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Evaluation of Locally Produced and Imported Reinforced Steel Rods for Structural Purposes in Nigerian Market

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***Abstract*— An investigation was conducted to evaluate the level of conformity of reinforced steel rods used for structural purpose in Nigeria with relevant to local and international standards. In this research, elemental analysis, tensile, hardness test was carried out on the sample of steel products from three indigenous steel industries and imported in accordance with ASTM A706. The results of the elemental analysis showed that the indigenous steel samples have higher carbon contents than the 0.30% recommended standard. The results obtained from the mechanical properties tests which ranged from 382.91 - 551.72 N/mm^2, 520.16 – 738.46 N/mm^2, 8.33 – 22.20%, 0.083 – 0.222, 1.20 – 1.68, and 170.13 – 299BHN for the yield strength, ultimate tensile strength, percentage elongation, strain, strain hardening ratio and hardness met the recommended standards. We can conclude that the tested steel rods are suitable for structural purpose since they have higher mechanical property values.**

***Keywords*— Steel rods, elemental analysis, structural purpose, mechanical property.**

I. INTRODUCTION

Steel rods are iron that has most of the impurities removed and they are used mainly for construction projects (i.e. buildings, bridges, hydraulic structures, etc.), automobile, furniture, manufacturing and in fabricating industries [1]. The use of steel in concrete is known as reinforced concrete. Concrete has considerable compressive or crushing strength, but is somewhat deficient in shearing strength, and distinctly weak in tensile or pulling strength. Steel on the other hand, have a good tensile strength and is easily procurable in simple forms such as long bars [1]. The strength of concrete will be enormously increased if a concrete slab be "reinforced" with a network of small steel rods is placed under surface where the tensile stresses occurs.

Cases of premature structural failure are fast becoming the order of the day with its consequences. It has been identified that the use of inferior quality and substandard steel rods are among the causes of construction collapse and failures [2].

The mechanical properties of steel must meet up with the quality specifications and standards of standard codes of practice on which designs are based for effective utilization [3].

From available literature, some works on steel rods produced in Nigeria has been done. Alabi and Onyeji, (2010) carried out a comparative assessment of the chemical and mechanical properties of locally produced reinforcing steel bars for structural purposes from four indigenous steel industries that use scraps as their major raw materials [4]. Kareem (2009) worked on the tensile and chemical analysis of selected steel bars produced in Nigeria [5]. Ejeh and Jibrin (2012) examined the tensile behavior of reinforcing steel bars used in the Nigeria construction Industry with a view to ascertain the level of conformity with relevant standards [6]. Arum, (2008) investigated the mechanical properties of 12mm steel rod from some parts of Nigeria [7]. The draw-back of their studies is that the test samples are narrow to 12mm bars, and no quality comparison between locally produced and imported steel rod with standards. There is dearth in research in this area and hence is the focus of this study.

There is need for adequate information on the actual behavior of most reinforcing steel rods used in structural concrete for the construction of all types of buildings, bridges, hydraulic structures, etc., in Nigeria market. Therefore, this research is aimed to evaluate 12mm and 16mm reinforced steel rods produced from recycled scraps by some steel industries in Nigeria and the imported one to ascertain their conformity with standards such as; Nigerian Steel Standard [8], British Standard [9], and American Society for Testing and Materials [10] and also to determine their suitability for structural purpose.

II. EXPERIMENTAL METHODS

The samples were obtained from local market in Osogbo, Ile-Ife, and Ikorodu under two major sources namely; locally produced steel bars and imported product.

The locally produced reinforcing steel bars were products of three steel industries in Nigeria that use scraps as their major raw materials for producing steel. The industries are; Prism Steel Mill (PSM), Ife Iron and Steel Nig. Ltd (ISL) and Phoenix Steel Mills Ltd (PSL). The imported steel sample (IMS) was purchased from Maruf Ishola and Sons, Ibadan.

The samples 12mm and 16mm diameter reinforced steel rods were collected and cut, 400 mm for tensile test analysis, and 25 mm for elemental analysis. The elemental composition analysis of the samples was carried out using Optical Emission Spectrometer (OES) at the Chemical Laboratory of the Grand Foundry and Engineering Works Limited, Ikeja. The mechanical properties tests were carried out at the Mechanical Workshop of the Engineering Materials Development Institute, Akure. The properties investigated include yield strength, ultimate tensile strength, percentage elongation and hardness. The samples were subjected into various standard test specimens and the hardness, tensile, and impact tests performed in accordance with ASTM A706.The hardness, tensile test and Impart tests were performed with the aid of a Brinell hardness testing device, Monsanto Tensometer and V-notch pendulum-type impact testing machine respectively. The strain, yield strength, ultimate tensile strength, percentage elongation were determined

III. Results And Discussion

Tables 1and 2 show the results of the investigations. Table 1 shows elemental compositions analysis of 12mm and 16mm iron rods (PSM, ISL, PSL, IMS samples respectively). The twenty six elements discovered in this test are Aluminium (Al), Arsenic (As), Boron (B), Bismuth (Bi), Calcium (Ca), Carbon (C), Chromium(Cr),Cerium (Ce), Cobalt (Co), Cupper (Cu), Iron(Fe), Lanthanum (La), Lead (Pb), Manganese (Mn), Molybdenum(Mo), Nickel (Ni), Niobium (Nb), Phosporus (P), Silicon(Si), Sulphur (S), Tin (Sn), Titanium (Ti), Tungsten (W), Vanadium (V), Zinc (Zn) and Zirconium(Zr). Table 1 shows the most frequent elements that occurred in each sample, the highest percentage element is Iron (Fe) which ranges from 97.7 percent to 98.4 percent for all samples tested followed by manganese, carbon, copper and chromium, while the rest depend on the sample. The higher the carbon content the greater the hardenability, the strength, hardness and wear resistance of the steel [11].

All the steel samples investigated have higher carbon contents than the three standards. PMS with carbon content of 0.416% is far more than the recommended. Other samples such as ISL have 0.321%C, PSL has 0.334%C and the IMS has 0.377%C. However, ISL with a carbon content of 0.321% is lower in carbon than that recommended by NST. 65-Mn. It is obvious that the 12mm PMS samples had more preferable tensile properties than the others samples because of their higher manganese content. Manganese major function in steel is to improve the tensile properties such as ductility and toughness. It was different percentage composition of all important elements for each sample produced by same company; this shows a negative signal with the production process, quality control, personnel, equipment or their combination.

The results of the tests of mechanical properties (yield strength, ultimate tensile strength, percentage elongation and strain) and hardness test results are shown in Table 2. From the tensile test results, the yield strength of the 12mm and 16mm steel rods respectively are 426.47 N/mm^2 and 499.26N/mm^2 for the PMS rods; 382.91N/mm^2 and 400.02N/mm^2 for the ISL steel; 399.44N/mm^2 and 503.41N/mm^2 for the PSL steel and 469.61N/mm^2 and 551.72 N/mm^2 for the imported rod. All these rods met the minimum standard requirement of ASTM A760 for medium carbon which is 415N/mm^2, except that of ISL and PSL steel 12mm rod which fell short.

The ultimate tensile strength results from Table 2 shows that the values for the 12mm and 16mm rods respectively are 715.25N/mm^2 and 599.75 N/mm^2 for the PMS rods; 520.16N/mm^2 and 550.39 N/mm^2 for the ISL steel; 649.34N/mm^2 and 918.82 N/mm^2 for the PSL steel and 738.46N/mm^2 and 645.45N/mm^2 for the imported rod. All these steel rods met the minimum standard requirement by ASTM A760 of 580N/mm^2. An iron rod with a high ultimate tensile strength does not necessarily have a good ductility or a good plastic deformation. The local samples can bear more loads but cannot extend more than the imported samples before fracturing because of the harder, stronger fine pearlite microstructure which does not undergo dislocation easily as compared to the ferrite-pearlite microstructure of the imported samples. It is evident that the imported samples are more ductile than the local ones due to the ferrite-pearlite microstructure.

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Table 1
Elemental Compositions Analysis Results

Sample	%C	%Si	%Mn	%P	%S	%Cr	%Ni	%Mo	%Cu	%Co	%V	%Sn	%Zn	%Fe
PMS12	0.416	0.366	0.820	0.067	0.067	0.145	0.103	0.0032	0.241	0.0071	0.0026	0.027	0.0074	97.7
16	0.112	0.149	0.58	0.071	0.060	0.186	0.118	0.0088	0.256	0.0079	0.0055	0.018	0.0019	98.4
ISL 12	0.321	0.251	0.670	0.062	0.055	0.136	0.106	0.0029	0.272	0.0076	0.0020	0.017	0.0067	98.1
16	0.277	0.319	0.72	0.069	0.057	0.138	0.115	0.0052	0.285	0.0099	0.0026	0.022	0.0055	97.9
PSL 12	0.334	0.221	0.60	0.077	0.058	0.096	0.105	0.0027	0.274	0.0077	0.0007	0.024	0.011	98.2
16	0.194	0.245	0.61	0.043	0.049	0.264	0.104	0.013	0.245	0.0055	0.0069	0.011	0.0018	98.2
IMS 12	0.377	0.227	0.62	0.076	0.077	0.147	0.114	0.0023	0.319	0.0086	0.0020	0.029	0.0079	98.0
16	0.244	0.294	0.70	0.045	0.058	0.111	0.106	0.011	0.246	0.0061	0.0028	0.014	0.0043	98.1
*BS4449	0.250			0.050	0.050									
^ASTM A706	0.30	0.50	1.50	0.035	0.045									
+NST65-Mn	0.035	0.30	1.60	0.040	0.040				0.25					

*Source: Author (2013); *BS4449 (1997); ^ASTM A706 (1994); +Nst65-Mn (1994)*

Table 2
Tensile and Hardness Test Results

S/N	Sample	Yield Strength (N/mm^2)	Ultimate Tensile Strength (N/mm^2)	% Elongation	Strain E	Strain Hardening Ratio	Hardness (BHN)
1	PMS12mm	426.47	715.25	21.5	0.215	1.68	290.0
	16mm	499.26	599.75	14.53	0.145	1.20	232.2
2	ISL 12mm	382.91	520.16	10.80	0.108	1.36	287.6
	16mm	400.02	550.39	9.93	0.099	1.38	243.6
3	PSL 12mm	399.44	649.34	22.20	0.222	1.63	170.13
	16mm	503.41	918.82	8.33	0.083	1.83	269.7
4	IMS 12mm	469.61	738.46	20.00	0.200	1.57	298.0
	16mm	551.72	645.45	13.90	0.139	1.17	299.0
5	*BS4449	460	600	12		1.15	120
6	^ASTM A706	415	580	10			179
7	+NST65--Mn	420	600	14			380

*Source: Author (2013); *BS4449 (1997); ^ASTM A706 (1994); +Nst65-Mn (1994)*

The percentage elongation results show that all the samples are very ductile having all their values greater than the required minimum value of 10% by ASTM A760 requirements (Table 2). The percentage elongation values for 12mm and 16mm steel rods respectively are 21.5% and 14.53% for the PMS rods; 10.8% and 9.93% for the ISL steel; 22.20% and 8.33% for the PSL steel and 20.0% and 13.9% for the imported rod. ISL and PSL show that only one of their products met code specification while for PMS and imported, two (12mm and 16mm rods) met code requirements of minimum 10% elongation value as specified by ASTM A706. Since percentage elongation is a measure of the material's ductility and thus, it toughness. The imported samples were ductile and had a higher percentage elongation because of the route of production and manganese content.

The local samples were hard and brittle because of the processing route used and the high quantity of the phosphorus and sulfur content.

The hardness value for 12mm and 16mm steel rods respectively are 290.0BHN and 232.2BHN for the PMS steel rods; 287.6BHN and 243.6BHN for the ISL steel; 170.13BHN and 269.7BHN for the PSL steel and 298BHN and 299BHN for the imported rod (Table 2). The minimum required value of Brinell Hardness Number (BHN) for carbon steel by ASTM A760 is 179 BHN. The 12mm steel rod from PSL which had a hardness value of 170.13BHN did not meet standard. However, all other samples met the minimum requirement. The PSL samples were ductile and had a higher percentage elongation because of the route of production and manganese content. The imported samples were hard and brittle because of the processing route used and the high quantity of the phosphorus and sulfur content.

IV. Conclusion

The elemental composition analysis and mechanical properties of 12mm and 16mm diameter reinforced steel rods of selected locally produced and imported were evaluated in accordance with international standards. The results revealed that yield strength, ultimate tensile strength, breaking strength, percentage elongation and hardness of all the reinforced steel samples tested met the Nigerian specifications and other international standards. It can be concluded that they were chemically and mechanically acceptable for use in- structural purpose. However, the values need for constant quality check and re evaluation by regulatory authorities within the industry from time to time to ascertain the due quality before any product is used for construction purposes to avoid inconsistency problem.

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