Comparative Study on the Strength Characteristics of Reinforcement Bars from Local Industries and Imported Sources

Nwakonobi, Theresa Ukamaka[1] and Umar, Suleiman Muhammad[2]

Abstract−This paper is a report of the investigations conducted to compare the strength characteristics of reinforcement bars obtained from industries: Zhong Yang Industry Nigeria Limited (ZYI), Ajaokuta Steel Company limited (ASC) and imported source. Strength properties analyzed include ultimate tensile strength, yield strength, and percentage elongation for 12 mm steel reinforcing bars. The mean values of ultimate tensile strength (UTS) obtained for the 12mm bar are 626.38 N/mm2, 638.36 N/mm2, and 766.29N/mm2 for Zhong Yang Industry Nigeria Limited (ZYI), Ajaokuta Steel Company limited (ASC) and imported (IMP), respectively. These UTS values are all higher than the recommended limit set by BS449 1997, ASTM A706, and Nst65-Mn 1994. The yield strength (YS) values recorded are 443.92 N/mm2 for ZYI, 432.57 N/mm2 for ASC and 656.62N/mm2 for IMP bars. The yield strength value of ZYI bars fall below the recommended limit by BS449 1997 but is higher than that set by ASTM A706 and Nst65-Mn 1994. The yield strength value of ASC bars is also below the BS449 1997 limit but higher than that by ASTM A706 and Nst65-Mn 1994. The yield strength value of IMP is higher than all the set standards. The percentage elongations obtained are 30.64%, 29.40% and 20.81% for ZYI, ASC and IMP, respectively. These elongation values are not within the set standard limits. The analysis of variance (ANOVA) conducted on the generated data indicate significant differences in the mean values of all the strength parameters. The imported bars recorded the highest strength values and least percentage elongation than that from local sources.

Index Terms− Steel bars, reinforcement, comparison, strength, imported, local source, Nigeria.

1 INTRODUCTION

Steel is an alloy, consisting mainly of iron and carbon. Though the use of carbon is most common for the production of steel, other alloying materials such as tungsten, chromium and manganese are also used. The proportions and forms in which these elements are used, affect the properties of the steel that is produced. Alabi and Onyeji [1] attributed high tensile strength values observed with steel products from four indigenous steel industries in Nigeria to higher carbon contents compared with the standards.

The recent incidences of building collapses in various countries of the world including Nigeria have been a source of concern to Engineers and other building experts. Several researchers have carried out studies into past failure incidences and have pointed out causes for these collapses. The results of investigations conducted on buildings that failed in United State of America from 1989 to 2000 were documented [2]. According to several studies also conducted in Nigeria by researchers, various reasons provided for collapse of buildings included: bad design, improper site investigations, foundation failure, faulty construction, unexpected failure modes, intrusion of quacks, use of substandard construction materials and combination of causes [3] [4] [5] [6].

Concrete has emerged as the most common building material in Nigeria and world at large and is best used in conjunction with reinforcing steel for optimal results. In the developing nations such as Nigeria, incidences of building collapse is very frequent and Anthony et al [7] reported that over 95% of the cases of collapse affect reinforced concrete structures, while Akintoye et al [6] noted that 100 percent of the collapsed buildings in Nigeria were built of reinforced concrete. The true behavior of the reinforcing steel adopted in Nigerian construction industries still need to be understood in order to know the true cause of building collapses. Substitution of inferior steel to that specified in reinforcing concrete has been reported as one of the major causes of structural failure [8]. It is also reported that steel reinforcing bars available in the Nigeria's construction Industry are obtained from both local and foreign sources. The local sources [6] are mainly from both the indigenous major plants and mini mills located in various parts of the country. Others are those imported for specific uses by multinational Companies for specific projects [9]. These steels however are sometimes used in buildings without being subjected to any test to confirm the adequacy and compliance with the Engineering standards.

[1]Nwakonobi Theresa Ukamaka is an Associate Professor in the Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi, Benue State, Nigeria. She is the corresponding author,
E-mail: napeth66@yahoo.com
[2]Umar, Suleiman Muhammad is a senior staff at Ajaokute Steel Company Nigeria Limited
E-mail:sulei_umar@yahoo.com

This work investigated the strength characteristics of 12 mm diameter size reinforcement bars from two indigenous industries and imported source to check the adequacy with set standards.

2 MATERIALS AND METHODS

2.1 Materials

The materials used in this study were 12mm diameter reinforcement steel bars. The 12 mm diameter ribbed steel rods were obtained from three sources namely: Ajaokuta Steel Company Limited, Zhong Yang Industry Nigeria Limited which are local producers of steel bars and an imported one obtained from the open market. Seven (7) specimens of each were collected. The specimens' mechanical properties which include yield strength, ultimate tensile strength and percentage elongation were investigated.

2.2 Sample preparation

All the 12mm reinforcement bars which were free from any apparent physical defects were neatly cut to the dimension for the various tests.

2.3 Testing Procedure

The Steel bar samples were turned into standard configuration using a lathe machine. The Steel rods were cut to required length of about 400 mm, applying a coolant to avoid generation of excessive heat. Each sample specimen was subjected to test to measure the Yield Load (YL) and Maximum Load (ML) using an Instron Universal Testing Machine at the Central Laboratory of Ajaokuta Steel Company Limited, Kogi State, Nigeria. The initial (Lo) and final length (Lf) of each specimen sample were recorded for the determination of the percentage elongation.

Tensile test results were analyzed using the following equations [10]:

$$UTS = \frac{\text{Maximum load (ML)}}{\text{Norminal area (A)}} \quad (1)$$

Where, UTS = Ultimate Tensile Stress (N/mm²)

$$YS = \frac{\text{Yield load (YL)}}{\text{Norminal area (A)}} \quad (2)$$

Where YS= Yielding stress, N/mm²

$$EL = \frac{Lf - Lo}{Lo} \times 100 \quad (3)$$

Where; EL = percentage elongation
Lf = final length
Lo = Original length

2.4 Experimental Design

The experimental design used was Complete Randomized Design (CRD) to study one (1) treatment effects on the 12 mm diameter reinforcement bars from Zhong Yang Industry Nigeria Limited, Ajaokuta Steel Company Limited and a foreign source. Seven (7) replicate samples were prepared for each test conducted on each sample source. Therefore, for the three tests and three sample sources a total of sixty-three (63) specimen samples were used. Analysis of Variance (ANOVA) was carried out to check the differences in the treatment means using SPSS version 22.0.

3 RESULTS AND DISCUSSION

The results obtained for the strength parameters of the 12 mm ribbed steel reinforcement bars from various sources are as presented in Table 1.

Table 2 presents the ANOVA results for the measured bar strength properties using CRD. The summary of the comparison of means to ascertain significance of difference of means based on the ANOVA results of Table 2 at 5% level according to Duncan's New Multiple Range Test (DNMRT) are shown in Table 3. It also shows alongside the standards, BS 4449:1997, ASTM A706 and Nst 65-Mn: 1994 against which the tested samples are compared.

Table 1 Strength characteristics of 12 mm ribbed steel reinforcement bars

Bar source	Ultimate Tensile Strength (N/mm²)	Yield Strength (N/mm²)	Elongation %
ZYI_1	624.18	445.02	31.17
ZYI_2	631.89	441.16	29.33
ZYI_3	624.18	445.02	31.17
ZYI_4	624.18	445.02	31.17
ZYI_5	624.18	445.02	31.17
ZYI_6	631.89	441.16	29.33
ZYI_7	624.18	445.02	31.17
ASC_1	645.65	431.53	28.50
ASC_2	645.88	438.71	29.00
ASC_3	622.84	428.45	30.33
ASC_4	639.79	430.59	30.17
ASC_5	645.88	438.71	29.00
ASC_6	622.84	428.45	30.33
ASC_7	645.65	431.53	28.50
IMP_1	761.65	651.97	19.00
IMP_2	769.77	660.10	22.17
IMP_3	769.77	660.10	22.17
IMP_4	769.77	660.10	22.17
IMP_5	761.65	651.97	19.00
IMP_6	769.77	660.10	22.17
IMP_7	761.65	651.97	19.00

Note: AYI = Zhong Yang Industry Nigeria Limited; ASC = Ajaokuta Steel Company Limited; IMP = Imported

Table 2 Summary of results of the Analysis of Variance (ANOVA) for the strength parameters

Strength parameters	Source of Variation	Df	SS	MS	F	Sig.
Ultimate Tensile Strength	Company	2	84194.166	42097.083	840.890*	0.000
	Error	18	901.125	50.063		
	Total	20	85095.292			
Yield Strength	Company	2	222990.290	111495.145	8026.827*	0.000
	Error	18	250.026	13.890		
	Total	20	223240.316			
% Elongation	Company	2	401.473	200.737	137.251*	0.000
	Error	18	26.326	1.463		
	Total	20	427.799			

Note: SS = sum of squares, MS = mean square, Df = degree of freedom; F = Fisher test, * = significant (P≤0.05)

Table 3 Comparison of difference of means of strength characteristics of reinforcement bars from various sources and the mean values with set standards

Strength Properties	ZYI	ASC	Imported	Standards		
				BS4449 1997	ASTM A706	Nst65-Mn 1994
Yield Strength(YS) N/mm^2	443.92^a (1.88)	432.57^b (4.35)	656.62^c (4.39)	460	415	420
Ultimate Tensile Strength(UTS), N/mm^2	626.38^a (3.76)	638.36^b (4.34)	766.29^c (10.83)	600	580	600
Elongation (%)	30.64^a (0.90)	29.40^b (1.69)	20.81^c (0.84)	12	14	10

Numbers in parenthesis indicates the standard deviation. Different letters (super script) along the same row indicate significant difference according to Duncan's New Multiple Range Test (P≤0.05)

The yield strength values obtained with the samples from the two local industries are 443.92N/mm^2 and 432.57N/mm^2 for ZY and ASC, respectively. These values are below the standard limit of 460N/mm^2 set by BS449; 1997 but above limits of 415N/mm^2 and 420 N/mm^2 set by ASTM A706 and Nst65-MN 1994, respectively. Anthony et al [7] reported that about 42% of 433 samples of 12mm reinforcement bars tested from local sites in ten (10) local Government Areas of Lagos State failed to meet the BS code prescription of 460N/mm^2. Ejeh et al (2012) also reported of some locally sampled steel bars failing to meet requirements of BS4449:1997 in terms of YS.

The results of Table 2 show that the source of procurement of reinforcement bars has significant effect (P≤0.05) on the Yield strength values. The separation of the property means and comparisons of the steel bars from three sources indicate that imported bar is significantly highest (P≤0.05) in yield strength, 656.62 N/mm^2, followed by that of **ZYI,** 443.92N/mm^2. Bars from **ASCL** attained the lowest value of yield strength, 432.57N/mm^2 and this is statistically different from that of ZYI (P≤0.05).

The ultimate tensile strength of all the steel product samples tested were higher than the recommended limit of 600N/mm^2 by BS449, 1997 and Nst65-Mn 1994, limit of 580N/mm^2 by ASTM A706. The imported reinforcement bar samples recorded the highest UTS Mean strength value of 766.29N/mm^2, followed by that of ASC, 638.36N/mm^2 and the least is 626.38N/mm^2 for ZY bars (Table 3). The ANOVA results in Table 2 indicate that Company source has significant effect on the ultimate tensile strength of the steel bars while the comparisons of the mean values in Table 3 show that the UTS value, 766.29N/mm^2 of the imported bars remain significantly higher (P≤0.05) than others produced from the local companies. The one from ZYI was significantly lower (P≤0. 05) than that of ASC.

The strength values of 12mm reinforcing bars imported into the country, Nigeria conform to the standards in terms of yield strength and ultimate tensile strength. This similar finding has been reported [1] [11].

This may be an indication that the imported bars contain more carbon than the locally produced bars as high percent carbon contributes to high strength in steel products [1].

The mean values of the percentage elongation at fracture for all the tested steel products are 30.64% for ZY; 29.40% for ASC and 20.81% for IMP. These values surpassed the 12 % limit recommended by BS 449, 10% by ASTM A706 and 14% by Nst65-Mn for reinforcing steel bars. The percentage elongation was also significantly affected by the products sources (Table 2). The comparison in Table 3 indicates that the differences between the percentage elongation of imported and that of ZYI and ASC are statistically significant. IMP recorded the least value, 20.81%, followed by ASC, 29.40% and ZYI remain significantly the highest, 30.64% at (P≤0.05). The high percentage elongation values

from the tested samples, especially ZYI and ASC, indicate high ductility. High ductility is not a desirable property in reinforcement bar as it makes it susceptible to bending. These materials will behave more as mild steel rather than high strength steel desired for reinforcement [12]. The high percentage elongation may be attributed to the absence of some trace elements such as Manganese in the tested samples [13].

4 CONCLUSION

It is well understood from this study that product sources affect significantly the strength characteristics of 12 mm steel reinforcing bars. All the samples from local and foreign sources met the recommended limits of the set standards in terms of ultimate tensile strength. The yield strength values of steel bars from the two local sources only met the recommended limit by ASTM A706 and NSt-Mn; 1994 but failed to meet that set by BS4449; 1997. The imported steel bars have the yield strength higher than the set standards. The percentage elongation of all the product samples surpassed all the set standards. The Manganese contents of the steel product, therefore, need to be increased to reduce the percentage elongation in 12mm reinforcement bars.

REFERENCES

[1] A. G. F. Alabi and L. I. Onyeji, "Analysis and Comparative Assessment of Locally Produced Reinforcing Steel Bars for Structural Purposes," *Journal of Research Information in Civil Engineering,* Vol.7, no. 2, pp. 49-60, 2010.

[2] W. Kumalasari and C. H. Fabian, "Study of Recent Building Failures in United States," *Journal of Performance of Constructed Facilities ASCE*. Vol. 17, no. 3, pp. 144–150, 2003

[3] S. O. Folagbade, "Case Studies of building collapse in Nigeria," D.R. Ogunseemi, eds., *proc. of Nigerian Institute of Building Conf. held at Ondo State, Nigeria on Building Collapse: Causes, Prevention, and Remedies,* pp. 110-121, 2002

[4] P. N. Opara, "Building Failures and Collapses: A Case Study of Port Harcourt,"
Nigeria Journal of Technology and Education in Nigeria Vol. 12, no. 1, pp. 35-39, 2007

[5] B. C. Chukwudi and J. O. Onyeka, "Assessment of the quality of a Steel Rods Available in Onitsha Market: In View of the Role of Poor Quality Rods in Building Failures in Nigeria," *The Pacific Journal of Science and Technology,* pp. 73-78, 2010

[6] O. Akintoye, F. Chris, and D. Oladimeji, "Effects of Source of Reinforcement on Microstructure and Strength Characteristics of Reinforced Concrete Beams," *Civil and Environmental Research*, Vol. 3, no. 9, pp. 26-35. 2013

[7] N. E. Anthony, M. O. Oluwarotimi, and J. Opeyemi, "Experimental Investigation of Yield Strengths of Steel Reinforcing Bars Used in Nigerian Concrete Structures," *International Journal of Scientific and Engineering Research*, Vol. 5, Iss. 4, pp. 76-83, 2014.

[8] J. B. Calvert, "Building Collapse, why the World Trade Center towers fell so rapidly" *Engineering and Technology Civil and Structural Engineering,* September, 2001

[9] S. P. Ejeh and M.U. Jibrin, "Tensile Tests on Reinforcing Steel Bars in the Nigerian Construction Industry," *IOSR Journal of Mechanical and Civil Engineering* Volume 4, Iss. 2, pp. 06-12, 2012

[10] J. O. Osarenmwinda and E. C. Amuchi, "Quality Assessment of Commercially Available Reinforced Steel Rods in Nigerian Markets," *Journal of Trends in Engineering and Applied Sciences,* Vol. 4, Iss. 4, pp. 462-565, 2013

[11] J. J. Moore, "Chemical Metallurgy: Metal, Melting and Recycling," Butterworth Heineman, Jordan Hill, Oxford, OX2 8D, Second Edition, pp. 310-328, 1997.

[12] Ponle, E. Olatunde, O. and Fatukasi, S. O. (2014). Investigation on the Chemical Analysis of Reinforcing Steel Rods Produced from Recycled Scrap. *International Journal of Scientific & Engineering Research,* Volume 5, Issue 4,

[13] J. J. Moore, "Chemical Metallurgy of Metal, Meltingand Recycling. Butterworth Heineman, Jordan Hill, Oxford, OX2 8D, Second Edition, pp. 310-328 1997

ASTM A706, American Standard for Testing Materials: Grade reinforcing bars, "Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement," 1996

BS 4449:1997, "*British Standard Institutions*, London," Carbon Steel Bars for the Reinforcement of Concrete, 1997

Nst 65-Mn: 1994, "Nigerian Standard," Raw Materials and Specifications for Federal Government Steel Companies, 1st Edition, 1994

.