Assessment Of Mechanical Properties Of Reinforcing Steel Used In Construction Works At F.C.T, Abuja.

BY

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Abstract.

The study assessed the mechanical properties (Yield stress, ultimate tensile stress and ductility) of reinforcing steel (ribbed bars) used in construction works in the Federal Capital Territory (FCT), Abuja, Nigeria with a view to ascertaining extent of conformity with (BS 4449) code requirements.The test samples obtained from Deidei market, Abuja,were produced from four different companies (coded A, B, C, D) in the former federal capital and its adjoining states. The samples (10mm, 12mm, 16mm and 20mm) diameter bars were subjected to tensile strength test using a universal testing machine and a digitalveniercalliper.Test results showed that the yield stress of company (A) products are 320, 350, 405 and 410N/mm^2 for 10mm, 12mm, 16mmand 20mm bars which is less than BS 4449 specification of 460N/mm^2. The corresponding values for the ultimate tensile stress are 420, 440, 480 and 508N/mm^2 as against BS 4449 value of 510N/mm^2. Except for 10mm bars, the products of the company are less ductile since their ductility is less than 12% minimum specified by BS 4449. For company (B) products tested, only 16mm and 20mm bars conform to BS 4449 standards and the products are fairly ductile. For company (C), the yield stress of their tested products does not conform to BS 4449 standard. Though their ultimate tensile stress values conform to code specification none meet the code's minimum 12% elongation indicating that their products are less ductile. For company (D) products, 10mm and 12mm bars fell short of BS 4449 specification in terms of yield and ultimate stress values but they are adequately ductile while for 16mm and 20mm bars that conform to code specifications, however, are less ductile. These results have far reaching consequences on construction works. In this light, it is strongly suggested that the composition of the elements and the type of alloy used in the production of steel in these companies be reviewed.

1.0 INTRODUCTION

A Client constructs a building solely for residential, commercial, Institutional, educational and industrial purposes. Such a building should secure the client from adverse conditions and threats to life and property satisfactorily without attaining limit state prematurely. Unfortunately,cases of premature structural failure is fast becoming the order of the day with its consequences. Although there are professional bodies whose members play active role(s) on construction sites, structural failures has continued unabated.

Arum and Babatola (2006) identified causes of building failures to include among others, supervision by unqualified personnel, poor quality control, and unprofessional conduct.

This is not unconnected with unqualified persons succumbing to monetary inducements by some contractors to allow the use of sub- standard materials like steel rods for construction works. Similar situation abound when non- construction professionals unschooled in the engineering professional code of ethics are awardedcontracts for the execution of various works use substandard materials for increased profit to the detriment of work quality. This assertion was strengthened in the findings of Ayodele (2009) on examination of role(s) of reinforcement in the collapse of buildings in Nigeria. His findings were obtained via a structured interview administered to steel fixers or iron benders and observation of steel work on construction sites of private building owners in Ondo state of Nigeria. The information was gotten from forty- eight building projects ranging from one storey to two storeys. The study revealed that 60-75% of reinforcements used in various structural elements (Columns,Beams, Slabs) were 11.5mm diameter size for 12mm diameter bars. Also, up to 75% of projects studied utilized three numbers (3nos) reinforcements in columns for minimum four numbers as specified in relevant codes. He advised client especially prospective private building owners to engage structural engineers to take care of structural aspects of their building projects. This is reinforced by Ayininuola and Olalusi (2004) when they established that the use of poor quality and substandard steel rods are among the causes of building failure in Nigeria.

Reinforcing steel helps to resist tensile stresses in reinforced concrete members and their use in construction works is specified by relevant codes such as BS 4449:1997 and NIS 1992 for steel among others. Reinforcing steel for construction works are specified in terms of their yield strength, ultimate tensile strength, percentage elongation. By assessing these properties, it is ensured that their use in construction works meet relevant code specifications.

Some works on mechanical properties of steel rods produced in Nigeria has been done. Kareem (2009) worked on the tensile and chemical analysis of selected steel bars produced in Nigeria. Samples were collected from the quality control unit of Oshogbo steel rolling Company. They were machined to standard tensile test pieces and then tested for tensile strength. Chemical analysis test was also conducted on the sample. Test results obtained were compared with that of global steel bars standard and found to be in good agreement. Oyetunji (2012) reinforced this fact when he investigated the chemical composition and resulting microstructures on the mechanical properties of rolled ribbed medium carbon steel. Samples were analyzed to determine chemical composition and then machined using the lathe machine to tensile, impact and hardness properties. Result show that percentage carbon content has great influence on the mechanical properties of the materials as they increased with increase in carbon content.Odusote et al (2012),Ndaliman (2006) took the study further when they evaluated the mechanical properties of medium carbon steel rods quenched in water and oil. Test result revealed that samples quenched in palm oil have better properties compared with that quenched in water.

Still along this direction, Offor and Obikwelu (2010) examined the mechanical properties of intercritically annealed steel quenched in SAE engine oil at room temperature. The samples were heat treated at 750, 760, 770, 780 and 790EC for 1hr in a laboratory muffle furnace and quenched to room temperature in SAE engine oil. They were further subjected to a low temperature tempering at 150EC for 1hr and air cooled to room temperature. The results revealed that strength and hardness values increased from 512.29N/mm^2 at 750EC to 674.62N/mm^2 at 790EC for strength but ductility and notch impact toughness decreased from 12.18% at 750EC to 7.42% at 790EC for ductility and from 9.08N/mm^2 at 750EC to 5.55J/cm^2 at 790EC for notch impact toughness. This shows that tempered steels presented better compromise between strength, hardness, ductility and notch impact hardness for automobile and not for other structural applications.

Kankam and Asamoah (2002) took the study to another dimension when they worked on the strength and ductility characteristics of reinforcing steel milled from scrap metals. Their physical and chemical properties were examined and found that the characteristic tensile strength is too high with very little elongation leading to limited ductility compared with standard mild and high yield steel. Ndiaye et al (2002) working in the same direction investigated the properties of Senegalese steel milled from scrap metals and established that they exhibit poor welding and bending abilities. Chukwudi (2010) examined the role of poor quality steel rods in building failures in Nigeria but concentrated on a sample size (16mm diameter bars) obtained from one company only.Alabi and Onyeji (2010) working in the same line of thought with Ndiayeet al (2009) however expand the frontiers of the study when they examined the chemical and mechanical properties of steel bars from four indigenous companies (with scrap metals as main source of raw material) and a foreign firm. Test results revealed that the carbon contents for all the indigenous steel samples surpassed that for relevant codes (BS 4449, NIS 117) while that of the foreign firm agrees with code specifications. This is reflected in the high characteristic tensile strength values obtained from the test results. Though the percentage elongation for the products agree with code values,this may be attributed to the lower manganese contents of these samples compared with the standards as opined by the researcher. Thedraw- back of this study is that it focused on only one sample size (12mm diameter bars) unlike what is obtainable in practice.

Arum (2008) also investigated the level of conformance to relevant international and local provisions of ribbed steel bars used in Nigeria's structural concrete practice. Both foreign and local steel bars whose origin of production were known were classified as steel of recognizable origin while those whose production origin could not be identified were classified as steel of non-recognizable origin. The samples were then tested for strength and ductility. Results showed that steel of recognizable origin satisfied both local and ISO (international standard organization) requirements for strength and ductility whereas those bars of non- recognizable origin failed to satisfy the above requirements for high yield bars but satisfied the localspecifications if used as mild steel.

On a wider scope, 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. A totalof thirteen (13) companies operating in Nigeria were considered and nineteen (19) samples, thirteen (13) were locally produced in Nigeria, while six (6) were imported was used. A total of 190 specimens were tested for strength and ductility. Test results showed that eleven (11) samples failed to meet the requirements of BS 4449 in respect of the characteristic strength while in terms of ultimate / yield stress ratio, only one (1) out of the nineteen (19) samples failed as prescribed by the code.The draw-back of this study is that the test samples isnarrow in scope in terms of size of bars. Only a single bar size is used for each company. Moreover the 12mm diameter bar apparently dominates the samples because it is used for five different companies. In structural design hardly any structural designer/engineer detail a structure or structural component with a single size of bar. Also, there was no chemical analysis on the test specimens.

The effect(s) of strain hardening ratio of steel rods on structures and structural elements cannot be over emphasized.It is imperative that strain hardening ratio of steel rods conform to code specifications. Values less than or greater than code value has outstanding consequences on the structure or structural component. There is dearth in research in this areaand hence is the focus of this study.

2.0 MATERIALS AND METHOD

2.1 SampleCollection and Preparation

The samples were collected from Deidei market, FCT, Abuja and produced from four indigenous Companies code named A, B, C and D respectively. Their major source of raw materials is scrap metals. For each company, four bars (10mm, 12mm, 16mm and 20mm) were randomly chosen and for each bar size ten (10nos) test specimens were prepared which led to a total of 160 samples. Each specimenis 500mm long with a gauge length. Each specimen diameter is measured in three places and average diameter is obtained as diameter for the bar. Then each specimen was subjected to tensile strength test in accordance with BS 4449:1997 specifications, and after fracture, the yield and ultimate strength, characteristic strength and percentage elongation were calculated. The results of the tensile tests are presented in figures i – iv.

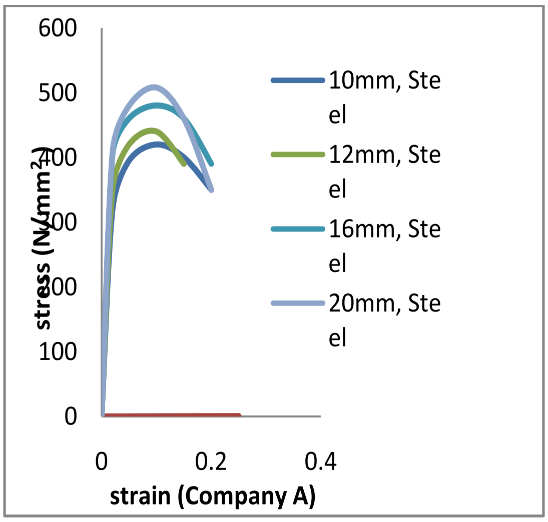

Figure i – Stress – strain curvefor Company AProducts.

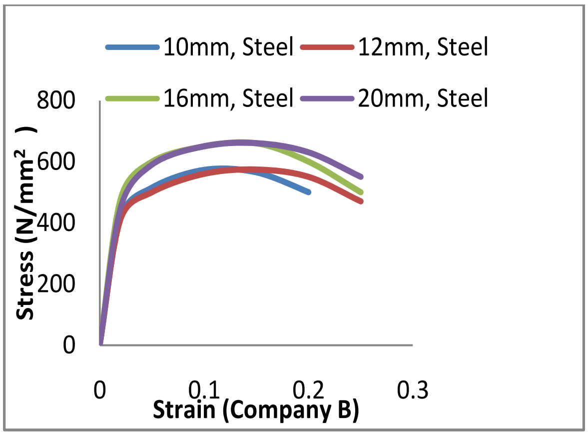

Figure ii – Stress – strain curvefor Company B Products.

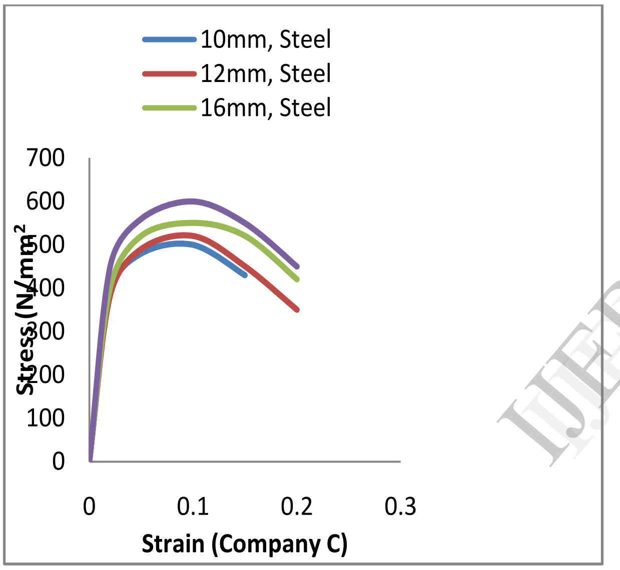

Figure iii – Stress – strain curvefor CompanyC Products.

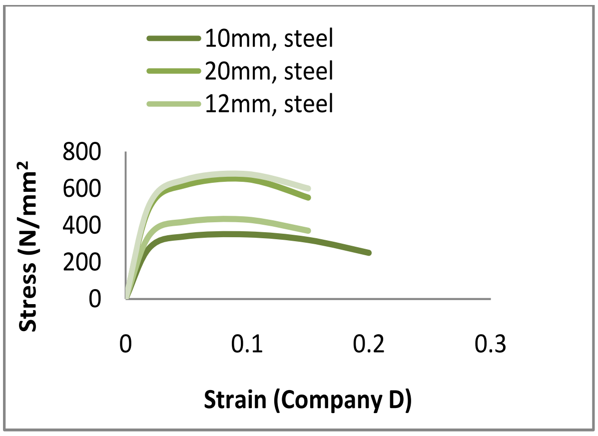

Figure iv – Stress – strain curvefor Company DProducts.

2.2 Tensile Tests

The results of the Tensile tests, indicating the yield stress, ultimate stress, strain hardening ratio for company A – D are as shown in table i below.

Table 1.0: Yield stress, Ultimate tensile stress and strain hardening ratio.

COMPANY	Bar (mm)	Yield stress (N/m m^2)	Ultimate stress (N/m m^2)	Strain hardening Ratio
A	10	320	420	1.31
	12	350	440	1.26
	16	405	480	1.19
	20	410	508	1.24
B	10	418	573	1.37
	12	412	574	1.39
	16	480	660	1.38
	20	450	660	1.47
C	10	370	500	1.28
	12	382	520	1.36
	16	400	550	1.38
	20	450	600	1.33
D	10	280	350	1.25
	12	350	430	1.23
	16	520	678	1.30
	20	500	650	1.30

2.3 Characteristic Strength

With the aid of the yield stress results the characteristic strengths for the company products under study were calculated and corresponding diameters of the bars measured using code specifications and with the aid of a venier caliper as shown in table 2 below.

Table 2.0 : Characteristic Strength Test Results with measured diameters

COMPANY	Nominal Bar dia.(mm)	Measured Bar dia (mm)	Characteristic Strength (N/mm^2)
A	10	9.43	317.68
	12	11.88	346.67
	16	15.24	403.27
	20	20.21	407.32
B	10	10.15	415.05
	12	11.37	408.91
	16	16.02	477.44
	20	20.17	447.56
C	10	10.65	387.44
	12	10.90	378.82
	16	16.27	397.56
	20	19.68	422.00
D	10	9.66	275.56
	12	11.00	346.79
	16	16.08	514.82
	20	20.05	496.90

2.4 **PercentageElongation**

The percentage elongation values for each company products (table 3.0) were calculated using the relation:

$$\% El = \frac{L_f - Lo}{Lo} \times 100$$

whereL_f = final gauge length at fracture, Lo = Original gauge length before application of force.

Table 3.0 : Percentage Elongation values for Company Products

COMPANY	Bar dia.(mm)	Percentage Elongation
A	10	11.90
	12	10.30
	16	9.98
	20	9.36
B	10	10.20
	12	11.00
	16	10.30
	20	11.50
C	10	10.10
	12	10.80
	16	9.93
	20	11.00
D	10	13.90
	12	11.00
	16	5.93
	20	2.75

3.0 ANALYSIS AND DISCUSSION OF RESULTS

Analyses and discussion of the test results were carried out so as to arrive at reasonable conclusion(s).

3.1 Percentage Elongation

From the percentage elongation values (table 3.0) the result for company A, B show that only one of their product met code specification while for company D, two (16mm and 20mm bars) met code requirements. For company C products, none met code value in terms of percentage elongation. As a whole, the products of the company are apparently brittle since only 25 percent of the products met minimum 12% elongation value as specified by BS 4449. Though no chemical analysis was conducted on the test specimens, for the fact that its

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major raw material is scrap metals with high carbon content is likely to account for this brittleness.

3.2 Characteristic Strength

Table 4.0 shows the characteristic strengths of the products of the company under study compared with code specification.For company A and C, none of their products met code requirement while for company B, only one (16mm bar) product met code value and for company D, two (16mm and 20mm) products met code value respectively in terms of characteristic strength. A closer look revealed that the bulk of the characteristic strength of the products fell below code specifications. This is not a healthy development especially for none of a company's product to meet code value leaves much to be desired.

Table 4.0 Comparism of Characteristic Strength with code values

COM	Bar Nominal dia.(mm)	Measured Bar dia (mm)	Characteristic Strength (N/mm^2)	BS 4449 Value (N/mm^2)	Rmks
A	10	9.43	317.68	460	Below code value
	12	11.88	346.67	460	Below code value
	16	15.24	403.27	460	Below code value
	20	20.21	407.32	460	Below code value
B	10	10.15	415.05	460	Below code value
	12	11.37	408.91	460	Below code value
	16	16.02	477.44	460	**Met code value**
	20	20.17	447.56	460	Below code value
C	10	10.65	387.44	460	Below code value
	12	10.90	378.82	460	Below code value
	16	16.27	397.56	460	Bel

					ow code value
	20	19.68	422.00	460	Below code value
D	10	9.66	275.56	460	Below code value
	12	11.00	346.79	460	Below code value
	16	16.08	514.82	460	**Met code value**
	20	20.05	496.90	460	**Met code value**

3.3Strain Hardening Ratio

The strain hardening (ratio of ultimate to yield stress) of the products were calculated using the ultimate and yield stress values (table 1) and then compared with code value as shown in table 5.0. All the products of the companies under study met code requirement in terms of strain hardening ratio. This is an indication of the level of ductility of locally produced steel samples. Though the samples met code value, these values are far in excess of code specification. It is also an indication of high carbon content which account for its level of ductility and given the fact that the raw materials are mainly scrap metals containing a lot of high carbon steel and the absence of metal refining stage during process of production. This tallies with the findings of Ndiaye (2009) and Balogun et al (2009) who established that most of steel products from the west African sub region has high carbon content, less weldable and bendable. This kind of steel, if used for ductility design of structural elements will have serious structural implication.

Table 5Strain Hardening Ratio of Company Products

COMPANY	Bar Nominal dia.(mm)	Strain hardening ratio (fu/fy)	BS 4449 Value	Remarks
A	10	1.31	1.15	Above code value
	12	1.26	1.15	Above code value
	16	1.19	1.15	Above code value
	20	1.24	1.15	Above code value
B	10	1.37	1.15	Above code value
	12	1.39	1.15	Above code value

	16	1.38	1.15	Above code value
	20	1.47	1.15	Above code value
C	10	1.28	1.15	Above code value
	12	1.36	1.15	Above code value
	16	1.38	1.15	Above code value
	20	1.33	1.15	Above code value
D	10	1.25	1.15	Above code value
	12	1.23	1.15	Above code value
	16	1.30	1.15	Above code value
	20	1.30	1.15	Above code value

3.4 Test Results With Design Implication

Some of the parameters calculated and measured were compared with design values with a view to determining or ascertaining design implications.The minimum design strength for reinforcement is 0.87fy, where fy is the characteristic strength. The measured characteristic strengths are compared with the design strength. The design strength is 400.20 N/mm^2 given the characteristic strength of steel (BS4449) as 460N/mm^2. The values are shown in table 6. From the result, none of company A and C products satisfy code requirement, for company B products, only 16mm bars met code specification and for company D, 16mm and 20mm bars complied with code requirements in terms of design. In other words, if steel produced from company A and C are used in design, it will suffer a design deficiency (difference) of up to -31% (company A) and up to -11% (company B) and up to -40% for company D. This is in close agreement with the findings of Ejeh and Jibrin (2012) whose results show a percentage difference ranging from -11% up to -31% for some of the steel products tested.

Table 6.0 Comparism of characteristic Strength with Design Strength

COMPANY	Bar Nominal dia. (mm)	Characteristic strength (fy)	Measured design strength (N/mm^2)	Code design strength = 0.87fy (N/mm^2)	% Difference	Remarks
	10	317.68	276.38	400.20	-31	Not satisfactory
A	12	346.67	301.60	400.20	-25	Not satisfactory
	16	403.27	350.84	400.20	-12	Not satisfactory

	20	407.32	354.37	400.20	-11	Not satisfactory
B	10	415.05	361.09	400.20	-10	Not satisfactory
	12	408.91	355.75	400.20	-11	Not satisfactory
	16	477.44	415	400.20	+1	**Satisfactory**
	20	447.56	389.38	400.20	-3	Not satisfactory
C	10	387.44	337.07	400.20	-16	Not satisfactory
	12	378.82	329.57	400.20	-18	Not satisfactory
	16	397.56	345.88	400.20	-14	Not satisfactory
	20	422.00	367.14	400.20	-8	Not satisfactory
D	10	275.56	239.74	400.20	-40	Not satisfactory
	12	346.79	301.71	400.20	-25	Not satisfactory
	16	514.82	447.89	400.20	+1	**Satisfactory**
	20	496.90	432.30	400.20	+1	**Satisfactory**

3.5 Overall Performance of Parameters for Steel Tested Specimen

Table 7.0 showthe overall performance of parameters for steel products for the companies under study. The result revealed that no product from any of the companies could attain full compliant of code specifications for the parameters of steel tested. The samples could only attain partial compliance.

Table 7.0 Overall performance of Parameters for steel tested specimen

COMPANY	Bar Nominal dia.(mm)	Characteristic strength (fy)	Strain hardening ratio	% Elongation	Remarks
A	10	X	√	√	Complied Partially
	12	X	√	X	Complied Partially
	16	X	√	X	Complied Partially
	20	X	√	X	Complied Partially
	10	X	√	X	Complied Partially

B	12	X	√	X	Com plied Parti ally
	16	√	√	X	Com plied Parti ally
	20	X	√	√	Com plied Parti ally
C	10	X	√	X	Com plied Parti ally
	12	X	√	X	Com plied Parti ally
	16	X	√	X	Com plied Parti ally
	20	X	√	X	Com plied Parti ally
D	10	X	√	√	Com plied Parti ally
	12	X	√	X	Com plied Parti ally
	16	√	√	X	Com plied Parti ally
	20	√	√	X	Com plied Parti ally

Legend: X - unsatisfactory; √ - satisfactory

4.0 Conclusion

From the results of the tensile test conducted and the analyses and observations carried out the following conclusions were made:

1. For the steel products of the companies studied, their characteristic strength values when compared to BS 4449: 1997 standards are low for high tensile steel which is 460N/mm2 minimum value. Only about nineteen percent of the samples were above code specification.
2. The characteristic strength values of the samples for the companies studied (80%) are similar or resembles that of mild steel. This is not out of place to say that the products are actually mild steel but presented as high yield steel and openly sold in the market.
3. All the reinforcements studied had strain hardening ratio which complied with code specifications theoretically but actually are less ductile.
4. Only about Nineteen (19%) of the samples have percentage elongation which complies with code values.
5. More than eighty (80%) percent of the sample design strength were below code specifications.
6. Considering the design and characteristic strengths of high tensile steel, the bulk of steel in the market at F.C.T, Abuja which are used in construction work are actually mild steel but presented as high yield steel. The Nigeria Industrial standard (NIS) and the

standard organization of Nigeria (SON) should intensify their efforts so as to correct this anomaly.

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