Spectrometer method file. Its microstructure was examined using a light microscope at 400x magnification. Universal Testing Machine (UTM) was used to test the mechanical properties of the steel samples. Each sample was subjected to tensile force. Tensile strength, yield strength, and ductility (percentage elongation and percentage reduction) was calculated with the following formulas:

Ultimate Tensile Strength UTS= (Fracture load (N))/(Original area (mm)) (1)

Yield Strength N⁄〖mm〗^2 Y= (Yield load (N))/(Original area (mm)) (2)

Percentage Elongation (ef): ef= (Change in length at fracture)/ (Original Length) ×100 (3)

Percentage Reduction (q): q= (Change in area at fracture)/(Original area) ×100 (4)

Also, the Vickers Hardness Number (VHN) was obtained using a micro Vickers hardness tester. The chemical composition results are given in table 1 and the tensile test results is given table 2, also the summarized strengths of all six samples is reflected in table 3 and the hardness results is given in table 4.

3. RESULT AND DISCUSSION

The results presented shows that steel from company A has failed to satisfy the SON standard for a carbon content of the range of 0.15-0.30% carbon and has also not agreed with SON minimum yield strength requirement of 420 MPa, as it exhibits a yield strength of 386 MPa. Although it does satisfy the SON minimum requirement for ultimate tensile strength and ductility which are 500 MPa and 10% respectively. The microstructural view of this steel shows that it has fine grain particles which can likely be attributed the presence of calcium.

Steel from company B although having carbon content of 0.20% which is well within the required range, has also showed an increased chromium content of 0.32% which has resulted in an increased strength and has in turn resulted to the brittleness of the steel. Steel from company B showed no value for yield strength and hence is not fit to be in the market, a careful observation of the micro structure shows and increased presence of cementite and ferrite in the steel.

Sample C has an excess of 0.003 and 0.005 for phosphorus and sulphur respectively. The excess phosphorus causes brittleness during cold working or when used in cold environments while the excess sulphur makes the steel brittle during hot forming or when used for high temperature application. This limits the area of application of this steel sample as it cannot be used anywhere above or below room temperature. All other elements appear to be within the acceptable range. Also, the presence of chromium of 0.2% tends to increase its hardness. Moreover the yield strength value exhibited by sample C is given as 410.77 MPa which is below the stipulated 420 MPa given by SON hence, steel from company C is not fit to be the Nigeria market.

Sample D has excess phosphorus of 0.007 while the sulphur has a precise percentage within its tolerance. According to ASM International (1998), 1026 steel should have Manganese content between 0.60-0.90 as against the 0.53 present in sample D. The excess phosphorus in the steel will make the steel brittle if used in cold environment but it will strive considerable well in hot environments. Also, low Manganese present in this steel sample will result in low hardness as manganese tends to impact hardness. Low chromium in the steel will also result in low hardness. Due to its carbon content, a better case hardening result can be obtained when heat treated, however sample D still exhibited a yield strength of 582.88 MPa which is well above the minimum requirement stipulated by SON and hence is fit to be in the market.

Results for sample E shows that all the alloying elements are of a good range except for Phosphorus, Sulphur and Manganese and this implies that the chemical composition of the steel is inaccurate, the carbon and manganese constitute the hardness of the steel, although these hardness will be accompanied with reduced ductility. Inclusions such as copper, nickel and aluminium will reduce grain growth in the steel causing it to have a fine grain aggregate but in so doing cause embrittlement especially with the presence of chromium. The steel exhibits a yield strength of 391.27 MPa which is below the required 420 MPa and can hence not be recommended for construction.

Analysis of the result for steel F shows a carbon content of 0.22, which is a mild steel, all of the elements are of specified range except for the manganese which is 0.47% while its required minimum is 0.7%, these causes the steel to be soft and ductile with a decrease in hardness. From the tensile test result, the steel have a tensile strength of 627.72 MPa, yield strength of 457.26 MPa, an elongation of 16, and a percentage area reduction of 54%. Hence steel F is satisfied to be in the Nigerian market as it meets the minimum required standard as stipulated by SON.

CONCLUSION

From the ensuing investigation, it is clear that out of every steel bought from the Nigerian market, there is a 66.67% chance of buying steels that are not fit for construction in the country. Steel from just two steel company could pass the SON minimum yield strength requirement of 420MPa, and very important to note is steel from company B which was completely brittle was also found in the market and was sold as a reinforcing steel bar, using such steel for reinforcement can be catastrophic, especially in the North-Eastern part of the country were there experience heavy wind during the harmattan season. This work has obviously made clear to users out there to ensure that before using any of the steel bought in Nigeria, proper testing should be carried out to ensure that the steel has the desired strength for construction purposes, however it is also important that SON steps up her quality control measures to ensure that such substandard steel product do not take over our market. In the light of experiences and exposure gained in carrying out this research it is strongly recommend that Other properties such as corrosion resistance, creep strength, and heat treatment test be carried out, in other to improve the information of the steel behaviors.

Table 1: Chemical Composition Result

Chemical Composition	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F
C	0.33	.20	.15	.26	.25	.22
Si	0.29	.18	.21	.18	.24	.084
Mn	0.80	.63	.61	.53	.71	.47
P	0.046	.051	.048	.052	.041	.044
S	0.041	.048	.06	.055	.051	.045
Cr	0.19	.32	.2	.092	.16	.17
Mo	0.014	.019	.017	.011	.013	.008
Ni	0.10	.089	.083	.088	.063	.079
Al	0.007	.001	.007	.002	.0005	.002
Co	0.010	.008	.004	.008	.003	.005
Cu	0.23	.22	.2	.22	.15	
Ti	0.001	.0004	.001	.0007	.0003	
V	0.002	.007	.005	.002	.0004	.001
W	0.001	.003	.002	.002		.0005
Pb	0.005	.002	.002	.002	.003	.007
Sn	0.035	.014	.016	.028	.009	.021
As	0.013	.011	.015	.014	.011	.011
Zr	0.0005	.0003	.0003	.0005	.0005	.0004
Bi	0.003	.003	.003	.003	.003	.003
Ca	0.001	.004	.023	.001	.0009	.005
Ce	0.005	.004	.005	.004		.19
Sb	0.022	.02	.02	.023	.02	.0004
Nb	0.0005	.0007	.0002	.001	.0009	.0003
Se	0.004	.003	.003	.004	.004	.004
Te	0.017	.016	.016	.016	.016	.017
Ta	0.065	.055	.073	.057	.069	.072
B	0.004	.001	.002	.002	.001	.002
Zn	0.041	.0002	.001	.008	.013	.031
La	0.0007	.0001	.0003	.0008	.0002	.0005
N	0.008	.041	.012	.004	.045	.009
Fe	97.9	98.2	98.4	98.5	98.3	98.6

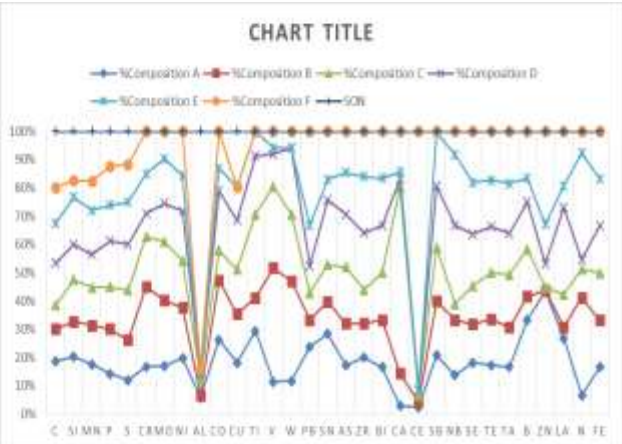


Figure 1: Chemical Constituents of made in Nigeria Steel in Relation to SON.

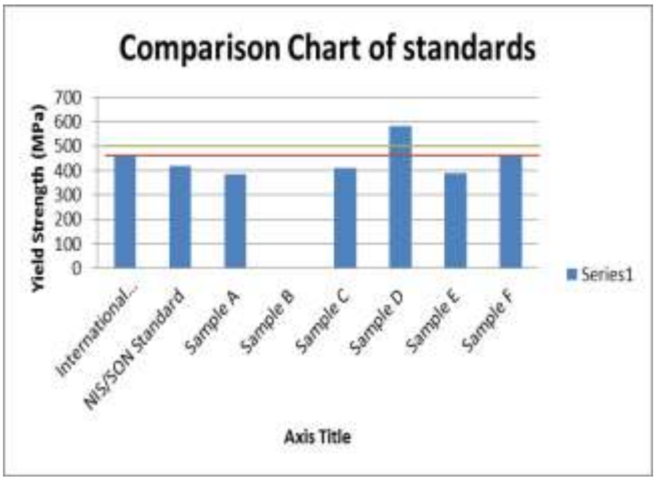


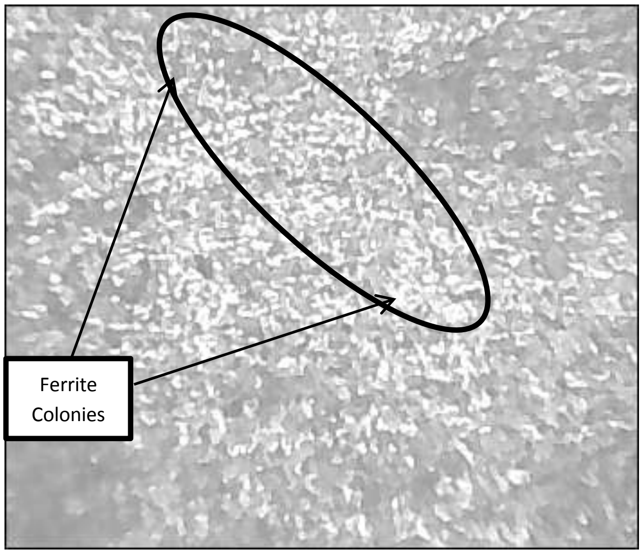
Figure 2: Steel samples yield strength against SON and International standard

Table 2. Tensile Test Result

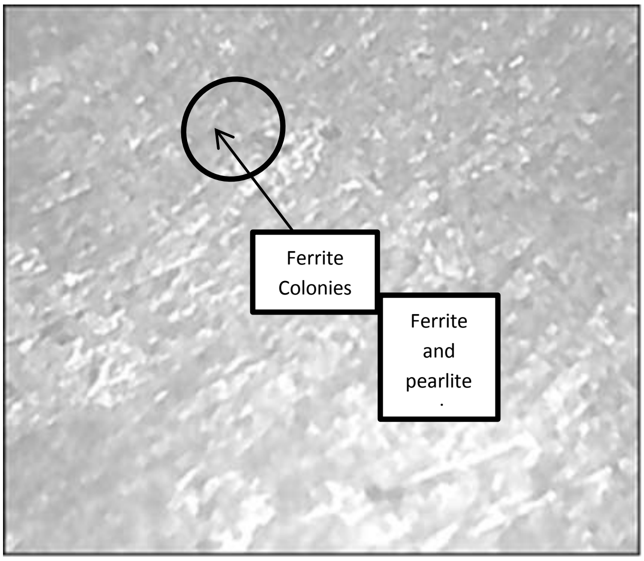
Table 3.5: Summary table of Ductility, Yield Strength, UTS and Hardness

% elongation	% Area reduction			
21.3	37.9	386	671	392.7
7.0	29.7	-	1586	535.7
22.7	54.4	410.77	516.16	452.33
17.3	42.8	582.88	724.9	442
21.0	58.7	391.27	563.69	314.67
15.7	53.7	457.26	627.72	358.33

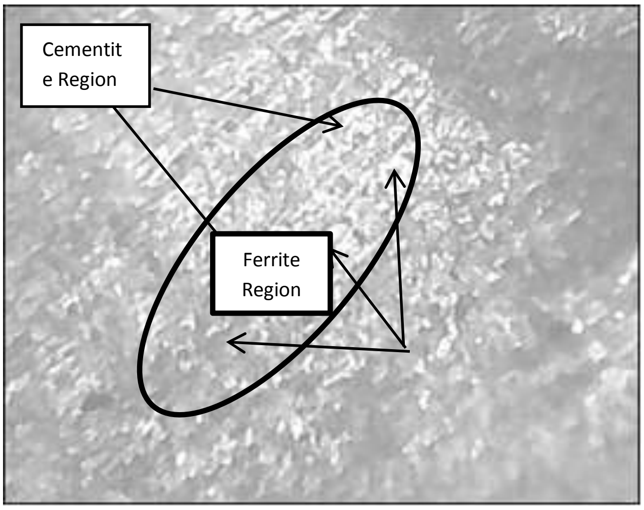
3.2 Microstructure Result



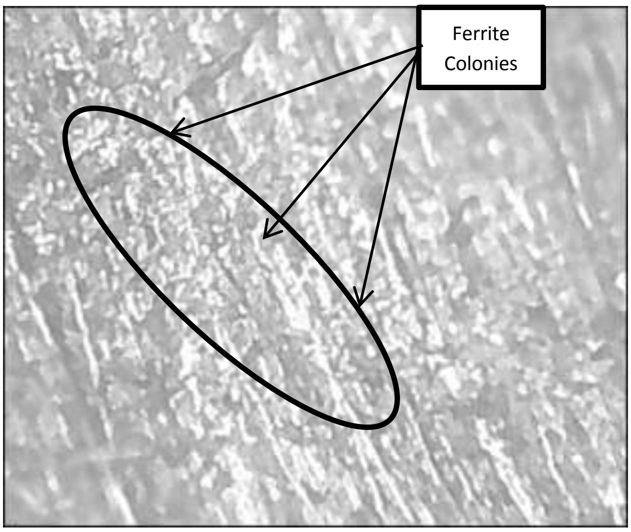
Sample A (400X)



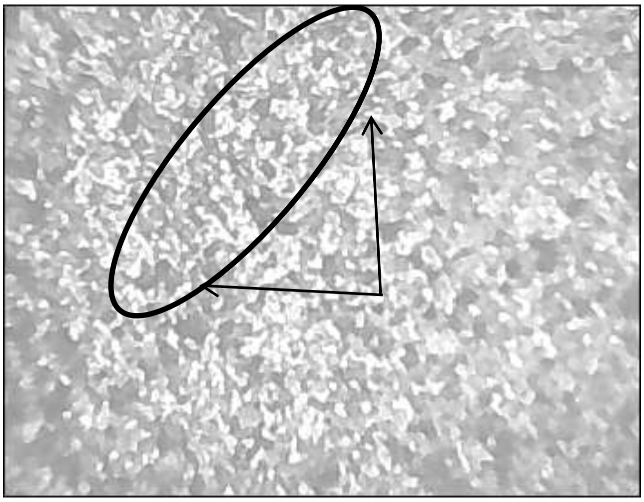
Sample B (400X)



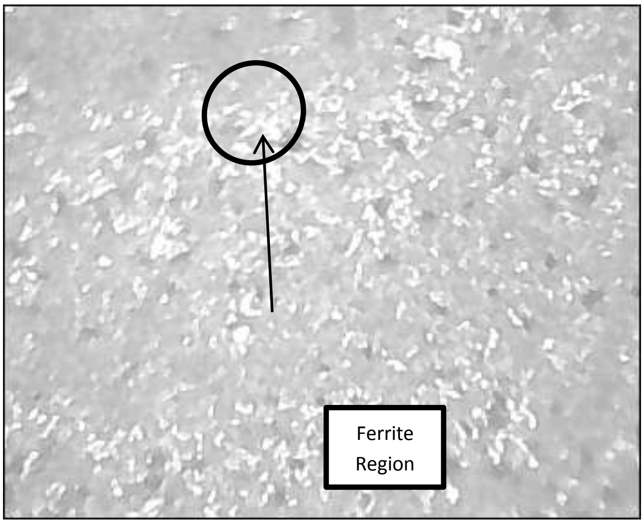
Sample C (400X)



Sample D (400X)



Sample E (400X)



Sample F (400X)

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