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Assessment of the Properties of Reinforcing Steel Bars Used In the Construction Industry within Lagos State and Its Environs

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ABSTRACT: *The properties of reinforcing steel bars used by construction industry in Lagos State and its environs were investigated. This was done to establish the level of conformity of steel bars being used with the code standard. Nine (9) locally produced steel bars and three (3) imported steel bars were randomly sampled and tested. Physical and chemical tests were performed on the samples in three consecutive years from 2013 to 2015. It was found that the local steel bars has minimum and maximum characteristic strength values of 282 N/mm^2 and 543 N/mm^2 respectively as while the imported steel bars has minimum and maximum characteristic strength values of 497 N/mm^2 and 600 N/mm^2. Most of the locally produced bars consistently failed to meet the requirements of BS4449: 1997 while all the imported bars consistently met the requirements.*

Keywords: *Compressive, Elongation, Fracture, Strain Ratio, Yield Strength*

I. INTRODUCTION

Metals including steel have a linear stress-strain relationship up to the yield point, and the stress decreases after the yield point. This is due to the interaction of carbon atoms and dislocations in the stressed steel. Cold worked and alloy steels do not show this effect. For most metals yield point is not sharply defined, below the yield strength all deformation is recoverable, and the material will return to its initial shape when the load is removed and this is known as elastic deformation. For stresses above the yield point the deformation is not recoverable, with the material not returning to its initial shape and it's known as plastic deformation. For many applications plastic deformation is unacceptable, and the yield strength is used as the design limitation.

The commonly used material in the building and construction industry is concrete and it is mostly used with steel bars as reinforcements to achieve a composite material called reinforced concrete. This composite material has cement and aggregates act as the matrix to absorb compressive stresses while the reinforcing steel bars embedded and protected by the concrete takes up the tensile stresses upon loading. A very good understanding and knowledge of the real behaviour of these construction materials is of prime importance for the proper behaviour of engineered structures. The physical properties of structural materials are expected to meet the fundamental assumptions and requirements of all structural codes of practice on which designs are based.

Steel reinforcing bars available for use in the Nigeria's Construction Industry are obtained from both local and imported sources. The local sources are from both the indigenous major plants and the mini steel mills located in different parts of the country. Imported steel bars coming into the country are mainly from Russia, Ukraine and Turkey. Majority of the local construction companies in Nigeria carry out all their reinforcing steel procurements from the open local markets that are unable to provide technical information that guide users on the appropriate use of the product they are selling out.

The use of reinforcing bars in construction works is specified by relevant codes such as [1] and [2] for steel among other available codes worldwide. [3] examined the tensile behavior of reinforcing steel bars used in the Nigeria construction Industry and *found out that majority of samples examined failed to meet the requirements in respect of the characteristic strength.* [4] established that the use of poor quality and substandard steel rods are among the causes of building failure in Nigeria. [5] identified causes of building failures to include among others, supervision by unqualified personnel, poor quality control, and unprofessional conduct. This was asserted by [6] 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. [7] 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. Test results obtained were compared with that of global steel bars standard and found to be in good agreement.

[8] carried out some investigation on Ghanian steel bars by working on the strength and ductility characteristics of reinforcing steel milled from scrap metals. They examined the physical and chemical properties 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. [9] 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. [10] examined the role of poor quality steel rods in building failures in Nigeria but his worked was limited to 16mm diameter bars obtained from one company only.

This paper aims at investigating the consistency in conformity or otherwise of steel bars used in the construction industry in Lagos State of Nigeria and its environs.

II. MATERIALS AND METHOD

2.1 Samples Collection

Samples of steel bars were obtained from Iyana Ipaja and Owode Onirin markets in Lagos State. In 2013, samples produced by only five locally manufacturing companies were collected and tested. In 2014 and 2015, the steels obtained were those produced by Nine (9) local steel manufacturing companies in Nigeria and three (3) imported steels whose actual names are not known but only the countries of origin are specified. For each of these years, four bar sizes (10mm, 12mm, 16mm and 20mm) were randomly chosen for each company and for each bar size three (3 Nos) test specimens were prepared.

2.2 Samples Labeling

All the samples collected were labeled as LC-1 to LC-9 for locally manufacture steels and IM-1 to IM-3 for imported steels.

2.3 Samples Preparation and Tests

Three specimens were tested for each bar size and each specimen made up of a length of 500 millimeters had its diameter measured with the aid of a venier caliper in three places to obtain average value as its diameter. Each specimen was weighed and then subjected to tension in accordance with the BS4449:1997 provisions, and after fracture, the yield strength, ultimate strength, strain ratios as well as elongations were calculated. The results of the tensile tests are presented in tables 1, 2 and 3 for 2013, 2014 and 2015 tests respectively.

The chemical analyses of the samples were carried out for samples used in 2014 and 2015. The tests were done using Spectrometer Metal Analyzer. Model- ARL3460. The results are as shown in Tables 4 and 5 for 2014 and 2015 tests respectively. Table 6 shows the Code requirements for chemical composition

Table 1: Yield Stress, Ultimate Stress, Strain Ratio and Elongation in 2013.

S/N	Bar I.D	Nominal Size	Yield Load at Failure (kN)	Yield Stress (N/mm²)	Ultimat Load at Failure (kN)	Ultimate stress (N/mm²)	Strain Ratio	Elongation (%)
1	LC-1	10	27.95	355.7	35.75	455.0	1.28	26.5
		12	49.75	439.7	68.65	606.8	1.38	28.45
		16	93.3	463.8	119.45	593.9	1.28	24.25
		20	132.55	421.8	174.55	555.4	1.32	22.3
2	LC-2	10	22.13	281.7	33.03	420.4	1.49	21.17
		12	33.17	293.2	49.51	437.6	1.49	21.59
		16	92.38	459.3	124.75	620.2	1.35	17.34
		20	149.33	475.1	187.41	596.3	1.26	19.65
3	LC-3	10	23.29	296.4	34.76	442.4	1.49	20.01
		12	57.88	511.6	72.3	639.0	1.25	12.33
		16	103.8	516.1	133.12	661.8	1.28	13.5
		20	170.69	543.1	219.45	698.3	1.29	15.67
4	LC-4	10	22.13	281.7	33.03	420.4	1.49	11.5
		12	33.17	293.2	49.51	437.6	1.49	11
		16	85.99	427.5	137.62	684.2	1.60	6.4
		20	140.18	446.0	178.22	567.1	1.27	18
5	LC-5	10	34.54	439.6	51.55	656.1	1.49	18.56
		12	48.71	430.5	72.71	642.6	1.49	18.72
		16	89.88	446.8	118.84	590.8	1.32	19.12
		20	143.37	456.2	178.99	569.5	1.25	17.98

Table2: Yield Stress, Ultimate Stress, Strain Ratio and Elongation in 2014

S/N	Bar I.D	Nominal Size	Yield Load at Failure (kN)	Yield Stress (N/mm²)	Ultimat Load at Failure (kN)	Ultimate stress (N/mm²)	Strain Ratio	Elongation (%)
1	LC 1	10	28.95	368.5	35.75	455.0	1.23	27.7
		12	50.75	448.5	68.65	606.8	1.35	28.45
		16	94.30	468.8	119.45	593.9	1.27	24.25
		20	142.78	454.3	174.55	555.4	1.22	22.3
2	LC-2	10	28.13	358.0	33.23	422.9	1.18	21.17
		12	38.17	337.4	49.51	437.6	1.30	21.59
		16	92.38	459.3	124.75	620.2	1.35	17.34
		20	140.18	446.0	187.41	596.3	1.34	19.65
3	LC-3	10	35.09	446.6	43.76	556.9	1.25	20.01
		12	56.99	503.7	72.30	639.0	1.27	12.33
		16	107.77	535.8	133.12	661.8	1.24	13.5
		20	165.65	527.1	219.45	698.3	1.32	15.67
4	LC-4	10	28.17	358.5	33.03	420.4	1.17	10.7
		12	42.07	371.8	49.51	437.6	1.18	12.1
		16	84.90	422.1	137.62	684.2	1.62	11.3
		20	140.14	445.9	187.40	596.3	1.34	10.9
5	LC-5	10	34.54	439.6	51.55	656.1	1.49	18.56
		12	48.71	430.5	72.71	642.6	1.49	18.72
		16	89.88	446.8	118.84	590.8	1.32	19.12
		20	143.37	456.2	178.99	569.5	1.25	17.98
6	LC-6	10	28.39	361.3	34.76	442.4	1.22	13
		12	44.66	394.7	73.09	646.0	1.64	8.7
		16	82.99	412.6	98.62	490.3	1.19	16
		20	141.21	449.3	174.00	553.6	1.23	11.4
7	LC-7	10	29.13	370.7	36.03	458.6	1.24	21.17
		12	44.44	392.8	52.24	461.7	1.18	32.75
		16	84.26	418.9	98.64	490.4	1.17	32.8
		20	131.22	417.5	154.00	490.0	1.17	17.4
8	LC-8	10	29.49	375.3	41.43	527.3	1.40	16.84
		12	44.01	389.0	62.10	548.9	1.41	12.2
		16	76.32	379.4	111.94	556.5	1.47	12.6
		20	124.54	396.3	176.44	561.4	1.42	14.7
9	LC-9	10	34.54	439.6	51.55	656.1	1.49	18.56
		12	47.99	424.2	64.15	567.0	1.34	11.6
		16	89.77	446.3	111.21	552.9	1.24	13.1
		20	140.18	446.0	182.21	579.8	1.30	17.6
10	IM-1	10	39.20	498.9	51.21	651.8	1.31	17.45
		12	61.95	547.5	84.21	744.3	1.36	21.5
		16	105.95	526.7	155.21	771.6	1.46	21.45
		20	156.18	496.9	198.11	630.4	1.27	21.11
11	IM-2	10	41.29	525.5	49.32	627.7	1.19	16.84
		12	58.80	519.7	72.99	645.1	1.24	16.9
		16	113.81	565.8	149.21	741.8	1.31	21.36
		20	170.18	541.5	210.21	668.9	1.24	18.3
12	IM-3	10	45.34	577.1	55.24	703.1	1.22	16.3
		12	67.13	593.3	78.20	691.2	1.16	18
		16	116.33	578.3	136.89	680.6	1.18	18.4
		20	176.41	561.3	217.67	692.6	1.23	17.5

Table 3: Yield Stress, Ultimate Stress, Strain Ratio and Elongation in 2015

S/N	Bar I.D	Nominal Size	Yield Load at Failure (kN)	Yield Stress (N/mm²)	Ultimat Load at Failure (kN)	Ultimate stress (N/mm²)	Strain Ratio	Elongation (%)
1	LC 1	10	29.29	372.8	34.76	442.4	1.19	23.6
		12	46.66	412.4	69.64	615.5	1.49	27.45
		16	76.88	382.2	96.58	480.2	1.26	24.25
		20	132.55	421.8	194.87	620.0	1.47	22.3
2	LC-2	10	29.13	370.7	35.03	445.8	1.20	21.17
		12	43.17	381.6	50.51	446.4	1.17	21.59
		16	98.57	490.0	147.12	731.4	1.49	17.34
		20	149.33	475.1	187.41	596.3	1.26	19.65
3	LC-3	10	36.29	461.9	44.76	569.7	1.23	20.01
		12	57.88	511.6	72.3	639.0	1.25	12.33
		16	113.8	565.8	133.72	664.8	1.18	13.5
		20	170.69	543.1	219.45	698.3	1.29	15.67
4	LC-4	10	28.13	358.0	33.03	420.4	1.17	9.7
		12	39.17	346.2	49.51	437.6	1.26	11.1
		16	85.99	427.5	137.62	684.2	1.60	11.3
		20	140.69	447.7	188.98	601.3	1.34	10.9
5	LC-5	10	34.54	439.6	51.55	656.1	1.49	18.56
		12	48.71	430.5	72.71	642.6	1.49	18.72
		16	76.63	381.0	118.84	590.8	1.55	19.12
		20	143.37	456.2	178.99	569.5	1.25	17.98
6	LC-6	10	29.29	372.8	34.76	442.4	1.19	20.01
		12	43.67	386.0	73.09	646.0	1.67	10.2
		16	86.01	427.6	119.22	592.7	1.39	19.5
		20	143.45	456.4	187.66	597.1	1.31	17.4
7	LC-7	10	28.13	358.0	33.03	420.4	1.17	21.17
		12	40.2	355.3	52.24	461.7	1.30	29,6
		16	74.26	369.2	92.64	460.6	1.25	21.22
		20	129	410.5	156.43	497.7	1.21	17.4
8	LC-8	10	30.49	388.1	45.43	578.2	1.49	16.84
		12	44.01	389.0	61.1	540.0	1.39	12.2
		16	86.32	429.1	119.94	596.3	1.39	12.6
		20	124.54	396.3	156.44	497.8	1.26	14.7
9	LC-9	10	28.54	363.2	40.55	516.1	1.42	18.56
		12	41.99	371.1	61.15	540.5	1.46	11.6
		16	84.77	421.4	111.21	552.9	1.31	13.1
		20	124.54	396.3	152.21	484.3	1.22	19.4
10	IM-1	10	38.24	486.7	57.09	726.6	1.49	17.45
		12	58.31	515.4	70.62	624.2	1.21	19
		16	120.73	600.2	150.34	747.4	1.25	18.4
		20	174.99	556.8	219.22	697.5	1.25	18.8
11	IM-2	10	44.49	566.2	60.43	769.1	1.36	16.84
		12	62.8	555.1	82.77	731.6	1.32	16.9
		16	110.57	549.7	143.09	711.4	1.29	17
		20	187.43	596.4	221.11	703.5	1.18	16
12	IM-3	10	41.34	526.1	51.24	652.1	1.24	13
		12	62.13	549.1	78.2	691.2	1.26	12
		16	110.33	548.5	136.89	680.6	1.24	13
		20	165.41	526.3	217.67	692.6	1.32	14

Table 4: Percentage Chemical Composition of Sample Steel Bars in 2014

BAR I.D	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6	LC-7	LC-8	LC-9	IM-1	IM-2	IM-3
ELEMENT												
Iron (Fe) (%)	98.140	98.260	98.080	98.470	97.920	97.920	98.340	98.010	97.920	98.400	97.810	98.110
Carbon (C) (%)	0.117	0.113	0.196	0.117	0.112	0.108	0.116	0.205	0.112	0.120	0.169	0.200
Silicon (Si) (%)	0.222	0.266	0.227	0.124	0.237	0.209	0.220	0.216	0.237	0.225	0.169	0.200
Manganese (Mn) (%)	0.562	0.636	0.698	0.451	0.623	0.576	0.502	0.601	0.623	0.569	0.553	0.660
Phosphorus (P) (%)	0.028	<0.000	0.028	<0.007	0.014	0.024	0.027	0.024	0.014	0.018	0.025	0.018
Sulphur (S) (%)	0.044	0.045	0.048	0.036	0.042	0.047	0.045	0.051	0.042	0.036	0.054	0.039
Chromium (Cr) (%)	0.125	0.085	0.096	0.132	0.156	0.224	0.125	0.147	0.156	0.078	0.235	0.104
Nickel (Ni) (%)	0.221	0.164	0.185	0.185	0.225	0.241	0.221	0.212	0.225	0.149	0.249	0.192
Molibdinum(Mo) (%)	0.050	0.037	0.045	0.072	0.106	0.086	0.050	0.058	0.106	0.034	0.115	0.060
Copper (Cu) (%)	0.157	0.178	0.145	0.216	0.233	0.237	0.157	0.199	0.233	0.149	0.238	0.163
Aluminium (Al) (%)	<0.004	<0.000	0.006	0.004	0.017	0.001	0.004	0.000	0.017	<0.000	0.014	0.000
Titanium (Ti) (%)	<0.001	<0.000	<0.001	<0.000	<0.000	0.000	0.001	0.000	0.000	<0.000	<0.000	0.000
Vanadium (V)(%)	0.009	0.006	0.010	<0.003	<0.002	0.009	0.009	0.011	0.002	0.007	<0.003	0.009
Cobalt (Co) (%)	0.045	0.033	0.034	0.031	0.030	0.039	0.045	0.037	0.030	0.031	0.037	0.034
Niobium (Nb) (%)	0.054	0.038	0.059	0.020	0.031	0.048	0.054	0.051	0.031	0.034	0.035	0.043
Tungsten (W) (%)	<0.000	<0.011	<0.020	<0.013	0.141	0.118	0.000	0.056	0.141	<0.032	0.183	0.050
Tin (Sn) (%)	0.020	0.027	0.021	0.013	0.015	0.015	0.020	0.022	0.015	0.032	0.015	0.012
Total (%)	99.89	99.90	99.88	99.89	99.90	99.90	99.94	99.90	99.90	99.90	99.90	99.89

Table 5: Percentage Chemical Composition of Sample Steel Bars in 2015

BAR I.D	LC-1	LC-2	LC-3	LC-4	LC-5	LC-6	LC-7	LC-8	LC-9	IM-1	IM-2	IM-3
ELEMENT												
Iron (Fe) (%)	98.240	98.260	98.080	98.470	97.920	97.920	98.340	98.010	97.920	98.400	97.810	98.110
Carbon (C) (%)	0.116	0.113	0.196	0.117	0.112	0.111	0.116	0.207	0.112	0.110	0.169	0.210
Silicon (Si) (%)	0.220	0.266	0.227	0.124	0.237	0.209	0.220	0.216	0.237	0.225	0.169	0.200
Manganese (Mn) (%)	0.562	0.636	0.698	0.451	0.623	0.576	0.502	0.601	0.623	0.569	0.553	0.660
Phosphorus (P) (%)	0.028	<0.000	0.028	<0.007	0.014	0.024	0.027	0.024	0.014	0.018	0.025	0.018
Sulphur (S) (%)	0.044	0.045	0.048	0.036	0.042	0.047	0.045	0.051	0.042	0.036	0.054	0.039
Chromium (Cr) (%)	0.125	0.085	0.096	0.132	0.156	0.224	0.125	0.147	0.156	0.078	0.235	0.104
Nickel (Ni) (%)	0.221	0.164	0.185	0.185	0.225	0.241	0.221	0.212	0.225	0.149	0.249	0.192
Molibdinum(Mo) (%)	0.050	0.037	0.045	0.072	0.106	0.086	0.050	0.058	0.106	0.034	0.115	0.060
Copper (Cu) (%)	0.157	0.178	0.145	0.216	0.233	0.237	0.157	0.199	0.233	0.149	0.238	0.163
Aluminium (Al) (%)	0.004	<0.000	0.006	0.004	0.017	0.001	0.004	0.000	0.017	<0.000	0.014	0.000
Titanium (Ti) (%)	<0.001	<0.000	<0.001	<0.000	<0.000	0.000	0.001	0.000	0.000	<0.000	<0.000	0.000
Vanadium (V)(%)	0.009	0.006	0.010	<0.003	<0.002	0.009	0.009	0.011	0.002	0.007	<0.003	0.009
Cobalt (Co) (%)	0.045	0.033	0.034	0.031	0.030	0.039	0.045	0.037	0.030	0.031	0.037	0.034
Niobium (Nb) (%)	0.054	0.038	0.059	0.020	0.031	0.048	0.054	0.051	0.031	0.034	0.035	0.043
Tungsten (W) (%)	<0.000	<0.011	<0.020	<0.013	0.141	0.118	0.000	0.056	0.141	<0.032	0.183	0.050
Tin (Sn) (%)	0.020	0.027	0.021	0.013	0.015	0.015	0.020	0.022	0.015	0.032	0.015	0.012
Total (%)	99.89	99.90	99.88	99.89	99.90	99.91	99.94	99.90	99.90	99.90	99.90	99.90

Table 6: Standard Chemical Composition of Steel Grades

S/N	ELEMENT	GRADE 250 % (MAX)	GRADE 460 % (MAX)	DEVAITION % (MAX)
1	Carbon (C)	0.25	0.25	0.02
2	Sulphur (S)	0.06	0.05	0.005
3	Phosphorus (P)	0.06	0.05	0.005
4	Nitrogen (N)	0.012	0.012	0.001
5	Carbon equivalent	0.42	0.51	0.03
6	Aluminium (Al)	0.1	0.1	
7	Silicon (Si)	0.25	0.3	
8	Manganese (Mn)	0.8	1.2	
9	Copper (Cu)	0.25	0.25	

Source: Standard Organization of Nigeria (SON); BS4449:1997

III. RESULTS AND DISCUSSION

3.1 Test results

3.1.1 Physical properties

Tables 7 and 8 show the summary of characteristic strength and elongations obtained for the tests in the three successful yearshe results of Statistical analysis shows that the steel bars exhibited significant variability in yield strength. From the results, the mean yield stress obtained for locally manufactured steel bars ranges from

282 kN/mm^2 to 543 kN/mm^2 in 2013, from 337 kN/mm^2 to 536 kN/mm^2 in 2014 and from 346 kN/mm^2 to 566 kN/mm^2 in 2015. For the imported steel bars, the mean yield stress from tests ranges from 497 kN/mm^2 to 593 kN/mm^2 in 2014 and from 487 kN/mm^2 to 600 kN/mm^2 in 2015.

Similarly, the percentage elongation of the locally manufactured steel bars ranges from 6.4 to 28.5 in 2013, from 8.7 to 32.8 in 2014 and from 9.7 to 27.5 in 2015. For the imported steel bars, the mean ultimate stress from tests ranges from 16.5 to 21.5 kN/mm^2 in 2014 and from 12.0 to 19.0 in 2015.

3.1.2 Strain Hardening Ratio

The strain hardening (ratio of ultimate to yield stress) of the products were calculated using the ultimate and yield stress values and then compared with code value as shown in Table 9. The mean values of the strain ratios of the locally manufactured steel bars ranges from 1.25 to 1.60 in 2013, from 1.17 to 1.64 in 2014 and from 1.17 to 1.67 in 2015. For the imported steel bars, the mean ultimate stress from tests ranges from 1.16 to 1.46 kN/mm^2 in 2014 and from 1.18 to 1.49 in 2015.

3.1.3 Chemical properties

The chemical analysis on the tested steel bars in 2014 shows that the carbon content ranges from 0.108 to 0,205 and from 0,120 to 0.200 for locally produced and imported steel bars respectively. The same trend was indicated in 2015 tests where the carbon content ranges from 0.110 to 0.207 and from 0.110 to 0.210 for locally produced and imported steel bars respectively.

The phosphorus and Sulfur contents of both locally produced and imported steel bars were below the permissible value in both years when compare with standards as indicated in Table 6.

Table 7: Summary of Characteristic Strengths with Code Values

S/N	Bar I.D	Measured Diameter (mm)	Nominal Size (mm)	Characteristic Strength (kN/mm²) 2013	Characteristic Strength (kN/mm²) 2014	Characteristic Strength (kN/mm²) 2015	Code Requirement BS4449-1997	REMARKS
1	LC 1		10	356	368	373	460	All below Code
			12	440	449	412	460	All below Code
			16	464	469	382	460	All below Code
			20	422	454	422	460	All below Code
2	LC 2		10	282	358	371	460	All below Code
			12	293	337	382	460	All below Code
			16	459	459	490	460	1 below code
			20	475	446	475	460	1 below code
3	LC 3		10	296	447	462	460	All below Code
			12	512	504	512	460	All Above Code
			16	516	536	566	460	All Above Code
			20	543	527	543	460	All Above Code
4	LC 4		10	282	359	358	460	All below Code
			12	293	372	346	460	All below Code
			16	428	422	428	460	All below Code
			20	446	446	448	460	All below Code
5	LC 5		10	440	440	440	460	All below Code
			12	431	431	431	460	All below Code
			16	447	447	381	460	All below Code
			20	456	456	456	460	All below Code
6	LC 6		10		361	373	460	All below Code
			12		395	386	460	All below Code
			16		413	428	460	All below Code
			20		449	456	460	All below Code
7	LC 7		10		371	358	460	All below Code
			12		393	355	460	All below Code
			16		419	369	460	All below Code
			20		418	410	460	All below Code
8	LC 8		10		375	388	460	All below Code
			12		389	389	460	All below Code
			16		379	429	460	All below Code
			20		396	396	460	All below Code
9	LC 9		10		440	363	460	All below Code
			12		424	371	460	All below Code
			16		446	421	460	All below Code
			20		446	396	460	All below Code
10	IM-1		10		499	487	460	All Above Code
			12		548	515	460	All Above Code
			16		527	600	460	All Above Code
			20		497	557	460	All Above Code
11	IM-2		10		526	566	460	All Above Code
			12		520	555	460	All Above Code
			16		566	550	460	All Above Code
			20		541	596	460	All Above Code
12	IM-3		10		577	526	460	All Above Code
			12		593	549	460	All Above Code
			16		578	549	460	All Above Code
			20		561	526	460	All Above Code

Table 8: Comparison of Elongation values with Code Values							
S/N	**Bar I.D**	**Nominal Size**	**Percentage Elongation 2013**	**Percentage Elongation 2014**	**Percentage Elongation 2015**	**Code Requirement BS4449-1997 (%)**	**REMARKS**
1	**LC 1**	10	26.5	27.7	23.6	12	Above Code Value
		12	28.5	28.5	27.5	12	Above Code Value
		16	24.3	24.3	24.3	12	Above Code Value
		20	22.3	22.3	22.3	12	Above Code Value
2	**LC 2**	10	21.2	21.2	21.2	12	Above Code Value
		12	21.6	21.6	21.6	12	Above Code Value
		16	17.3	17.3	17.3	12	Above Code Value
		20	19.7	19.7	19.7	12	Above Code Value
3	**LC 3**	10	20.0	20.0	20.0	12	Above Code Value
		12	12.3	12.3	12.3	12	Above Code Value
		16	13.5	13.5	13.5	12	Above Code Value
		20	15.7	15.7	15.7	12	Above Code Value
4	**LC 4**	10	11.5	10.7	9.7	12	Below Code Value
		12	11.0	12.1	11.1	12	2 Below Code Value
		16	6.4	11.3	11.3	12	Below Code Value
		20	18.0	10.9	10.9	12	2 Below Code Value
5	**LC 5**	10	18.6	18.6	18.6	12	Above Code Value
		12	18.7	18.7	18.7	12	Above Code Value
		16	19.1	19.1	19.1	12	Above Code Value
		20	18.0	18.0	18.0	12	Above Code Value
6	**LC 6**	10		13.0	20.0	12	Above Code Value
		12		8.7	10.2	12	Below Code Value
		16		16.0	19.5	12	Above Code Value
		20		11.4	17.4	12	1 Below Code Value
7	**LC 7**	10		21.2	21.2	12	Above Code Value
		12		32.8	29,6	12	Above Code Value
		16		32.8	21.2	12	Above Code Value
		20		17.4	17.4	12	Above Code Value
8	**LC 8**	10		16.8	16.8	12	Above Code Value
		12		12.2	12.2	12	Above Code Value
		16		12.6	12.6	12	Above Code Value
		20		14.7	14.7	12	Above Code Value
9	**LC 9**	10		18.6	18.6	12	Above Code Value
		12		11.6	11.6	12	Below Code Value
		16		13.1	13.1	12	Above Code Value
		20		17.6	19.4	12	Above Code Value
10	**IM-1**	10		17.5	17.5	12	Above Code Value
		12		21.5	19.0	12	Above Code Value
		16		21.5	18.4	12	Above Code Value
		20		21.1	18.8	12	Above Code Value
11	**IM-2**	10		16.8	16.8	12	Above Code Value
		12		16.9	16.9	12	Above Code Value
		16		21.4	17.0	12	Above Code Value
		20		18.3	16.0	12	Above Code Value
12	**IM-3**	10		16.3	13.0	12	Above Code Value
		12		18.0	12.0	12	Above Code Value
		16		18.4	13.0	12	Above Code Value
		20		17.5	14.0	12	Above Code Value

Table 9: Comparison of Strain Ratio to BS4449-1997 Min Provision.

S/N	Bar I.D	Nominal Size	Strain Ratio 2013	Strain Ratio 2014	Strain Ratio 2015	BS4449-1997 MIN PROVISIONS	REMARKS
1	LC 1	10	1.28	1.23	1.19	1.05	Above Code Value
		12	1.38	1.35	1.49	1.05	Above Code Value
		16	1.28	1.27	1.26	1.05	Above Code Value
		20	1.32	1.22	1.47	1.05	Above Code Value
2	LC 2	10	1.49	1.18	1.20	1.05	Above Code Value
		12	1.49	1.30	1.17	1.05	Above Code Value
		16	1.35	1.35	1.49	1.05	Above Code Value
		20	1.26	1.34	1.26	1.05	Above Code Value
3	LC 3	10	1.49	1.25	1.23	1.05	Above Code Value
		12	1.25	1.27	1.25	1.05	Above Code Value
		16	1.28	1.24	1.18	1.05	Above Code Value
		20	1.29	1.32	1.29	1.05	Above Code Value
4	LC 4	10	1.49	1.17	1.17	1.05	Above Code Value
		12	1.49	1.18	1.26	1.05	Above Code Value
		16	1.60	1.62	1.60	1.05	Above Code Value
		20	1.27	1.34	1.34	1.05	Above Code Value
5	LC 5	10	1.49	1.49	1.49	1.05	Above Code Value
		12	1.49	1.49	1.49	1.05	Above Code Value
		16	1.32	1.32	1.55	1.05	Above Code Value
		20	1.25	1.25	1.25	1.05	Above Code Value
6	LC 6	10		1.22	1.19	1.05	Above Code Value
		12		1.64	1.67	1.05	Above Code Value
		16		1.19	1.39	1.05	Above Code Value
		20		1.23	1.31	1.05	Above Code Value
7	LC 7	10		1.24	1.17	1.05	Above Code Value
		12		1.18	1.30	1.05	Above Code Value
		16		1.17	1.25	1.05	Above Code Value
		20		1.17	1.21	1.05	Above Code Value
8	LC 8	10		1.40	1.49	1.05	Above Code Value
		12		1.41	1.39	1.05	Above Code Value
		16		1.47	1.39	1.05	Above Code Value
		20		1.42	1.26	1.05	Above Code Value
9	LC 9	10		1.49	1.42	1.05	Above Code Value
		12		1.34	1.46	1.05	Above Code Value
		16		1.24	1.31	1.05	Above Code Value
		20		1.30	1.22	1.05	Above Code Value
10	IM-1	10		1.31	1.49	1.05	Above Code Value
		12		1.36	1.21	1.05	Above Code Value
		16		1.46	1.25	1.05	Above Code Value
		20		1.27	1.25	1.05	Above Code Value
11	IM-2	10		1.19	1.36	1.05	Above Code Value
		12		1.24	1.32	1.05	Above Code Value
		16		1.31	1.29	1.05	Above Code Value
		20		1.24	1.18	1.05	Above Code Value
12	IM-3	10		1.22	1.24	1.05	Above Code Value
		12		1.16	1.26	1.05	Above Code Value
		16		1.18	1.24	1.05	Above Code Value
		20		1.23	1.32	1.05	Above Code Value

3.2 Discussion

3.2.1 Characteristic Strength

Table 7 shows the summary of test results for the characteristic strengths of the steels under study and compared it with code specification. The yield strength results show that only imported steel bars were able to meet characteristic strength requirement as specified by the code, the bulk of the characteristic strength of the of the locally produced steel bars fell below code specifications. This gives serious concern as it is not healthy for structural design.

This is not a healthy development especially for none of the local steel mills to meet code value leaves much to be desired.

3.2.2 Percentage Elongation

The summary of percentage elongation of tested steel bars in comparison with code requirement is as shown in Table 8. The results show that the percentage elongation for most of the locally produced bar samples met the minimum code requirements on elongation, similarly, all of the foreign bars also met the minimum codes requirement value of 12% (BS4449-1997). Though, this indicate that all imported steel bars and majority of the locally produced steel bars are ductile and will give warning signs before failure, the fact that some of the local steel bars have percentage elongation values falling below code requirement implies that some local steel will exhibit brittle behaviour and will fracture without adequate warning.

3.3.3 Strain Hardening Ratio

The strain hardening (ratio of ultimate to yield stress) of the products were calculated using the ultimate and yield stress values and then compared with code value as shown in Table 9. Imported steel bars and most of the locally produced steel bars under study met code requirement in terms of strain hardening ratio. This is an indication of the level of ductility of locally produced steel as well as the imported steel bars. 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 for locally produced bars are mainly scrap metals containing a lot of high carbon steel and the absence of metal refining stage during process of production.

IV. CONCLUSION

From the tests results, it can be seen that while all imported steel met and satisfy all codes requirement, Almost all of the tested locally produced steel failed to satisfy code requirement for characteristic strength. Consequently, their use for structural design with code requirement of 460 N/mm^2 as characteristic strength needs to be given serious consideration. Also, the tendency to have locally produced steel bars behaving as brittle materials is real and will require special attention before use. Efforts should be intensified to improve the quality of steel produced in Lagos and Ogun states of Nigeria as data from this research does not offer comfortable news. It is even strongly suggested that locally produced 10 mm diameter bars are better used only as links in beams and should be avoided as main reinforcement.

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