Locally Manufactured Steel Reinforcing Bars Used in the Nigerian Construction Industry

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Abstract: ***The research focused on the yield strength of locally manufactured high tensile steel reinforcement bars (12mm and 16mm) produced and used in Nigeria. The high tensile steel samples were purchased from the famous Building market at mile4 Porthar court, Rivers state. A total of forty samples were prepared for testing. These samples were made up of products from seven different companies. Some of the companies had both 12mm and 16mm bars while others had either 12mm or 16mm. Each company had a total of four samples for each diameter (12mm and 16mm). The study investigated the physical and mechanical properties of these steel bars and compared the results obtained with the British standard code of practice (BS4449:1997). From the tensile strength results of the samples tested, none of the samples conformed to the BS4449:1997 code of practice. The 12mm high yield steel bars the highest mean yield strength was 327.95N/mm^2 and the 16mm high yield steel bars the highest mean yield strength was 401.85N/mm^2. All the steel samples had varying minimum percentage elongation. The 12mm high tensile steel bars did not satisfy the required 12% minimum percentage elongation in the BS4449:1997 code. On the other hand,60% of the 16mm bars met the minimum required12% minimum percentage elongation to satisfy the BS4449:1997. In conclusion, it is necessary to re-examine the strength of steels obtained from Nigeria before using them.***

Keywords: High Tensile steel bars, Strength. Physical and Mechanical Properties

1. Introduction

In construction steel reinforcement is provided in combination with concrete to make the composite reinforced concrete. The coefficient of thermal expansion of steel reinforcement and concrete are similar in that they undergo similar expansions during temperature changes (Raju 2000). Wikipedia (2023), they could also be described as tension device in reinforced masonry structure strengthening concrete under tension.

The two main factors that provide strength to the concrete structures are steel and concrete. The design engineer combines both elements to design the structural element in such a way that both steel and concrete resist the induced tensile, compressive and shear force, with the concrete resisting more of the compressive forces.

Mild steel and high tensile steel bars are known to be the two types of steel bars, with Carbon contents ranging from 0.15% to 0.90% by weight (Alabi 2010). Steel bars are manufactured in long lengths and can be cut quickly and bent easily without damage.

High tensile steel bars, are bars of steels provided with lugs or ribs on surface of the bar and are designed to have higher strength by adding some strengthening alloy elements (Alabi 2010). These bars minimize slippage in concrete and increase the bond between the two materials. Alabi described these bars as having more tensile stresses than those of mild steel plain bars and also higher yield strength. Cold twisted (Ribbed or Tor Steel Bars) bars are mostly used as best quality steel bars for construction work by Structural Engineers.

Tensile testing is a fundamental material science and engineering test in which a sample is subjected to controlled tension (being stretched) until failure (Van Vlack 1959). Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area.

The test process involves placing the test specimen in the tensile testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force.

Nigeria's construction industry comprises of steel bars delivered on site that are produced by different manufacturers, often without adequate and reliable information regarding their structural properties, this makes the industry a fertile ground for dumping substandard steel bars. Quality control process is not made available from the manufacturer to the point of sale in the market.

The paper investigated tensile strength of steel reinforcement bars from different manufacturers in Nigeria. The aim is to determine the yield strength of 12mm and 16mm bars. Then compare the yield strength of these products with the Bs 4449:1997 code of practise. The results from the high tensile steel bars of these different companies will be graded on the percentage standard met in regards to Bs 4449:1997.

2. Materials and Equipment

The test samples for this investigation were bars of 12mm and 16mm diameters of high tensile ribbed steel bars of recognizable origin dominantly used in Nigeria. They were sourced from the famous building material market, Mile 4, Kala market in River State. The samples were labelled with Alphabets to replace the company name for the bars purchased. Physical examination and tensile yield strength test was done for the acquired bars. The materials for the investigation included:

1) Steel samples

The steel samples were made up of high tensile steel bars. These bars were from seven different companies, labelled with different distinctive names. Same names were given to samples from same companies.

For this investigation, the high tensile steel bars of 12mm and 16mm bars were sourced from the famous building market Kala Market in Mile 4 Rivers State. The products acquired for 12 mm:

Sample A12, B12, C12, D12, E12 Steel bars.

A total of twenty steel samples, four for each company, acquired for 12mm high tensile steel bars.

The products acquired for 16 mm bars:
Sample A16, F16, G16, B16, E16 Steel bars.

A total of twenty steel samples, four for each company, acquired for 16mm high tensile steel bars.

A total of 40 samples were obtained for high tensile ribbed bars. Twenty samples each for both 12 and 16 mm from six major suppliers respectively.

2) Tensile strength testing machine

The tensile strength testing machine was the Hydraulic universal testing Machines "F 060/U - F 060" Tecno (2021).

3) Method

Test specimens obtained for high tensile ribbed bars of circular cross section of nominal diameters, 12 and 16mm, represented the most widely used bar size for concrete reinforcement needs in Nigeria. Forty (40) test samples were prepared. The 12mm samples were twenty in number from five different companies. The 16mm samples were twenty in number from five different companies. A total of seven companies produced these forty samples with some having both 12 and 16mm samples. The sample gauge length was 610mm in length. The gauge length was marked on each sample using the tape, scriber, and prior to testing. The test pieces were cut off from full 12m lengths of high tensile ribbed bars sampled randomly from the local bar markets.

A tape and Verniercalliper were used to measure the dimensions of the test pieces. The tensile test was carried out in accordance with the recommendations of ISO (1991). The test was conducted at the Materials Testing Laboratory of the Federal Polytechnic Nekede Imo State, using a Universal Testing Machine (F 060/U).

The Analysis was carried out in accordance to and in compares with the BS4449 specifications for each section. Secondly analysis of percentage compliance to the BS4449 specification was done.

3. Results and Discussion

The results are as presented in tables 4-23**.** The physical and mechanical properties are in tables 4-13, while the percentage compliance is in tables 14-23.

Table 4: Results for A12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
A16 Steel	12	11.61	0.845	105.88	314.41	423.78	1.348
	12	11.61	0.845	105.88	314.50	423.82	1.348
	12	11.61	0.845	105.88	314.62	423.74	1.347
	12	11.61	0.845	105.88	314.43	423.77	1.348
Mean		11.61	0.845	105.88	314.49	423.78	1.348

Table 5: Results for E12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
E16 Steel	12	11.52	0.838	104.24	296.17	354.17	1.196
	12	11.52	0.838	104.24	296.17	354.17	1.196
	12	11.52	0.838	104.24	296.17	354.17	1.196
	12	11.52	0.838	104.24	296.17	354.17	1.196
Mean		11.52	0.838	104.24	296.17	354.17	1.196

Table 6: Results for B12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
B16 Steel	12	11.72	0.851	107.90	321.66	426.66	1.326
	12	11.72	0.851	107.90	321.59	426.32	1.326
	12	11.72	0.851	107.90	322.01	426.81	1.326
	12	11.72	0.851	107.90	321.87	426.78	1.326
Mean		11.72	0.851	107.90	321.78	426.64	1.326

Table 7: Results for C12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
C16 Steel	12	12.02	0.882	113.50	327.52	432.25	1.320
	12	12.02	0.882	113.50	328.04	433.64	1.322
	12	12.02	0.882	113.50	328.61	433.75	1.320
	12	12.02	0.882	113.50	327.64	432.98	1.322
Mean		12.02	0.882	113.50	327.95	433.16	1.321

Table 8: Results for D12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
D16 Steel	12	11.93	0.876	111.80	322.78	428.61	1.328
	12	11.93	0.876	111.80	323.41	428.91	1.326
	12	11.93	0.876	111.80	323.70	429.05	1.326
	12	11.93	0.876	111.80	322.94	428.89	1.328
Mean		11.93	0.876	111.80	323.21	428.87	1.327

Table 9: Results for A16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
A16 Steel	16	15.49	1.480	188.47	355.61	463.61	1.304
	16	15.49	1.480	188.47	355.64	463.67	1.304
	16	15.49	1.480	188.47	355.61	463.61	1.304
	16	15.49	1.480	188.47	355.65	463.82	1.304
Mean		15.49	1.480	188.47	355.63	455.68	1.304

Table 10: Results for E16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
E16 Steel	16	15.74	1.597	195.84	380.14	488.14	1.284
	16	15.74	1.597	195.84	382.10	489.67	1.284
	16	15.74	1.597	195.84	381.59	487.61	1.284
	16	15.74	1.597	195.84	381.41	488.62	1.284
Mean		15.74	1.597	195.84	381.31	488.51	1.284

Table 11: Results for B16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
B16 Steel	16	15.80	1.610	196.09	395.82	503.82	1.273
	16	15.80	1.610	196.09	395.79	503.76	1.273
	16	15.80	1.610	196.09	395.66	503.54	1.273
	16	15.80	1.610	196.09	395.81	503.80	1.273
Mean		15.80	1.610	196.09	395.77	503.73	1.273

Table 12: Results for G16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
G16 Steel	16	16.02	1.795	201.60	401.61	509.84	1.270
	16	16.02	1.795	201.60	404.01	510.62	1.270
	16	16.02	1.795	201.60	399.65	507.61	1.270
	16	16.02	1.795	201.60	402.11	509.94	1.270
Mean		16.02	1.795	201.60	401.85	509.50	1.270

Table 13: Results for F16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
F16 Steel	16	15.88	1.617	198.10	370.64	478.85	1.292
	16	15.88	1.617	198.10	370.64	478.83	1.292
	16	15.88	1.617	198.10	370.63	478.82	1.292
	16	15.88	1.617	198.10	370.66	478.81	1.292
Mean		15.88	1.617	198.10	370.64	478.82	1.292

B. Percentage Compliance:

Table 14: Results for A12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
A16 Steel	12	96.70	95.15	93.62	68.35	128.38	98.33
	12	96.70	95.15	93.62	68.35	128.38	98.33
	12	96.70	95.15	93.62	68.35	128.38	98.33
	12	96.70	95.15	93.62	68.35	128.38	98.33
Mean		96.70	95.15	93.62	68.35	128.38	98.33

Table 15: Results for E12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
E16 Steel	12	96.00	94.40	92.17	64.38	113.90	78.33
	12	96.00	94.40	92.17	64.38	113.90	78.33
	12	96.00	94.40	92.17	64.38	113.90	78.33
	12	96.00	94.40	92.17	64.38	113.90	78.33
Mean		96.00	94.40	92.17	64.38	113.90	78.33

Table 16: Results for B12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
B16 Steel	12	97.67	95.83	95.40	69.92	126.29	77.5
	12	97.67	95.83	95.40	69.92	126.29	77.5
	12	97.67	95.83	95.40	70.00	126.29	77.5
	12	97.67	95.83	95.40	69.97	126.29	77.5
Mean		97.67	95.83	95.40	69.95	126.29	77.5

Table 17: Results for C12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
C16 Steel	12	100.00	99.32	100.35	71.20	125.71	80.83
	12	100.00	99.32	100.35	71.31	125.91	80.83
	12	100.00	99.32	100.35	71.43	125.71	80.83
	12	100.00	99.32	100.35	71.22	125.91	80.83
Mean		100.00	99.32	100.35	71.31	125.80	80.83

Table 18: Results for D12mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
D16 Steel	12	99.41	98.65	104.78	70.01	126.48	68.33
	12	99.41	98.65	104.78	70.30	126.28	68.33
	12	99.41	98.65	104.78	70.37	126.28	68.33
	12	99.41	98.65	104.78	70.37	126.48	68.33
Mean		99.41	98.65	104.78	70.30	126.37	68.33

Table 19: Results for A16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
A16 Steel	16	96.81	93.73	93.72	77.30	124.19	142.50
	16	96.81	93.73	93.72	77.30	124.19	142.50
	16	96.81	93.73	93.72	77.30	124.19	142.50
	16	96.81	93.73	93.72	77.30	124.19	142.50
Mean		96.81	93.73	93.72	77.30	124.19	142.50

Table 20: Results for E16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
E16 Steel	16	98.38	101.13	97.40	82.64	118.10	135.00
	16	98.38	101.13	97.40	83.07	118.10	135.00
	16	98.38	101.13	97.40	83.00	118.10	135.00
	16	98.38	101.13	97.40	82.92	118.10	135.00
Mean		98.38	101.13	97.40	82.64	118.10	135.00

Table 21: Results for B16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
B16 Steel	16	98.75	101.96	97.50	86.05	121.24	59.17
	16	98.75	101.96	97.50	86.05	121.24	59.17
	16	98.75	101.96	97.50	86.05	121.24	59.17
	16	98.75	101.96	97.50	86.05	121.24	59.17
Mean		98.75	101.96	97.50	86.05	121.24	59.17

Table 22: Results for G16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
G16 Steel	16	100.01	113.68	100.24	87.31	120.95	114.16
	16	100.01	113.68	100.24	87.82	120.95	115.00
	16	100.01	113.68	100.24	86.88	120.95	113.00
	16	100.01	113.68	100.24	87.42	120.95	113.00
Mean		100.01	113.68	100.24	87.31	120.95	114.01

Table 23: Results for E16mm High Tensile Steel Bars

Sample	Bar Diameter (mm)	Measured Diameter % (mm)	Mass % (Kg/m)	Cross Sectional Area % (mm^2)	Yield Strength (Re) % (N/mm^2)	Stress Ratio % (Rm/Re)	Elongation %
F16 Steel	16	99.25	102.41	98.51	80.57	123.04	51.67
	16	99.25	102.41	98.51	80.57	123.04	51.67
	16	99.25	102.41	98.51	80.57	123.04	51.67
	16	99.25	102.41	98.51	80.57	123.04	51.67
Mean		99.25	102.41	98.51	80.57	123.04	51.67

Discussion

The result highlighted the standards of these bars produced by local manufacturers in the following categories:

a) Cross sectional area and mass

The cross sectional area was uniform across the length of the bar from visual inspection. Most of the bars tested did not have an exact diameter of 12mm and 16mm. The BS4449 (1997) mass per meter for 12mm and 16mm are 0.888kg and1.579kg. None of the samples for 12mm and 16mm met this standard.

b) Mechanical properties

1) Yield strength *R*ea (YS):

High tensile steel bars, BS4449 (1997) stated a yield strength of 460N/mm2. None of the high tensile steel bars had such yield strength for both 12mm and 16mm bars. The highest yield strength for 12mm was 328.61 N/mm^2 and 16mm 404.01 N/mm^2.

2) Ultimate Tensile Strength, (UTS):

High tensile steel bars, ultimate tensile strength for 12mm were 432.98 N/mm^2, and 16mm was 510.62 N/mm^2.

3) Stress ratio *R*m/*R*b (min.):

For high tensile steel bars, BS4449 (1997) stated a Stress ratio of 1.05. None of the high tensile steel bars had such Stress ratio for both 12mm and 16mm bars. They all had high Stress ratio for 12mm with 1.348, and 16mm with 1.304.

4) Percentage Elongation at fracture A_5 (min.):

For high tensile steel bars, BS4449 (1997) stated a percentage elongation fracture of 12. None of the high tensile steel bars for 12mm had such percentage elongation at fracture but 16mm had three companies that had more percentage elongation at fracture, IGS 17.10, RS 16.20 and YXS 13.70, making IGS 16mm bars the highest in percentage elongation at fracture. For 12mm was IGS with 11.80.

4. Conclusion

The Study determined the percentage compliance of locally manufactured steel bars to the BS4449:1997 code of practice and also the quality of these products in the Nigerian Building markets.

In areas such as cross sectional area and mass, the high tensile steel bars had 20% of both 12mm and 16mm meeting the required standard for same code.

Secondly, the most important aspect of these bars which has to do with the mechanical properties of these steel bars, in areas such as yield strength and percentage elongation, it was noted that many of these tested products had varied properties different from the Bs4449 (1997) code standards. These High tensile steel bars had a 100% failure in Yield Strength both 12mm and 16mm.

When it came to the aspect of percentage elongation these tensile steel bars; 100% of 12mm steel bars failed to meet the minimum percentage elongation standard but surprisingly 60% of the 16mm bars met the minimum standard and some surpassed it, making these products more ductile than brittle.

It is sad to note that most of the steel bars produced in Nigeria are substandard. With this study exposing that the markets are filled with substandard products. It can be asserted that in Nigeria locally manufactured steel bars are all mild steel bars with threaded mild steel bars regarded as the so called high tensile steel bar name given to them.

5. Recommendations

Based on the findings of this research the following recommendations are made:

1) It is important that proper testing should be done on all supplied steel bars to be used on the site, with the results from these test included in making design decisions by the structural / construction engineer. This test should be a must for all steel bars to be used on site.
2) Companies should establish good quality control process, from material selection to batching down to processing and final product. Companies should also employ qualified personnel to man various stages of production.
3) Companies should prioritize quality check on products, with defective products withdrawn from supply batches and the market.
4) The government should setup a task force to checkmate these products, steel bars sold in the market. Secondly defaulters should be prosecuted, sanctioned and names published in the dailies to help guide the public in making safe choices.

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