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PROPERTIES ASSESSMENT OF SOME COMMERCIAL STEELS FROM SELECTED MAJOR STEEL MARKETS IN NIGERIA

*YUSUF LANRE SHUAIB-BABATA AND ** S.O. TANIMOWO
* Department of Materials & Metallurgical Engineering, University of Ilorin, Ilorin (sylbabata@gmail.com)
** PhD Student, Mechanical Engineering Department, University of Ilorin, Ilorin

Abstract

Occurrence of structural failure in Nigeria is frequently high and is greatly affecting the nation's economy through loss of human lives and other resources. In appropriate applications of materials for structural development / constructional works has been identified as a major contributing factor to this menace. In this study, many samples of commercial steels were obtained from major steel markets in Ibadan, Ilorin and Lagos. The chemical composition and mechanical properties of the steels were tested using ASTM guidelines. This information was to provide accurate information on characteristics/behaviours of commercial steels in Nigeria to aid appropriate materials selection and applications. This would help to reduce high rate of frequent structural failures in the country. The experimental results revealed inconsistencies in the properties of some steels. Larger proportions of the steels from "used steels" markets exhibited low qualities in strength, ductility and hardness. This problem can be addressed through appropriate heat treatment processes. The study identified the need to re-awake the minds of the materials users towards effective material testing prior to their selection and applications for structural development

Key words: chemical compositions, mechanical properties, microstructures

INTRODUCTION

Integrity of a structure is the ability of that structure to support a designed load or force without breaking, rupture, collapsing or tearing. Metallurgist, Designers and Engineers have been forced to look into the ways of developing materials that will be able to suite specific engineering applications, as a result of the quest for materials that can perform such task at optimum efficiency (Merchant, 2015). It is a common practice that materials are sourced for suitability through consideration for specific and general properties for design and construction purposes. The effective usage of materials can be realized only when an engineer fully understands the various properties of materials. The reason for this is that practically all useful properties of materials are strongly dependent on international standards (Craig *et al.*, 1973). Indiscriminate selection and applications of materials for structural developments has been identified as one of the major contributing factors to high rate of structural failures. According to Olanitori (2011), "poor quality of material for construction is part of possible cause of structural failure". The Constructor (2016) also identified unwanted belief in calculations and in specified loads and properties as part of causes of structural failure. Atlas (2004) classified common leading structural factors into four, in which defective materials which occur during manufacturing process is one of them. Bright Hub Engineering (2016) also identified inferior constructional material as part of causes of structural failure. Defectiveness or inferiority of a material could be known through better understanding of the material's properties.

Occurrence of structural failures in Nigeria is frequently high and is greatly affecting the nation's economy through loss of human lives and other resources. The Users of engineering materials (mostly local fabricators), do embark on the use of various materials, especially commercial steels, without recourse to their properties. Mean while, adequate knowledge of material behaviours enhances effective utilization of such material for different applications. Mechanical properties of a material include strength (yield and ultimate tensile strength), hardness, and toughness, among others. Balance must exist between the mechanical properties and the quantity of load the material intends to support in service. It is then highly essential for an Engineer to consider the mechanical properties of a material prior to its certification for usage, like in constructional works. The information on materials' characteristics could be reliably obtained through mechanical tests, such as tensile test. According to Fearnehough (1973), tensile test is good for small-scale material characterization test that gives actual results, which can be considered as a material behaviour or properties. The mechanical properties obtained through the test are important measure of product quality and one way to certify the product (Richarch, 2005). Apparently, because of excellent mechanical properties of steels, especially low carbon steel (such as strength, high ductility, toughness, ease of fabrication, and availability), they are mostly preferred for structural engineering works out of 90% of all steels available in the world market (Shuaib-Babata, 2006). The steels which are mostly obtained commercially (especially in Nigeria) are used by local fabricators, engineers, among others for applications like reinforcement in concrete that are used in construction of buildings, bridges, vehicles, boilers, building roof, truss conveyors, tanks and other storage facilities, and several domestic utensils. According to Piccard, Lefebure and Tremillion, "low carbon steels are preferred as the container, tubing material for heat transfer and storage processes below 600°C, partly due to the ease with which they are fabricated" (Shuaib-Babata, 2004).

The metallurgical structure and the carbon content are major contributors to the overall properties of different carbon steel materials. Higgins (1993) showed the relationship between carbon content, microstructure and mechanical properties of plain carbon steels and their various areas of applications in every day usage.

In Nigeria, steels for structural developments are commercially obtained in different forms. These forms include new steels (imported and locally produced), fairly used, popularly known as "Tokunboh" and recycled. The new steels are sold as produced by the manufacturers, though might have been subjected to different environmental degradation under rain and sun.

In attempt to find solution to the structural problems originated as a result of inappropriate use of engineering materials, especially commercial steels, Engineers and many Researchers have embarked on different studies related to mechanical testing of materials. Ahaneku (2000) reported a study that revealed the importance of tensile testing of mild steel rod before it could be used for engineering applications, especially as bolts and studs in coupling agricultural machinery to avoid structural failure in service. Onyeji (2010) investigated the chemical and mechanical properties of 12mm steel rods of four indigenous steel industries and one imported foreign steel. The results showed that percentage carbon content and the values of tensile testing, hardness and impact test for the reinforcing steel bars were more than standard recommended by BS 449 of 1997, NST 65-Mn and ASTM A706. It was therefore concluded that the steel rods satisfy the required quality for construction. The results of the findings show that some local and some foreign samples conformed with specified standards. However, the percentage elongation was higher than standards in most cases. It was finally recommended that proper examination and supervision of the steel products in the metal markets were necessary before they could be used for construction purposes. In a related development, Shuaib-Babata (2008) evaluated the tensile properties of commercially available steels in different forms (rods/sheets) obtainable from three metal markets in Ilorin metropolis. Some inconsistencies in the properties of steels obtainable in Ilorin metropolis were observed. The results of his findings showed that the same type of steel purchased at different metal markets in Ilorin exhibited different mechanical properties. It was concluded that the effects of history and consequently importance of mechanical testing of materials before selection and onward applications of such materials for industrial use were necessary. The researcher further recommended that chemical composition and micro-structural examination of Ilorin steels were necessary, most especially, when needed for large structural developments.

This study therefore aimed at investigating properties of various available steels in major Nigerian steel markets for appropriate characterization. The information from this study would serves as a guide to the users of locally available commercial steels towards appropriate selection and utilization of such materials for different engineering applications. This would assist to reduce significantly frequent occurrence of structural failures in the country.

MATERIALS AND METHODS

Materials

Steels of different types, forms and sizes for commercial purposes were obtained from Lagos, Ibadan and Ilorin major steel markets in Nigeria. The types of steels obtained include mild steel, galvanised steel and stainless steel in forms of flat bar sheet and rod as shown in Table 1.

Table 1: Details of materials used for the study

S/N	MATERIALS	SPECIFICATIONS (DIAMETER, mm)	SOURCE
1	Mild steel rod (Local)	8 mm, 10mm, 12mm	Ibadan, Ilorin, Lagos
2	Mild steel rod (Foreign)	8mm, 10mm, 12mm	Ibadan, Ilorin, Lagos
3	Mild steel sheet / flat bar (Foreign)	0.7 mm, 0.8 mm. 1.17 mm	Ibadan, Ilorin, Lagos
4	Mild steel sheet / flat bar (Local & Foreign)	0.8mm	Ilorin
5	Galvanised steel (Foreign)	1.0mm	Ilorin
6	Galvanised steel (Local)	1.0mm	Ilorin
7	Stainless steel flat bar (Foreign)	0.6mm, 1.0mm	Ilorin

Chemical Composition of the Test Specimens

To classify the studied steels appropriately, the chemical composition of various commercial steels were determined using an Optical Emission Spectrometer (OES), (Type ARL 3460) and output obtained on a monitor of a dedicated computer system.

Preparation for Micro-structural Examination

Each specimen for micro-structural examination was adequately prepared through process of cutting, grinding and polishing. The flat polished surfaces of the above specimens were examined under an Inverted Materials Microscope (made by Medline Scientific Limited, Oxfordshire OX44 7RW, UK, Serial No. 21027), and the microstructures were obtained and displayed on a Personal Computer System and printed out.

Tensile Test

The tensile specimens as shown in Figure 1 were prepared using a lathe machine (Type V-I-145, Serial No. 1473 made by PEXSVAREN AB, STOREBRO, SWEDEN), in line with the BSI standard formats. Individually, the specimens were

23	Mild steel Rod 6.0 mm	0.310	98.70	0.2300	-	-	-
24		0.176	99.23	0.2000	-	-	-
25	Ilorin	0.111	83.71	0.1270	0.24	0.29	0.120
26		0.270	97.60	0.2200	0.016		0.410
27		0.331	99.23	0.3110		-	0.399
28	Lagos	0.330	99.61	0.2710		-	0.450
29		0.293	99.54	0.3310		-	0.510
30	Mild steel rod 5 mm	0.340	99.32	0.1600	0.06	0.03	0.460
31	Stainless rod 6.0 mm	-	-	-	-	-	-
32		-	-	-	-	-	-
33		-	-	-	-	-	-
34	Galvanised steel flat	0.08		0.08	0.02	0.03	0.39
35	bar 0.6 mm	0.08		0.058	0.067	0.03	0.09

Chemical properties

To evaluate the properties of the selected available commercial steels in major markets in Ibadan, Ilorin and Lagos, consideration was giving to their elemental chemical compositions. This is in line with American Iron and Steel Institute (AISI) categorisation of steel, which is based on chemical compositions (AZoM, 2012a). AISI categorised steels into four basic groups, namely: carbon steel, alloy steel, stainless steel and tool steel. Considering a variety of different factors, types of steel can also be classified as composition (carbon range, alloy, stainless); the production method (continuous cast, electric furnace); finishing method used (cold rolled, hot rolled, cold drawn or cold finished); form or shape (bar, rod, tube, pipe, plate, sheet, structural); de-oxidation process /oxygen removed from steelmaking process (killed and semi-killed steel); microstructure (ferritic, pearlitic, martensitic); physical strength (per ASTM Standards); Heat Treatment (Annealed, Quenched & Tempered); Quality Nomenclature (Commercial Quality, Drawing Quality, Presthsure Vessel Quality) (AZoM, 2012b).

Comparing the studied steels compositions with the acceptable steels' standards shown in Table 2, wide variations were observed in some cases, most especially in the carbon and iron contents. Though, some of the chemical compositions of the studied steels were within the acceptable standard ranges (Table 2). More so, some steel samples also possessed outrageous basic elemental compositions. Some specimens classified as "mild steel" commercially possessed very low iron and outrageous carbon contents, which were not within the acceptable ranges. For instant, samples of 1.17 mm mild steel flat sheet bar possessed 14.908 wt %; 17.874 wt% and 0.11 wt %; 0.05 wt carbon and iron contents respectively. Iron and carbon were the major contents of typical carbon steel. The required iron and carbon contents of acceptable low carbon steel fall within 98.81 – 99.26 and 0.05 – 0.33 % respectively (AZoM, 2012 a & b, Merchant, 2015, Oneal, 2016). With the results, the specimen did not belong to mild steel group, since the steels' contents were different and did not meet the required standards (chemical composition and mechanical properties). If the specimens were used for structural development where a mild steel sample with appropriate specifications was required, definitely, there were rooms for high failure tendency.

The chemical composition shows that 1.0mm Type F galvanized steel fall within the recommended ASTM steel grade A569 (Tanimowo, 2011). Whereas the Type L sample was outside specification in terms of chemical composition.

Mechanical Properties

Some mechanical properties exhibited by the specimens are presented in Table 3. The properties include tensile strengths, ductility and hardness.

Table 3: Some mechanical properties exhibited by tested Nigerian commercial steels

S/N	SPECIMEN	YIELD STRENGTH (N/mm^2)	ULTIMATE TENSILE STRENGTH (Nm)	DUCTILITY	HARDNESS (BHN) ROCKWELL C
1	-	-	-	-	-
2	Mild steel flat	182.44	233.29	0.672	94.1
3	bar 1.17 mm	51.71	89.71	11.79	19.77
4	Ilorin	172.76	218.93	0.597	91.7
5		182.74	271.02	0.763	92.8
6	Ibadan	57.71	79.41	8.321	8.71
7		175.49	232.30	0.695	92.0
	Lagos				
8	Mild steel flat	272.61	311.39	19.59	91.5
9	bar	296.84	347.07	16.60	83.3
10	0.7 mm	258.52	316.71	17.79	82.7
11	Mild steel flat	153.10	263.77	26.17	83.9
12	bar	241.67	301.78	18.10	83.7
	0.8 mm				

13	Mild steel flat	316.34	584.07	13.41	121.3
14	bar 10.0mm	261.12	316.31	16.93	108.60
	(Ilorin)				
15	Mild steel flat	235.7	317.2	21.91	97.9
16	bar 10.0mm	283.90	353.25	19.84	97.3
17	(Lagos)	398.16	595.87	28.32	98.7
18	8mm Mild	376.65	573.17	27.32	98.1
19	steel rod	149.27	155.47	37.5	89.7
20	10mm Mild	403.05	581.69	23.7	73.0
21	steel rod	133.32	137.6	19.8	143.7
22	12mm Mild	482.76	679.15	16.9	91.6
	steel rod				
23	Mild steel rod	271.37	303.03	3.360	
24	6.0 mm	247.53	375.07	4.387	
25	Ilorin	14.67	24.56	0.6845	
26		411.77	634.89	18.73	
27		401.02	671.05	21.60	
28	Lagos	513.00	521.10	18.90	
29		382.91	514.73	19.97	
30	Mils steel rod	166.09	257.635	10.639	100.51
	5.0 mm				
31	Stainless rod	691.03	711.11	15.89	
32	6.0 mm	659.79	677.15	16.17	
33		635.15	676.05	18.23	
34	Galvanised	371.55	380.74	11.686	
35	steel flat bar	366.43	380.86	11.834	
	0.6mm				

In this study, a part from chemical composition of the steel, tensile and yield strengths of the steels would be another basis for evaluation of the steels' properties. This is in line with the view of Khurmi and Gupta (2005) that the main criterion in selection and inspection of steel is the tensile strength or yield stress.

Generally, the results in Table 3 showed variations in the values of strengths and ductility of the studied commercial steels irrespective of the types, sources and sizes of the steels. For instance, low carbon steels (mild steel) of the same size (1.17 mm) obtained from Ibadan, Ilorin and Lagos exhibited different properties. The yield strength and ultimate tensile strength (UTS) possessed by the steels ranged from 51.71 mm - 175.49 Nm and 79.41 - 271.02 Nm respectively. The results also revealed certain level of inconsistence in the properties. The lower yield strengths and UTS values of 51.71mm; 57.71 mm and 89.71 Nm; 79.41 respectively exhibited by the mild steel samples were reflection of their elemental chemical composition deficiencies as shown in Table 2. In an ideal situation, steels within the same class or group supposed to exhibit similar properties within an acceptable range values. More so, these steels were supposed to be suitable for the same applications, being classified to be in the same steel group. Mean while, if the strengths and ductility were to be major considerations for selection and application of the steel for any structural development, the specimens classified commercially as same steel were not the same and could not be suitable for the same applications.

The inconsistency in the properties of the steels has shown in this study apparently revealed the need and the significant to carry out mechanical test (such as tensile test), prior selection and application of the material for any structural development to curtain the high rates of structural failures in Nigeria. Adequate awareness (among the local fabricators and even professionals) on the need and important of mechanical tests for appropriate selection and application of steel emanated from this study. The local fabricators and other major users of steels in Nigeria (in most cases) rely on steel sellers for information on commercial steels without recourse to ascertain the materials properties before use (Shuaib-Babata, 2008).

It is also interested to know that some commercial mild steel samples possessed relatively similar tensile properties, especially mild steel flat bar 0.7 mm and 0.8 mm. The exceptional case in this class of commercial steel was recorded in a specimen with yield strength and UTS of 153.1 N/mm^2 and 263.77 N/m respectively (Table 3). The values were too low compared to that of other specimens in this steel class. This calls for appropriate standardization of locally produced steels. This measure could be effectively monitored by the appropriate agencies like Standard Organization of Nigeria (SON). Considering the mild steel rod samples group, steel sample with 6.0 mm size exhibited low qualities in terms of strength, and ductility compared to other specimens in the group as in Table 3. These steels were obtained from the same source. Disparities in the steels' properties were attributed to the history of the steels. Some of the steels had been left under sun and rain for main years ignorantly by the sellers. These conditions contributed to deterioration of the steel, which eventually affected the steels negatively. Thus, Engineer, Fabricators or other users of steels need to ascertain the steels' properties before its certification for use. This could be achieved through appropriate mechanical testing of materials, like tensile test.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this study has confirmed the need ascertain required properties of commercial steel through appropriate mechanical testing before their selection and application for structural developments to curtain high rate of structural failures in Nigeria, inconsistency in the properties of commercial steel were recorded in this study, which call for appropriate standardization of locally produced steels. Appropriate relevant agencies like *SON* need to be proactive to ensure effectiveness of the appropriate standardization. The study also identified the need to re-awake the minds of the users of commercial steels towards effective material testing prior to certification, selection and application for structural developments. Further study on the evaluation of the commercial steels' microstructure is recommended.

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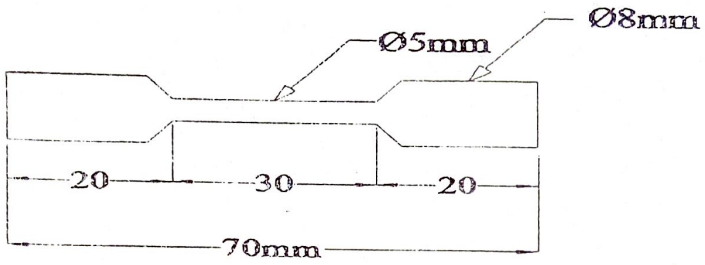
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subjected to tensile forces on a computerized Universal Testing Machine, UTM (made by Testometric Co. Ltd, Rochdale, England, and Type DBBMTCL-5000 Kg Serial No. 17819). The values of the tensile stress, tensile strain and energy (toughness) at various points (yield, peak, and fracture) for each specimen were obtained and documented from the system.



Determination of Brinell Hardness (BHN) values

The BHN value for each of the tested specimens was determined using Brinell Hardness tester.

RESULTS AND DISCUSSION

Chemical Composition

The results of the specimen's elemental chemical composition and that of standard carbon steels obtained in the literature are presented in Table 2.

Table 2a: Chemical composition of commercial carbon steel samples and standard steel carbon from literature

S/N	ELEMENTS SPECIMENS	C	Fe	Si	S	P	Mn
1	Low Carbon Steel , LCS (Merchant, 2015)	0.135 – 0.33		0.18-0.28	0.19		0.40 - 0.60
	ASTM A36 Mild/Low Carbon Steel (AZoM, 2012a)	0.25 – 0.29	98.0	0.28	0.05	0.04	1.03
	AISI 1018 Mild/Low Carbon Steel (AZoM, 2012b)	0.14 – 0.2	98.81 – 99.26		≤0.05	≤0.04	0.6 – 0.9
	Mild Steel Medium carbon steel High carbon steel (Oneal, 2016)	0.05 – 0.25 0.29 – 0.54 0.55 – 0.95					Up to 0.4 0.6 – 0.9 0.3 – 0.9
2	Mild steel flat bar	0.032	99.50		0.02	0.012	0.306
3	1.17 mm	14.9080	0.11	10.50	4.81	24.28	1.6200
4	Ilorin	0.0320	99.50		0.02	0.012	0.306
5		0.0318	99.22	0.016	0.04	0.10	
6	Ibadan	17.874	0.05	19.00	5.05	6.43	3.3483
7	Lagos	0.2300	97.90	0.190	0.20	-	-
8	Mild steel flat bar	0.0335	99.18	0.015	0.0429	0.11	0.2767
9	0.7 mm	0.472	98.72	0.015	0.0314	<0.007	0.3536
10		0.0486	98.75	0.020	0.0406	0.0261	0.3654
11	Mild steel flat bar	0.0500	96.79	0.008	0.03	0.010	0.320
12	0.8 mm	0.0015	98.93	0.0260	0.014	0.011	0.277
13	Mild steel flat bar	0.3200	95.87	0.1000	0.02	0.01	0.700
14	10.0mm (Ilorin)	0.2330	97.73	-	0.04	0.04	0.100
15	Mild steel flat bar	0.3100	98.34	0.0340	-	-	-
16	10.0mm (Lagos)	0.2823	98.70	0.0356	-	-	-
17		0.3200	98.67	0.0321	0.02	0.03	0.340
18	8.0 mm Mild steel rod	0.2710	99.37	0.1900	0.01	0.02	0.660
19		0.1830	98.97	0.2400	-	0.02	0.420
20	10.0 mm Mild steel rod	0.3330	99.10	0.0317		0.03	0.536
21		0.1334	85.37	0.2100	0.01	0.02	0.234
22	12.0 mm Mild steel rod	0.2510	95.83	0.3400	0.02	0.03	0.720