Tensile and Chemical Analyses of Selected Steel Bars Produced in Nigeria

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Abstract

In this study, tensile and chemical nature of selected locally made steel bars is investigated. Three sizes of the two selected models of concrete reinforcement steel bars, which are ST44-2 and ST66-2, produced in Osogbo steel rolling company of Nigeria, were collected from its quality control section. These samples were machined to a standard tensile test pieces and tensile test was done on it with the use of tensile testing machine. Chemical analysis of the specimen was done. The results obtained were compared with that of the global concrete reinforcement steel bars standards. The results revealed that the selected steel bars are in good agreement with what is obtainable in both local and international standards, except that, in the case of chemical analysis results, percentage carbon content in steel is somewhat low as compared to the foreign similar steel product.

Keywords: *Steel bars, tensile test, chemical analysis, tensile testing machine, quality control, steel standards.*

Introduction

Steel, essentially is an alloy of iron and carbon containing up to 1.5% Carbon. Modern methods of steel making are now available but traditionally and generally, steel are made by oxidizing the impurities that are present in iron produced in the blast furnace (Skinner and Rogers 1979; Walker 1986; Ghilchrist 1989; and Kareem 2002). The percentage composition of carbon between 0.05-1.5 percent played a major role in steel classification/grading. Dead mild steel, mild steel, medium carbon steel and carbon tool steel grades are having a percentage carbon range of 0.07-0.15, 0.15-0.30, 0.30-0.60, 0.60-0.80 and 0.80-1.50 respectively. Percentage of carbon in each steel class has a direct influence on its hardness (John 1983; Amstead *et al.* 1987; Colin 1987; and Kareem 2002). Therefore the chemical analysis of a given sample of steel can determine the class of steel from which the sample is being taken through evaluation of its percentage carbon content. It is practically difficult to determine tensile strength of such sample without resulting to tensile test experiment. This procedure is being monitored by Nigeria Standards Organization (SON) with the establishment of Nigeria Industrial Standard (NIS) on steel production that is basically measured in term of chemical composition and tensile strength analyses.

The established Industrial Standards (NIS) monitored the standard of output steel bars from Nigeria steel companies such as Delta Steel Company (DSC), Ajaokuta Steel Complex (ASC), and the Inland Steel Rolling Mills at Osogbo, Jos and Katsina. The steel industry has been identified as the most outstanding outlet of industrialization and economic growth of many developed nations including Britain, America and Germany. Steel are used as raw material for downstream industries such as automobile, manufacturing, constructing, furniture, electrical and electronic sectors that its performance determines the level of economic development in every nation (Kareem 2005). Other areas of application of steel include defense, ship building, oil, gas, energy, containers, engineering components and health industry.

In the olden days, the rolling of wire rod and merchant steel bars were done adequately in Nigeria, using mill layouts such as open mill, staggered open mill, semi-continuous mill, fully-continuous mill and fully-continuous multi-line arrangement. Today, many steel rolling mills in Nigeria are limited to fully-continuous or fully continuous multi-line arrangement (SMS-AG 1981). However, the choice of any method of layouts for steel bar production has no adverse effect on output unless there is an evidence of impairment in chemical composition. There is no need to quest for foreign steel bars provided that one produced locally has satisfied the necessary conditions laid for its acceptability, that is, to be in conformity with both local and international standards. NIS specification for steel bar based on ladle analysis, mechanical properties, dimensional requirements, deformation requirements for hot rolled and cold rolled bars are stated in NIS (1992). Works on reaffirming the quality of made in Nigeria steel bars based on certain properties such as heat treatment are available (Gery *et al.* 2004; and Inegbenebor 2004). These studies conclude that Nigeria steel bar has ability to withstand a considerable amount of heat. This approves high temperature application of made in Nigeria steel bars. The study wants to look more in the area of tensile and chemical composition nature of the made in Nigeria steel bar. The related work of Kareem (2006, 2007) on quality verification of made in Nigeria steel bars defer from this work in the areas of chosen sample, tensile test and chemical analyses. In the work of Kareem (2006) sample used was limited to one and only mechanical test of tensile strength was done. In this study a complete tensile test analysis was done from three randomly selected steel bar samples each designated as ST 44-2 and ST66-2. Besides, chemical analysis was also carried out on samples to determine their chemical composition.

Material and Methods

Six test pieces of hot rolled plain bars are machined into standard tensile test specimens. Three of the specimens were produced from hot rolled plain bar designated ST44-2 and the remaining three were from ST66-2. These two sample types, ST44 -2 and ST66-2 were collected from the Osogbo Steel Rolling Company (OSRC), Osogbo. Tensile test was carried out on the specimens using Avery Denison Universal Testing Machine (ADUTM). The tensile test helped in the determination of Yield Strength (*YS*) Ultimate Tensile Strength (*UTS*), Fracture/ Breaking Strength (*BS*), Percentage Elongation (*PE*) and Percentage Reduction in Area (*PRA*). Each specimen was tested on Optical Emission Spectrometer (OES) after a thorough polishing to analysis its chemical composition. The results of the analyses, chemical and tensile were then compared with the minimum allowable range as specified in the Nigeria Industrial Standard (NIS 1992). The tensile test results for the six specimens of ST66-2 and ST44-2 are given in Tables 1 and 2 respectively. The analyzed results are present in Tables 3 and 4 respectively for ST66-2 and ST44-2 while that of chemical composition are shown in Table 5.

Tensile test results were analyzed using the following equations:

Ultimate Tensile Strength,
UTS = Maximum Load, *ML*/Nominal Area, A_1;
Yield Strength, *YS* = Yield Load, *YL*/ A_1;
Breaking Strength,
BS = Breaking Load, *BL*/ A_1;
Percentage Elongation,
$PE = [(L_2 - L_1)/ L_1] \times 100$;
Percentage Reduction in Area,
$PRA = [(A_1 - A_2)/ A_1] \times 100$;
Area, $(A_1 \text{ or } A_2) = \pi D_1^2/4 \text{ or } \pi D_2^2/4$;

where: L_1 is the initial length of the test piece; L_2, final length of test piece; D_1, initial diameter of piece; D_2, final diameter of piece; A_1, initial area of test piece; A_2, final area of the piece. Length and diameters of the test pieces were measured before and after the test by Veneer caliper and Micrometer screw gauge.

Results and Discussion

The results of the analyses showed that the concrete reinforcement steel bar investigated namely ST44-2 and ST66-2 fell within the acceptable region provided in the

NIS 177-1992 standard with the carbon content of 0.17% and 0.24% respectively (Table 5). This results fell within the acceptable limits of 0.14-0.20%C for ST44-2 and 0.18-0.24%C for ST66-2 as imposed by the NIS (1992) (Table 6). The proportions of other elements such as Silicon, Manganese, Phosphorous, Sulfur, Copper, and Nitrogen were also in agreement with the NIS standard.

The results obtained from tensile test showed that tensile strength and yield strength of average of 485.40N/mm^2 and 317.38 N/mm^2 for ST44-2 and 677.19 N/ mm^2 and 448.06N/mm^2 (on average) for ST66-2 steel bar were satisfactorily in agreement with what is obtainable in NIS (1992) (Tables 3 and 4). A compared value of these results with similar steel specification in British Standard which is BS070M20 (ST44-2 equivalent) have 0.16-0.24% carbon. This shows that steel bars considered have appreciable tolerance which may be utilized in applications required tensile properties further above the minimum standard set by Nigeria Standards Organisation (SON) for steel bars.

The results further showed that ST66-2 is better in strength than ST44-2 but it as less application where ductility property is of ultimate interest (Table 6). Based on the chemical analyses result ST66-2 seems harder than ST44-2 because it has a higher percentage of carbon. This is in consonant with the tensile test results as compared to NIS minimum standard shown in Table 6.

Conclusion

The steel manufacturing industries have been identified as one of the most important sectors that dictate the level of economic development of any nation, because steel is very useful virtually in all sectors of economy such as machine building and factory infrastructures. Therefore, a special attention should be directed to steel manufacturing industries so that they can meet up with the global challenges in the steel industry in the area of nano-steel material development. The efforts in this direction will not only help in determining the suitability of the outputs for its intended purpose but new areas of application could be devised based on the results of tensile and chemical analyses.

The chemical and tensile analyses of the two bars ST66-2 and ST44-2 showed that the made in Nigeria concrete reinforcement steel bars were chemically and mechanically acceptable for use in-house and abroad. The extra strengths obtained from tensile analyses have extended the application of made in Nigeria steel bars to the areas where high strength above the minimum set standard by NIS is required.

The result further showed that ST66-2 is of higher strength than ST44-2 but of lower percentage elongation. Therefore it can be concluded that ST44-2 will find application in areas where high ductility is considered while the second steel ST66-2 will be useful in applications required high hardness but less ductility.

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Table 1. Tensile test results for ST66-2 steel bar samples.

Nature of Test	ST66-2 Sample 1		ST66-2 Sample 2		ST66-2 Sample 3	
	Load (N)	Extension (mm)	Load (N)	Extension (mm)	Load (N)	Extension (mm)
Elastic load	8200	1.50	8400	1.52	8000	2.40
Yield load	8400	1.75	9200	2.00	8800	2.75
UTS-maximum load	12800	5.25	13900	4.75	13200	6.25
Breaking load	8000	7.20	10900	7.20	9200	7.80
Initial length (mm) L_1; Initial diameter (mm) D_1	27.3; 5.00		27.2; 5.00		27.6; 5.00	
Final length (mm) L_2; Final diameter (mm) D_2	34.4; 3.20		33.0; 3.00		33.5; 3.10	

Table 2. Tensile test results for ST44-2 steel bar samples.

Nature of Test	ST44-2 Sample 1		ST44-2 Sample 2		ST44-2 Sample 3	
	Load (N)	Extension (mm)	Load (N)	Extension (mm)	Load (N)	Extension (mm)
Elastic load	6000	1.40	5200	0.80	6000	1.60
Yield load	6800	2.20	5600	1.20	6300	1.80
UTS-Ultimate (maximum) Tensile Load	9900	6.20	9300	6.70	9400	6.60
Breaking load	7200	7.70	5800	7.80	5900	7.80
Initial length (mm) L_1; Initial diameter (mm) D_1	27.33; 4.90		26.9; 5.00		27.6; 5.00	
Final length (mm) L_2; Final diameter (mm) D_2	34.5; 2.90		35.2; 3.00		35.6; 3.20	

Table 3. Tensile test results analyses for ST66-2 steel bar samples.

Nature of strength	Test piece (1)	Test piece (2)	Test piece (3)	Average
Ultimate tensile strength, *UTS* (N/mm^2)	651.73	707.74	672.10	677.19
Yield strength, *YS* (N/mm^2)	427.70	468.43	448.06	448.06
Breaking strength (N/mm^2)	407.33	554.99	468.43	476.92
% Elongation (%E)	20.64	21.32	21.38	21.11
%Reduction in Area (%)	59.06	64.00	61.56	61.54

Table 4. Tensile test results analyses for ST44-2 steel bar samples.

Nature of strength	Test piece (1)	Test piece (2)	Test piece (3)	Average
UTS (N/mm^2)	504.07	473.52	378.62	485.40
Yield strength (N/mm^2)	346.23	285.13	320.77	317.38
Breaking strength (N/mm^2)	366.60	295.35	300.41	320.78
% Elongation (%)	26.37	26.37	28.99	27.24
%Reduction in Area (%)	66.64	66.64	59.06	64.11

Table 5. Average Chemical Composition (%) Results for ST44-2 and ST66-2 Steel Bar Samples.

Chemical composition (%)	Carbon C	Silicon Si	Manganese Mn	Phosphorus P	Sulfur S	Copper Cu	Nitrogen N	Tin Sn
ST44-2	0.17	0.21	0.55	0.02	0.02	0.18	0.01	0.02
ST66-2	0.24	0.20	0.60	0.03	0.02	0.21	0.01	0.03

Table 6. Summary of test results as compared to NIS standards.

Sample	NIS 117-1992 minimum standards (N/mm^2) and (%)					Established tensile test results (N/mm^2) and (%)					Percentage Differences (%)		
	%C	%Mn	*UTS*	*YS*	%E	%C	%Mn	*UTS*	*YS*	%E	*UTS*	*YS*	%E
ST44-2	0.14-0.20	0.40-0.60	340	225	20	0.17	0.55	485.40	317.38	27.24	42	41	36
ST66-2	0.18-0.24	0.40-0.60	420	280	18	0.24	0.60	677.19	448.06	21.11	61	60	33