EUROPEAN JOURNAL OF MATERIALS SCIENCE AND ENGINEERING
Volume 9, Issue 4, 2024: 295-309 | www.ejmse.ro | ISSN: 2537-4338

DOI: 10.36868/ejmse.2024.09.04.295

COMPARATIVE REVIEW OF PROPERTIES OF STEELS USED IN NIGERIA TO FORESTALL BUILDING COLLAPSES

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Abstract

This research analyzed the mechanical properties of reinforcing steel bars used in Nigeria and compared them to four different standards (AISI 1018, ASTM A706, BS4449, and NST-65-Mn). This was done as a result of frequent building collapses in Nigeria, which has revealed the knowledge gap between what the designers expect and the true mechanical properties of the products they typically receive from manufacturers. Related literature from published articles was collected and analyzed based on the mechanical properties of locally produced and imported steels. Results showed that the tensile strength, yield strength, hardness, percentage elongation, and percentage carbon composition of most products met and exceeded the requirements of AISI 1018, ASTM A706, BS4449, and Nst-65-Mn when compared, while some fell below what these standards required. Federated Steel Mills Limited, Ogun State, has the highest tensile stress value at 799.49 MPa, followed by Real Steel Reinforcing Pty Limited, Auckland, New Zealand, at 726.34 MPa, and Landcraft Industries Limited, Ikorudu, Lagos, at 708.3 MPa, according to a yield and tensile strengths analysis of 16 mm steel bars produced locally and imported. The lowest tensile strengths ever reported are 410 MPa for African Steel Nig. Limited, Ikorodu, Lagos, and 538.51 MPa for steel imported from Brazil. It is hoped that the data from this study will bridge the knowledge gap between the team players in this field, thus preventing catastrophe.

Keywords: *properties of steel, comparative review, Nigeria, building collapse, concrete reinforcement.*

Introduction

The mechanical properties of an engineering material determine its behavior when subjected to mechanical stresses. These characteristics include hardness, ductility, elastic modulus, and various strength measurements. Because a product's ability to withstand deformation under the forces it experiences in use determines its functionality and performance, mechanical characteristics are crucial in design. The goal of design is often to allow the product and its constituent parts to endure these forces without experiencing a major alteration in shape. Properties like yield strength and elastic modulus affect this capability. The goal in production is precisely the contrary. Here, the material must be subjected to stresses greater than its yield strength in order to change shape. The success of mechanical operations like forming and machining is attributed to the development of forces greater than the material's resistance to deformation. Consequently, the following conundrum exists: Desired mechanical properties for the designer, like great strength, typically complicate the product's manufacturing process. It is

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beneficial for the designer to understand the manufacturing perspective, and for the manufacturing engineer to value the design viewpoint [1].

Steel rods are mostly employed in the manufacturing and fabrication sectors for building projects. Therefore, it is thought that in order for steel to be used as effectively and optimally as possible, its mechanical properties must match the quality requirements and accepted standards of practice that serve as the foundation for designs for which it is applied [2]. However, catastrophe will be inevitable once there is a knowledge gap between the manufacturers and designers viewpoints about a product.

Numerous materials, including fiber-reinforced polymers, bamboo, plastic filament, ceramic composites, and steel rods, can be used to reinforce concrete [3], [4]. But in whichever case, if an engineering project is to be suitable for its intended purpose, an understanding of material mechanical characteristics is necessary for its design, manufacturing, and application. And a material's capacity to function well under service conditions reveals a number of its mechanical qualities [2].

In Nigeria, inland rolling mills generate a portion of the structurally necessary steel reinforcement bars, with private entrepreneurs sourcing the remaining supply through imports [2]. It has been determined that one of the reasons for building collapses and failures is the use of subpar and inferior steel rods [5]. This research reviews the mechanical properties of steel materials used in the reinforcing of concrete structures in Nigeria to compare the mechanical properties values reviewed from locally made steels with those of foreign ones to see if they meet global concrete reinforcement steel standards suitable for house building applications. This will enable engineers, builders, designers, manufacturers, and marketers to make well-informed decisions regarding the use of steel rods in Nigeria and to prevent the use of subpar and inferior steel rods that could result in engineering failure and building collapses. It is hoped that the data from this study will not only add to the information already available to the players in this field but will bridge any knowledge gap between the manufacturers and designers on constructional materials properties to forestall catastrophe.

How steels are made in Nigeria and the certification bodies

In the past, Nigerian mill design such as open mill, staggered open mill, semi-continuous mill, completely continuous mill, and fully continuous multi-line arrangement were used to roll wire rod and merchant steel bars effectively. Currently, completely continuous or fully continuous multi-line configurations are the only options available to many Nigerian steel rolling mills [6]. However, unless there is proof of a chemical composition impairment, selecting any layout approach for the fabrication of steel bars has no negative impact on output. If local production of steel bars satisfies the requirements set forth for its acceptability—namely, that it conforms to both local and international standards—there is no need to look elsewhere for steel bars. Kareem 2009 [6], asserts that NIS (1992) contains NIS specifications for steel bars based on mechanical properties, dimensional requirements, ladle analysis, and deformation criteria for both hot-rolled and cold-rolled bars. There are studies available that confirm the quality of steel bars made in Nigeria based on specific characteristics, like heat treatment (Gery et al., 2004; and Inegbenebor, 2004) as put forth by [6]. These investigations show that Nigerian steel bars are capable of withstanding a significant amount of heat and support the use of Nigerian steel bars in high-temperature applications [6].

The Nigerian steel businesses Delta Steel Company (DSC), Ajaokuta Steel Complex (ASC), and the inland steel rolling mills at Osogbo, Jos, Katsina, etc. are among those whose output steel bars are monitored by the Industrial Standards (NIS) that was formed. In addition to the Nigeria Industrial Standard (NIS) on steel manufacturing, the Nigeria Standards Organization (SON) also conducts monitoring. Tensile strength and chemical composition analyses are the basis for both monitoring programs [6].

Problems of differences and assumptions of properties are the major cause of structural failures

Nigeria's inland rolling mills generate a significant portion of the steel reinforcing bar required for structural concrete, but imports supply the remaining portion. Most private business owners import steel products, and there's seldom a guarantee on the quality of these imports. When it comes to the structural qualities of steel used in concrete reinforcement, Nigerian design practices modify British Standard specifications while taking into account the data on bar characteristics supplied by regional rolling mills that produce steel bars. For instance, high-yield ribbed bars have a minimum assured yield stress of 420 N/mm^2, a tensile strength of 500 N/mm^2, and a percentage elongation of 10%, according to the information provided by the local mills. As a result, the typical value for the yield strength of high-yield ribbed bars in design is 420 N/mm^2 [7].

There will inevitably be differences between the strengths of steel assumed in design and those used for actual construction if tests are not performed on every batch of imported steel delivered on the construction site. This is because the reinforcement steel used in Nigeria is neither always of British origin nor necessarily produced by the nation's rolling mills. This is due to the fact that Nigerian building practices reveal that the majority of steel bars sent to a particular site are made by various suppliers, frequently lacking sufficient and trustworthy information on their structural characteristics. Members of the International Organization for Standardization (ISO) that export steel often marks their products in a recognized way, and each length of bar bears a recognizable form identifying the producer countries. However, bar retailers import steel from both non-member and ISO member nations, and frequently, steel offered in the neighborhood bar market lacks information regarding the manufacturer nations or the steel's strengths [7].

Whereas information on the producing mills and the structural characteristics of the product may be present in the individual batches of steel bars supplied by the local rolling mills, this information is not available as markings on the bodies of individual bars. Furthermore, a lot of building sites buy their supplies as single bars in bulk from the open market rather than directly from the mills. As a result, some steel bars are placed at construction sites without any trustworthy information regarding the mills that produced them or their structural condition. As a result, it is challenging to distinguish visually between bars made locally and bars imported from nations that are not members of the ISO [7].

(a) (b)

Fig. 1. Sample images of building collapse caused by different variables, (a) building collapse in Federal Capital Territory, Abuja [8], and (b) building collapse in Ondo State as a result of substandard materials [9]

Steel rebar

Usually, a reinforced concrete structure is made up of both reinforcing bars and concrete. However, concrete itself is made up of cement, aggregate (sand, rock, or gravel), and water. The reinforced concrete construction is primarily designed to handle induced forces. This is because concrete on its own is known to be good at compression but extremely weak at tension. Hence, to make up for this concrete weakness, steel reinforcing rods with higher tensile strength are typically used. The chemical composition of a steel reinforcing rod can have a significant impact on its quality [10][11].

Reinforcing bar, sometimes referred to as "rebar," comes in form of wires, mesh, or bars and is used to reinforce concrete under tension. To put it in a more humane perspective, rebar can be thought of as a component of a building's skeletal structure. Concrete and rebar work together to strengthen a structure's resistance to tensile stresses and extend its useful life, which prevents sudden structural collapses. Humans could not securely cross wide stretches of water or build structures that reached high into the sky without rebar. But there is a significant amount of embodied carbon produced during the production and delivery of conventional rebar. Fortunately, new reinforcement options are becoming more widely available, and the steel sector is working hard to promote more environmentally friendly construction [12][13].

Steel has historically been used as reinforcement. Rebar made of carbon steel is a common "black" bar found on many types of construction sites. Although it corrodes readily, its great tensile strength makes it an unsuitable material for matrices where moisture exposure is likely. The requirements for lengths and coils of different reinforcements are covered by ASTM A615M-09, Standard Specification for Deformed and Plain-Carbon Steel Bars for Concrete Reinforcement [12].

Standard steel rebar covered with a thin layer of epoxy is known as epoxy-coated rebar. Although the epoxy coating itself is sensitive and easily chips during the shipment or installation, it provides better resistance to corrosion. This may make the impacted areas more prone to corrosion. The Standard Specification for Epoxy-Coated Steel Reinforcing Bars, ASTM A775M-19, contains guidelines for rebar with protective epoxy coatings [12].

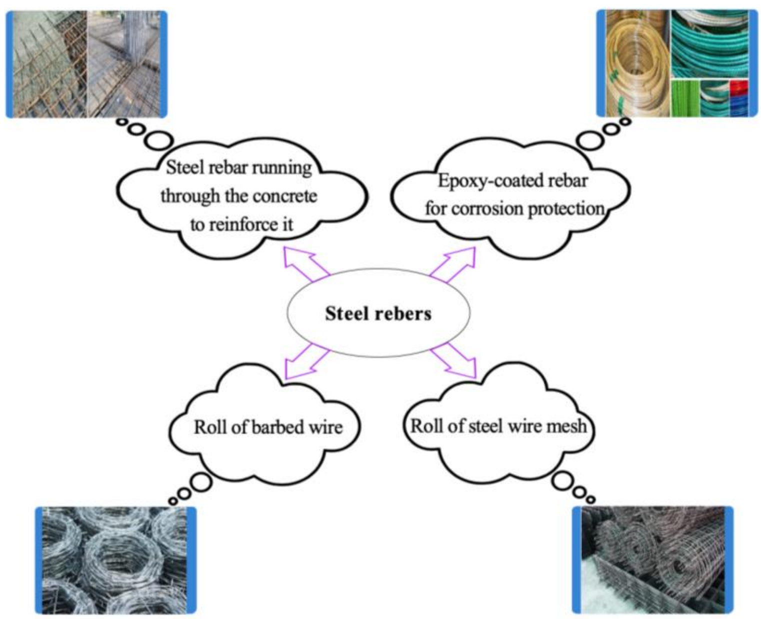

Fig. 2. Forms of steel rebars for concrete reinforcement

Materials and Methodology of Research

In order to achieve the purpose of the investigation, the literature of published articles that worked on the analysis of the properties of locally produced and imported steels was collected as raw materials through the internet. Data were assembled in Table 1 and analyzed to provide insights into the mechanical properties of steel so far used for building in Nigeria, and possible causes of building collapses were traced.

Table 1. Mechanical Properties of local and imported Steels used for House Building Application in Nigeria

Producer/sample denotation	Carbon (%. wt.)	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Hardness	Ref.
Diameter (5 mm)						
Osogbo steel rolling company, Osun State (ST66-2)	0.24	448.06	677.19	21.11	-	[6]
Osogbo steel rolling company, Osun State (ST44-2)	0.17	317.38	485.40	27.24	-	[6]
Diameter (10 mm)						
Katsina Steel Rolling Mills Ltd., Katsina State	0.35	324.5	473.7	22.77	186.3 HV	[14]
Sharada Steel and Investment Ltd., Ikeja, Lagos	0.41	441.1	621.6	16.04	247.3 HV	[14]
Dawanau rolling mills, Kano	0.311	-	573	-	256.0 HBN	[15]
Ajaokuta Steel Company Limited, Kogi state	0.339	-	576	-	152.0 HBN	[15]
African foundries limited, Ogijo, Ogun	0.1480	551.80	682.63	13.609	-	[16]
Pulkit alloy and steel limited, Ikorodu, Lagos	0.2260	450.67	644.44	15.707	-	[16]
Phoenix steel mills, Ikorodu, Lagos	0.1910	437.21	574.26	15.919	-	[16]
Real steel reinforcing pty Limited, Auckland, New Zealan	0.2320	461.80	669.17	13.415	-	[16]
Imported steel, China	-	459	778	21.5	226 BHN	[2]
Diameter (12 mm)						
Sun Flag Nig. Limited, Ikorodu, Lagos	0.53	400	692.73	17	47.87 HRC	[3]
Unique Steel Industries Ltd, Lekki, Lagos State	0.398	450	651.88	27.5	44.27 HRC	[3]
Nigerian-Spanish Engineering Ltd, Kano	0.393	300	610.79	27.5	47.27 HRC	[3]
African Steel Nig. Limited, Ikorodu, Lagos State	0.483	340	660.17	25	45.53 HRC	[3]
Steel rolling mill, Osun State (A12)	0.259	405.14	582.44	31.42	18.04 HRC	[4]
Delta Steel Company, Warri, Delta State	0.32	424.58	649.35	25	26.31 HRC	[17]
Phoenix steel mills, Ikorodu, Lagos	0.1930	444.61	545.28	15.437	-	[16]

Producer/sample denotation	Carbon (%. wt.)	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Hardness	Ref.
Pulkit alloy and steel limited, Ikorodu, Lagos	0.2200	554.68	657.10	11.690	-	[16]
African foundries limited, Ogijo, Ogun State	0.0956	709.10	709.39	11.016	-	[16]
Dawanau rolling mills, Kano	0.313	-	577	-	258.7 BHN	[15]
Ajaokuta Steel Company Limited, Kogi State	0.335	-	580	-	211.9 HBN	[15]
Imported steel, China	-	469	738	20	227 BHN	[2]
Real steel reinforcing pty Limited, Auckland, New Zealan	0.2590	472.61	655.00	13.070	-	[16]
Diameter (16 mm)						
Steel rolling mill, Osun State (A16)	0.329	389.12	591.01	27.95	18.21 HRC	[4]
Universal Steel Limited, Ikeja, Lagos	-	418	590	28.6	43 HRC	[18]
African Steel Nig. Limited, Ikorodu, Lagos	-	380	410	19.6	56 HRC	[18]
Phoenix steel mills, Ikorodu, Lagos	0.0818	403.44	603.84	17.300	-	[16]
Pulkit alloy and steel limited, Ikorodu, Lagos	0.1880	516.45	677.16	14.710	-	[16]
African foundries limited, Ogijo, Ogun State	0.1740	520.28	672.12	14.340	-	[16]
Dawanau rolling mills, Kano	0.315	-	612	-	261.1 HBN	[15]
Ajaokuta Steel Company Limited, Kogi state	0.338	-	612	-	219.6 HBN	[15]
Tiger TMT iron rods, Lekki, Lagos State	0.488	446.05	631	27.83	214.1 BHN	[19]
Federated Steel Mills Limited, Ogun State	0.266	640	799.49	29.29	126.3 HV	[20]
Landcraft Industries Limited, Ikorudu, Lagos	0.172	520	708.30	25.64	190 HV	[20]
Real steel reinforcing pty Limited, Auckland, New Zealan	0.2220	517.67	726.34	13.950	-	[16]
Ukraine	0.195	420	544.81	25.64	130 HV	[20]
Brazil	0.114	425	538.51	25.04	128 HV	[20]
Nst-65-Mn	0.350	500	550	12	-	[4]
BS4449	0.250	460	600	12	13.48 HRC	[17]
ASTM A706	0.300	415	550	14	23.85 HRC	[17]
AISI 1018	0.2	370	440	15	131 HV	[21]

Results and Discussion

Fig. 3 shows that there are disparities between the percentage carbon compositions. Sharada Steel and Investment Ltd., Ikeja, Lagos has 0.41% of carbon which is the highest, followed by Katsina Steel Rolling Mills Ltd., Katsina State with 0.35% of carbon, and Ajaokuta Steel Company Limited, Kogi state with 0.339% of carbon, in that order. These values are against the advice by AISI 1018, ASTM A706, and BS4449 especially. Phoenix steel mills, Ikorodu, Lagos with 0.191% of carbon and African foundries limited, Ogijo, Ogun with 0.148% of carbon are largely lesser than what is acceptable by all standards.

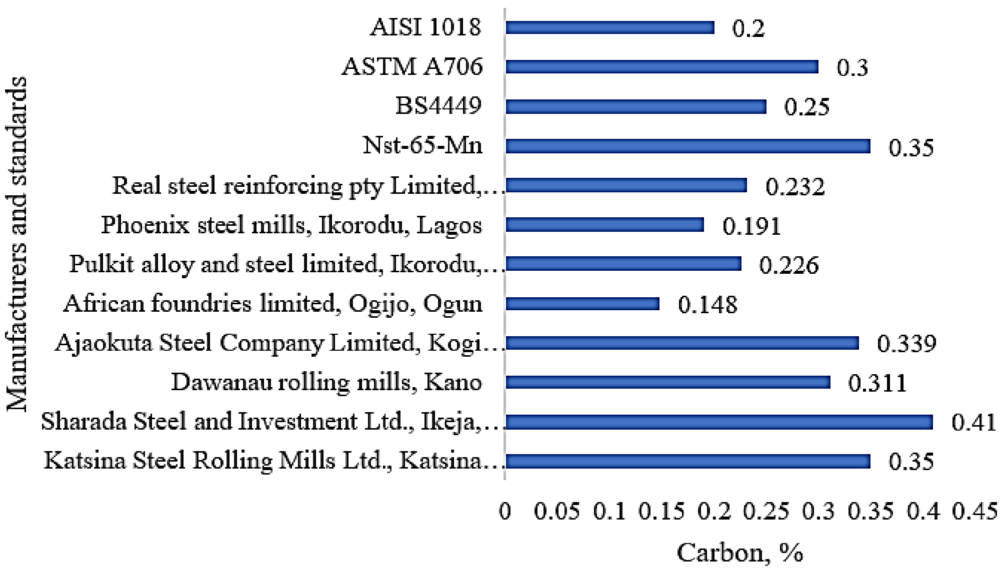

Fig. 3. Carbon content of 10 mm steel bars compared with one another and some standards

Carbon is very principal in enhancing the mechanical properties of steel and anything lesser what is recommended will drastically affect the strength of the steel [17]. This could render the material unemployable for concrete reinforcement.

Fig. 4 and 5 show the typical 12 and 16 mm steel bars mostly adopted and used for concrete reinforcement purposes in Nigeria, most especially within all local government areas in Lagos State, which have witnessed so many cases of building collapse in Nigeria [22]. The maximum percentage carbon composition in Fig. 4 could be seen on samples from manufacturers such as Sun Flag Nig. Limited, Ikorodu, Lagos, African Steel Nig. Limited, Ikorodu, Lagos State, Unique Steel Industries Ltd., Lekki, Lagos State, Nigerian-Spanish Engineering Ltd., and Kano in that descending order, with all having a higher percentage carbon composition than every recognized standard they are compared with. Those with very low carbon percent compositions of 0.0956% and 0.193 are African foundries limited, Ogijo, Ogun State, and Phoenix Steel Mills, Ikorodu, Lagos, as indicated, respectively. Extremely low carbon percent composition will render the material too soft and unacceptable to be used as a reinforcement enhancer for concrete beams.

Samples from every manufacturer have mechanical characteristics that meet all requirements, Fig. 6 shows. Thus, in order to prevent a significant decline in the mechanical properties of the steel, other remaining components like manganese, copper, etc., must be kept to a very low level [17]. On the other hand, it indicates that every product is appropriate for structural uses.

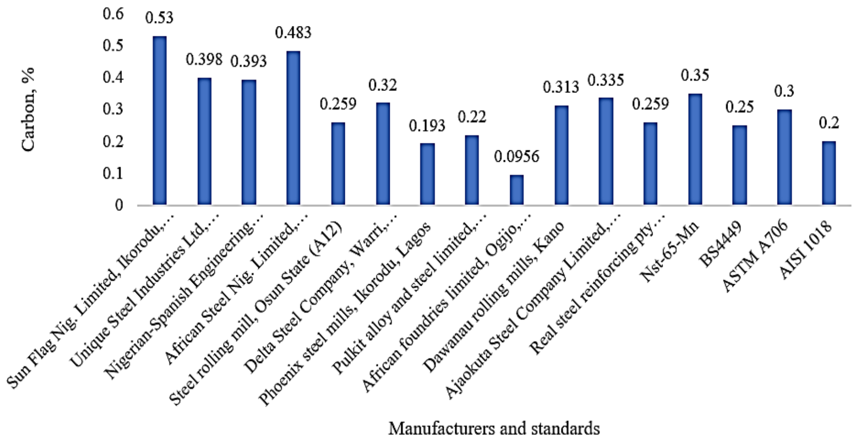

Fig. 4. Carbon content of 12 mm steel bars compared with one another and some standards

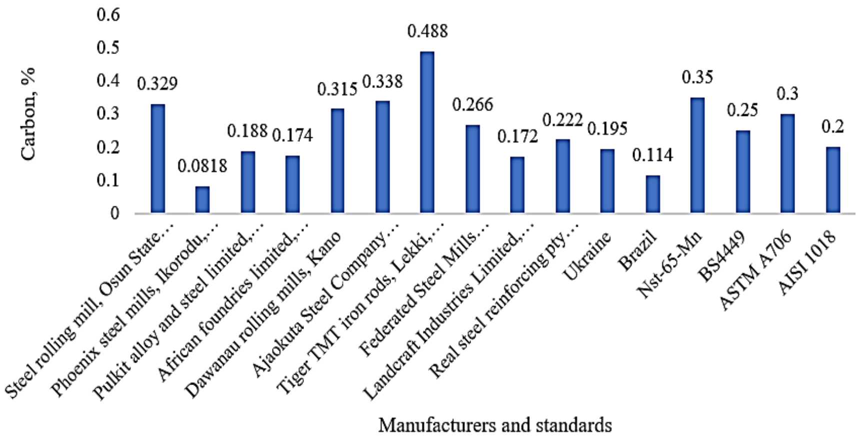

Fig. 5. Carbon content of 16 mm steel bars compared with one another and some standards

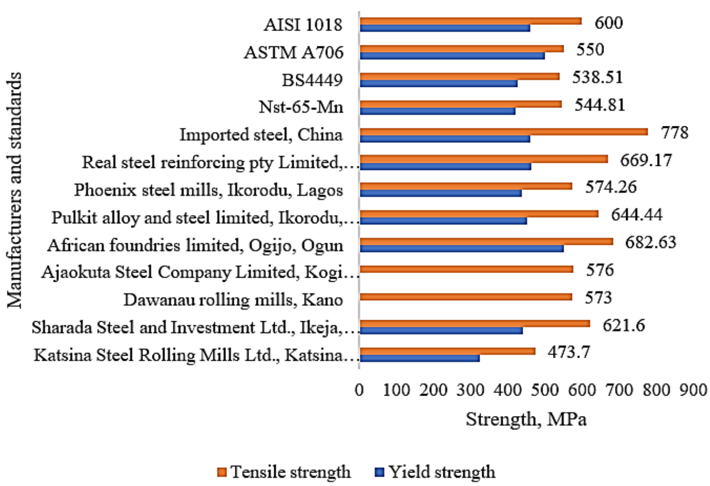

Fig. 6. Tensile strength of 10 mm steel bars compared with one another and some standards

The 12 mm reinforcing steel bars from all manufacturers have higher tensile strength compared to all standards as shown in Fig. 7. Tensile strength is the maximum load a material can withstand before fracture [1], or its load carrying capacity. The AISI 1018 is 440 MPa, BS4449 is 600 MPa, Nts-65-Mn is 550 MPa, and ASTM A706 is 550 MPa, respectively.

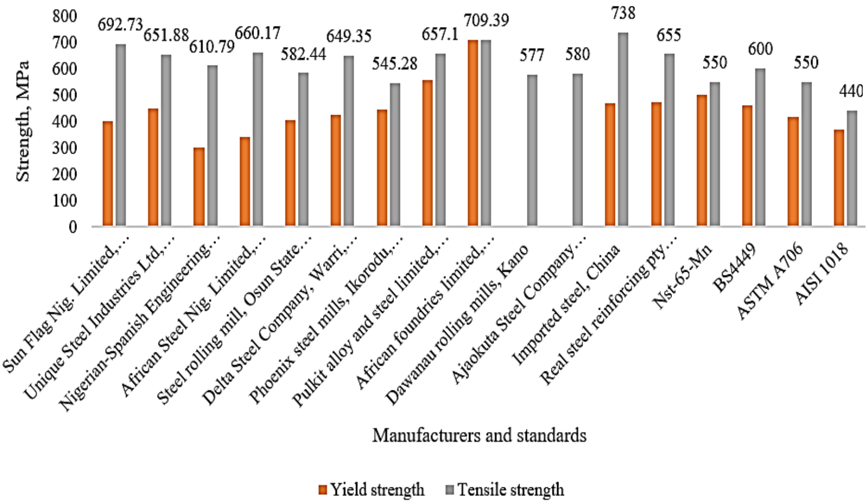

Fig. 7. Tensile strength of 12 mm steel bars compared with one another and some standards

The yield and tensile strengths analysis as shown on Fig. 8 for 16 mm steel bars produced locally and imported pointed that Federated Steel Mills Limited, Ogun State has the highest tensile stress value of 799.49 MPa, followed by Real steel reinforcing pty Limited, Auckland, New Zealand with 726.34 MPa, and Landcraft Industries Limited, Ikorudu, Lagos with 708.3 MPa respectively. While African Steel Nig. Limited, Ikorodu, Lagos has tensile strength of 410 MPa and the Brazilian imported steel has tensile strength of 538.51MPa which are the least tensile strengths recorded. Other local manufacturers also recorded reasonable tensile strength values than most imported ones. Most of these values are far greater than the 440, 550, and 600 MPa tensile strength values suggested by AISI 1018, ASTM A706 and Nst-65-Mn, and BS4449 respectively when compared.

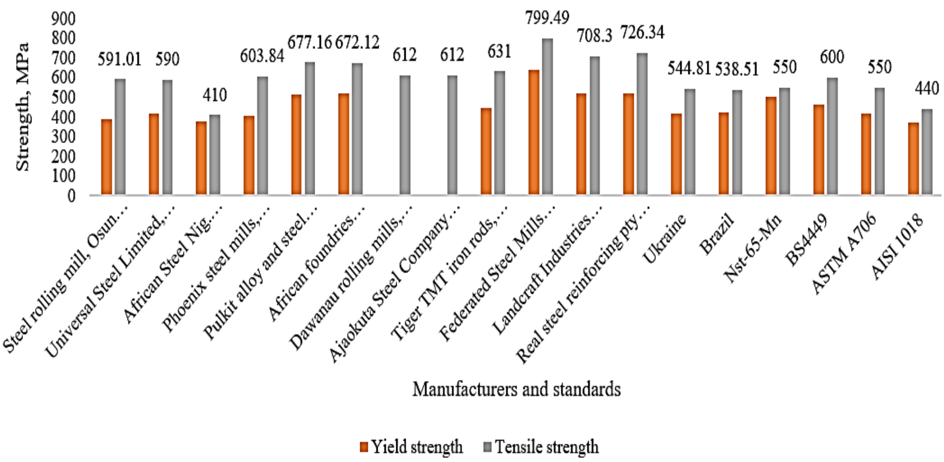

Fig. 8. Tensile strength of 16 mm steel bars compared with one another and some standards

Correlation of Tensile Strength with Hardness

Some hardness values that were not given were estimated using their tensile strength value with equation (1), while some other hardness values on different hardness scales were harmonized by converting them to Brinell hardness scale values [1], [23]:

$$TS = K_h(HB) \tag{1}$$

where K_h is a constant of proportionality. Hence, if TS is given in megapascal (MPa), then K_h = 3.454; and if TS is in pounds per square inch (Ib/in^2), then K_h =500.

Table 2. Tensile strength and hardness comparison of local and imported steel bars used in Nigeria

Producer/sample denotation	Tensile strength (MPa)	Hardness estimated/ converted (HBN)	Diameter
Katsina Steel Rolling Mills Ltd., Katsina State	473.7	190	**(10 mm)**
Sharada Steel and Investment Ltd., Ikeja, Lagos	621.6	240	
Dawanau rolling mills, Kano	573	256.0	
Ajaokuta Steel Company Limited, Kogi state	576	152.0	
African foundries limited, Ogijo, Ogun	682.63	197.86	
Pulkit alloy and steel limited, Ikorodu, Lagos	644.44	186.79	
Phoenix steel mills, Ikorodu, Lagos	574.26	166.45	
Real steel reinforcing pty Limited, Auckland, New Zealan	669.17	193.96	
Imported steel, China	778	226	
Sun Flag Nig. Limited, Ikorodu, Lagos	692.73	445	**(12 mm)**
Unique Steel Industries Ltd, Lekki, Lagos State	651.88	415	
Nigerian-Spanish Engineering Ltd, Kano	610.79	445	
African Steel Nig. Limited, Ikorodu, Lagos State	660.17	419	
Steel rolling mill, Osun State (A12)	582.44	212	
Delta Steel Company, Warri, Delta State	649.35	255	
Phoenix steel mills, Ikorodu, Lagos	545.28	158.05	
Pulkit alloy and steel limited, Ikorodu, Lagos	657.10	190.46	
African foundries limited, Ogijo, Ogun State	709.39	205.62	
Dawanau rolling mills, Kano	577	258.7	
Ajaokuta Steel Company Limited, Kogi State	580	211.9	
Imported steel, China	738	227	
Real steel reinforcing pty Limited, Auckland, New Zealan	655.00	189.85	
Steel rolling mill, Osun State (A16)	591.01	212	**(16 mm)**
Universal Steel Limited, Ikeja, Lagos	590	402	
African Steel Nig. Limited, Ikorodu, Lagos	410	572	
Phoenix steel mills, Ikorodu, Lagos	603.84	175.02	
Pulkit alloy and steel limited, Ikorodu, Lagos	677.16	196.27	
African foundries limited, Ogijo, Ogun State	672.12	194.81	

Producer/sample denotation	Tensile strength (MPa)	Hardness estimated/ converted (HBN)	Diameter
Dawanau rolling mills, Kano	612	261.1	
Ajaokuta Steel Company Limited, Kogi state	612	219.6	
Tiger TMT iron rods, Lekki, Lagos State	631	214.1	
Federated Steel Mills Limited, Ogun State	799.49	116	
Landcraft Industries Limited, Ikorudu, Lagos	708.30	190	
Real steel reinforcing pty Limited, Auckland, New Zealan	726.34	210.53	
Ukraine	544.81	127	
Brazil	538.51	121	
Nst-65-Mn	550	159.42	
BS4449	600	190	
ASTM A706	550	240	
AISI 1018	440	127	

Steel gains strength and hardness from the presence of carbon, which is the most stable component. The strength, hardness, and wear resistance of the steel increase with increasing carbon content, as does its hardenability [17]. As illustrated in Fig. 9, the hardness of the 10 mm reinforcing steel samples from Ajaokuta Steel Company Limited, Kogi state, Pulkit alloy and steel limited, Ikorodu, Lagos, and Phoenix steel mills, Ikorodu, Lagos, manufacturers did not fulfill any requirements specified by ASTM (199 HBN) and BS4449 (190 HBN) respectively, according to [24].

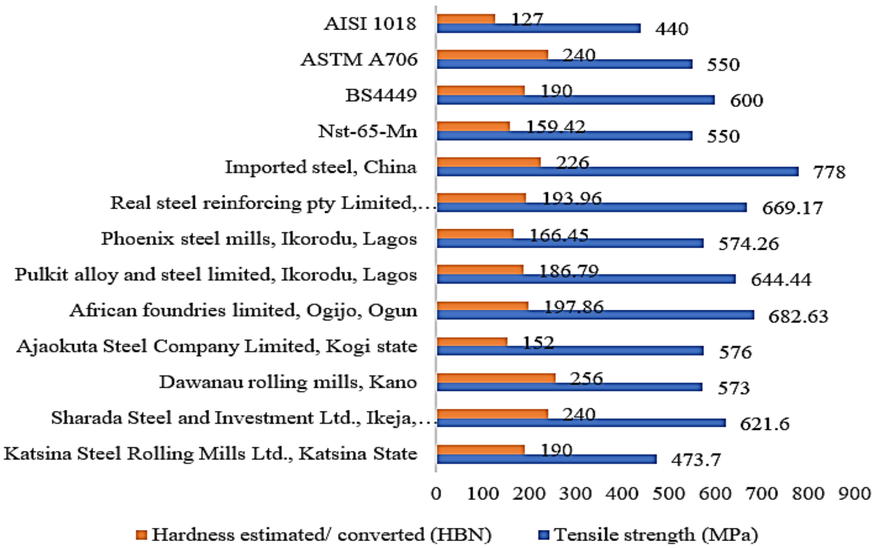

Fig. 9. Tensile strength of 10 mm steel bars compared with hardness of one another and some standards

Fig. 10 illustrates that the hardness of the 12 mm reinforcing steel rebars from all manufacturers were able to meet AISI 1018 (127 HBN) and Nts-65-Mn (159.42 HBN) set criteria.

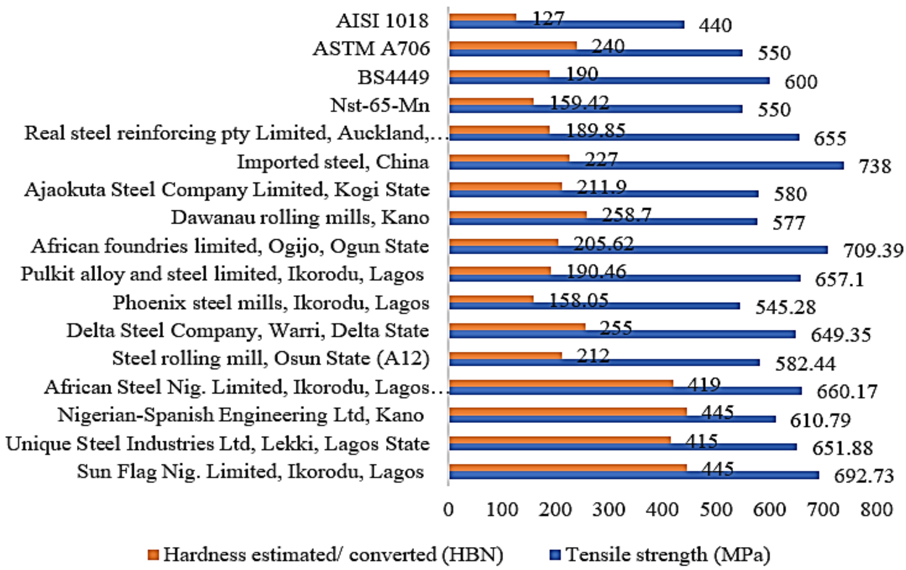

Fig. 10. Tensile strength of 12 mm steel bars compared with hardness of one another and some standards

Fig. 11 shows the hardness value variation of 16-mm concrete reinforcement steel bars. Different manufacturers in Nigeria were able to meet the prescriptions of AISI 1018 (127 HBN), Nts-65-Mn (159.42 HBN), and BS4449 (190 HBN), respectively, except for products from Federated Steel Mills Limited, Ogun State, and imported products from Brazil. Maximum hardness values were observed for African Steel Nig. Limited, Ikorodu, Lagos, as 572 HBN and Universal Steel Limited, Ikeja, Lagos, as 402 HBN, respectively. The hardness value of 116 HBN as observed among products from Federated Steel Mills Limited, Ogun State, portrays the products from this manufacturer as lacking reasonably wear resistance.

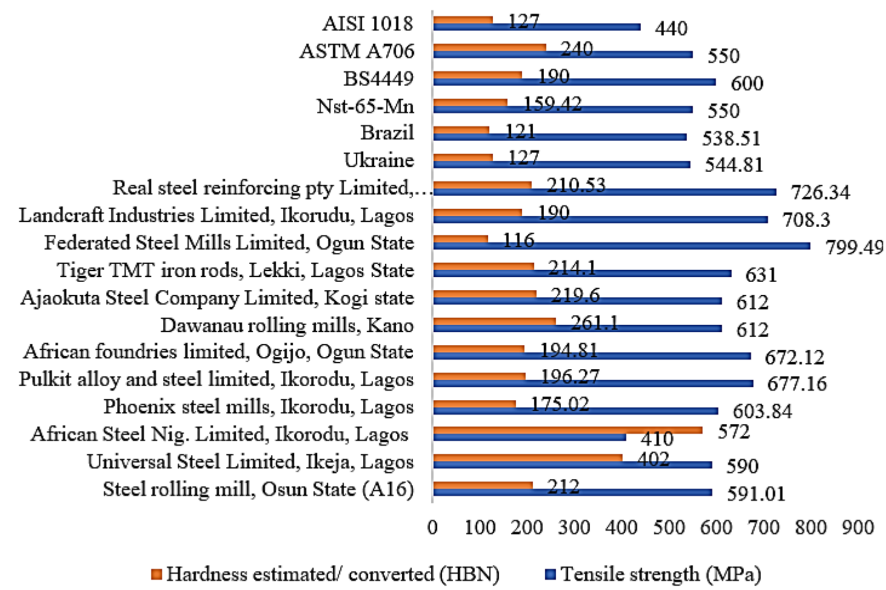

Fig. 11. Tensile strength of 16 mm steel bars compared with hardness of one another and some standards

Conclusions

Based on the results of the aforementioned analysis, it is possible to draw the following conclusion:

Federated Steel Mills Limited, Ogun State, has the highest tensile stress value at 799.49 MPa, followed by Real Steel Reinforcing Pty Limited, Auckland, New Zealand, at 726.34 MPa, and Landcraft Industries Limited, Ikorudu, Lagos, at 708.3 MPa, according to a yield and tensile strengths analysis of 16 mm steel bars produced locally and imported. The lowest tensile strengths ever reported are 410 MPa for African Steel Nig. Limited, Ikorodu, Lagos, and 538.51 MPa for steel imported from Brazil.

Samples from manufacturers including Sun Flag Nig. Limited, Ikorodu, Lagos, African Steel Nig. Limited, Ikorodu, Lagos State, Unique Steel Industries Ltd., Lekki, Lagos State, Nigerian-Spanish Engineering Ltd., and Kano, in that descending order, showed the maximum percentage carbon composition in Figure 4, with each having a higher percentage carbon composition than every acknowledged standard they are compared with. African Foundries Limited, Ogijo, Ogun State, and Phoenix Steel Mills, Ikorodu, Lagos, have very low carbon percent compositions of 0.0956% and 0.193, respectively. If the material has a very low carbon percent composition, it will be too soft and unsuitable to be employed as an enhancer for concrete beam reinforcement.

As seen in Figure 9, the 10 mm reinforcing steel samples' hardness did not meet the requirements set forth by ASTM (199 HBN) and BS4449 (190 HBN), respectively, for manufacturers Ajaokuta Steel Company Limited, Kogi state, Pulkit alloy and steel limited, Ikorodu, Lagos, and Phoenix steel mills, Ikorodu, Lagos.

The findings demonstrated that while some items fell short of the requirements of AISI 1018, ASTM A706, BS4449, and Nst-65-Mn, the majority of them met or surpassed their requirements in terms of tensile strength, yield strength, hardness, % elongation, and percentage carbon content.

It is intended that by bridging the knowledge gap amongst the team members in this area, the data from this study, if properly utilized, will offer a solution to the epidemic of building collapses in Nigeria. Tables and figures clearly highlight these properties against one another, while the plots of a property against another rightly indicate the pros and cons that could be associated with using products from manufacturers that fall below the standard specification admissible for each of the sizes of the steel rods.

Acknowledgement

The researchers of this study are grateful to their colleagues at the department of Mechanical Engineering, Faculty of Engineering and Technology, Alex Ekwueme Federal University Ndufu-Alike, Ikwo, Ebonyi State, Nigeria, for their encouragement.

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Received: March 12, 2024
Accepted: July 29, 2024