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COMPARATIVE STUDY OF THE REINFORCED STEEL BARS OBTAINED FROM A FAILED RESIDENTIAL BUILDING AND THE SHELVES

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ABSTRACT

Nigeria is a developing nation, the need to build structures is on high rise. The rate of structure failure and building collapse is also on the rise. This paper presents a comparative study on Mechanical Properties of Reinforced steel bars obtained from the shelves, and that obtained from the failed structure of a residential building which is then compared to International standard NO-432. Steels are main reinforcing materials for most structural buildings, but when the integrity is compromised, it leads to devastating consequences. The quality of concrete and steel reinforcement must be such that has appropriate yield strength so that the structure can sustain the require load within the required time interval. The Ultimate Tensile Strength and percentage elongation of the steel bars obtained from the two sources were investigated. One of the sources was a reinforcing bar used in Millennium Estate, Mary Land, Lagos State, Nigeria. The steel bar samples of sizes 10mm and 16mm diameter were subjected to mechanical testing using a universal testing machine. The percentage elongation met with the standards while the 16mm samples are below the standards for both the failed structure and shelves.

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1.0 INTRODUCTION

Over the ages, the world has experienced a tremendous improvement and growth in every area of human endeavor and the built environment is not left out in the process. Construction materials have evolved over the years. The real breakthroughs in the construction industries is the variety of materials with versatile options and ease of combined applications of such materials. The components of concrete widely varies from each other (Taiwo, 2011). Although, as a result of aging, the integrity of many of the structures is declining, a lot of this structures has surpassed their designed fatigue limit. Many of such buildings do not possess the required integrity for structural applications and this results in catastrophic failures. (John, 2014). Residential buildings are structures designed to sustain loads which includes, peoples weight, permanent objects like refrigerator, generators and other fixed household appliances without failure. The structures are also exposed to many

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environmental conditions like wind, rain and constant change in temperature. Ahzahar (2011) stated that the central focus of building a structure is to safe guard the occupants and properties in the building. Therefore, it is paramount that such structures must be able to withstand the stress that will be imposed on it by various human activities and environmental factors.

Housing is ranked among the critical factors for survival considering the three basic needs of life. Structural Buildings plays important role in the social, economic, health and environmental welbeing of an individual. The need for various forms of buildings increases on daily basis with growing population and this has become a point of concern for not just the Nigerian government but for the world. To meet this ever growing demand, there are various building equipment and materials readily available for use. The saddening part of this rising concern is shortages, which arise as a result of building collapse. The collapse might come as a partial form of failure or overall crumbling of the entire framework of the building (Ebehikhalu, 2014, Taiwo, 2011 and John, 2014.

Arayela and Adam 2001 reported that the rate of building collapse is so rampant in Nigeria that at least in six months, there would be an incidence of building collapse in one of the major cities of the country. When this devastating incidences occur, it leaves loss of lives and properties in its wake. The victims of some of this unfortunate incidences tend to seek out compensation and the results of their actions includes filing a court law suit against the owners of such buildings. Though, the fault for the failing structures might not have come from the owners of such structures. The failure has been attributed to non standard materials from the manufacturing company, faulty structural designs due to poor workmanship, increase in the load imposed on the building as a result of incompetent contractors and poor project supervision (Adewole *et.al.,* 2014). In Nigeria, the standard yield strength for the reinforcing steel to be used is 460N/mm^2, but many of the available reinforcing steels are lesser than that, which makes it a negligent habit on the part of the regulatory body and also on the part of the stakeholders and engineers taking the job. Kolawole, 2018 reported that the main reasons of building failure is due to man's carelessness in important areas of construction. The negligence ranges from substandard building materials, disregard for environmental conditions, overloading, lack of proper maintenance, illegal alteration and conversion of existing buildings, quackery, use of inadequate and improper foundation, inadequate preliminary site investigation, poor concrete mix ratio, inadequate structural design, non-adherence to material specification and poor building material specification, inadequate supervision by professionals and natural disasters.

Oloke *et.al.,* 2017 advised that since over 60% of the building collapse across the country are structures that are already occupied. It is of paramount importance that the structural integrity of the materials used in the constructions be investigated, in order to identify the problems before it results in catastrophic failure. If the materials fails the integrity test, then it will be certified unfit and demolition and reconstruction would take place. The importance of steel in structures

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cannot be neglected as the proper combination of both steel and concrete form the major components that ensures a structure is in perfect condition (Mansur and Tahar, 2017).

Bamigboye *et al.,* 2019 in their review discovered that the roles played by constuction materials such as reinforcing steels, cement, sand, granite, blocks and concrete in the stability and integrity of a buiding is very vital, but when any of these materials are compromized, the effect is drastic. They reported that a good number of collapsed building in Nigeria is as a result of poor quality of building materials.

Ayodeji, 2011 in his studies reveal that the reasons for catastrophic failures of buildings arises from the poor maintenance culture, design error, poor quality of materials and workmanship, natural phenomenon and excessive loading. These contributed to about 7%, 15%, 52%, 7% and 20% of the failures respectively. Since the result showed that the poor quality of materials is the major contributing factor to the structural collapse of building in Nigeria. It is therefore recommended that the Standard Organization of Nigeria (SON) should intensify their effort in scrutinizing building materials made available to the populace (Odeyemi *et al.*, 2019). The material to be chosen must be able to withstand the loads generated by the design loads.

Durodola *et al.*, (2012) interacted with stakeholders and discovered that unqualified workmen have taken over the duties of architects and engineers in building construction which leads to faulty buildings, which eventually result in catastrophic failures of such structures in the nearest future. They recommended that stakeholder should take corrective actions where necessary to avoid incidences. Although the issue of collapsing structures cannot be totally eradicated, necessary actions would keep it to the minimum.

Material failure has been noted to contribute majorly to building collapse and has called for major concern among engineering professionals (Oke *et al.*, 2009). The procedure of designing a building begins with the selection of materials based on their properties and the type of loads to be supported. A structural material is a material that carries its self-weight and tributary load transferred from other structural members as a result of its properties (Ede *et al.*, 2015).

The evolution of concrete has pass through plain concrete, precast concrete reinforced concrete, pre-stressed concrete to the contemporary concretes. Plain concrete made of Portland cement, coarse and fine aggregate and water is usually called the first generation of concrete while the steel bar-reinforced concrete is the second generation concrete. Concrete development have been accompanied by the search for increase of its compressive strength and the best approach is by reducing cement/water ratio to the limit that permits good work ability (Arum, 2008).

Steel is an essential material for society and sustainable development in the world and it is needed for people to satisfy their aspirations and needs. Steel is part of people's everyday lives, in both the developed and developing countries. Steel is produced from two key components: iron which is one of Earth's most abundant elements and recycled steel. Its combination of strength, recyclability,

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availability, versatility and affordability makes steel unique. Steel is truly a versatile material and the quality of reinforcing steel in structural engineering is usually investigated in terms of its mechanical properties such as, yield strength, ultimate strength and elongation (Yeon, *et. al.*, 2007, Joshua et. al., 2013 Ponle *et. al.*, 2014, Ponle *et. al.*, 2014b).

In Nigeria, the rate at which buildings collapse in the world, especially in Nigeria calls for urgent interception and this has caused a great concern to all professionals in the construction industry, stakeholders, private developers, clients and users and as well the government (Akande *et. al.*, 2016).

Several researchers have investigated the causes of building collapse. They stated that the most frequently adduced causes is the non-conformance of structural properties of materials used to the actual design specifications.

This work is a comparative study of the mechanical properties of reinforcing steel bars obtained from a failed structure at Millenium Estate in Lagos State Nigeria and the steel rods obtained from the shelves of steel Rods vendors. Eventually comparing to the values provided by the International Standard Organization (ISO), ASTM Standards and the NST Standards.

2.0 METHODOLOGY

2.1 Materials

The samples used in the study were 10mm and 16mm diameter reinforced steels bars. These samples were obtained from a failed residential building structure in Millennium Estate, Mary Land, Lagos State, Nigeria and the other set of samples of steel bars were obtained from the shelves of rod vendors. The steel bars from the shelves of sellers were obtained from two different vendors. A total of 12 samples were used in the experiment. The experiment were carried out thrice and the mean values reported for reproducibility of results.

2.2 Tensile Strength.

The samples were turned into standard configuration using the lathe machine. Steel are cut into required length of the machine acceptability. A universal Testing Machine at the Engineering workshop in the Federal University of Technology, Akure, Ondo State, Nigeria was used. The resulting, load, tensile strength and elongation were measured.

Ultimate tensile strength of the material helps in determining the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contract. The relationship is shown in equation1

$$\textit{Ultimate Tensile Strength} = \frac{\frac{\text{Load}}{10} \times 1000}{\frac{\pi D^2}{4}} \quad \text{.......................} (1)$$

where D= diameter of the steel bar

2.2.1 Elongation

The elongation is the increase in length of the gauge length, expressed as a percentage of the original length. In reporting elongation values, give both the percentage increase and

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the original gauge length. This express by equation 2

$$E = \frac{L_f - L_0}{L_0} \times 100 \qquad \text{.................(2)}$$

Where L_f=length of specimen at fracture

L_0= original gauge length

3.0 RESULTS AND DISCUSSION

The tensile strength is 534.48 and 492MPa for the control sample of 10mm and 16mm respectively. With the 10mm control sample having the highest the result agreed with Alabi et. al., (2016). The tensile strength value from the site are 573.35 and 495.38 MPa for 10mm and 16mm respectively. These also agreed with the previous work. The values for 16mm for both failed site and the shelves are lower than the recommended values of 500MPa by BS4449, A707M-15 (Alabi *et. al.*, 2016)

Tables 1 and 2 showed the tensile test results which is necessary for the computation of the characteristic values of the tensile strength, as well as the elongation properties for the steel bars of diameters 10mm and 16mm. These tables include test results for both steel bars from the shelves (designated "control"). The steel bars from the shelve of bar diameters 10mm and 16mm,

Figures 1 and 2 showed the values of the ultimate tensile strength which indicate better uniformity in quality. The percent elongation of both samples were satisfactory according to the standards of BS4449, Nst.65-Mn, and ASTM A706 (Alabi *et. al.*, 2016). The samples of 16mm rods which fails the ultimate tensile strength test should not be used in reinforcement because they are not strong enough to withstand the load bearing capacity of the building, which will result in catastrophic failure.

On the other hand, Tables 3 and 4 shows the mechanical properties for steel bars from the failed structure designated as site. From Fig. 3 and 4, it is observed that the test values of the characteristic ultimate tensile strength are lower than the specified minimum value for all bar diameters tested. For both categories of steel bars obtained, the values of the ultimate tensile strength indicate better uniformity in quality. The percentage elongation of both samples was satisfactory according to the standards of BS4449, Nst.65-Mn, and ASTM A706. This agreed with previous work stating

Table 1: The mechanical properties of the 10mm (Control) Steel Bar

	Sample 1	**Sample2**	**Sample3**	**Average**
D_0	4.59	4.54	4.64	4.59
L_0	27.82	27.12	27.31	27.42
D_f	2.55	3.00	3.86	3.14
L_f	32.89	31.11	29.67	31.22
Load	95	86	95	92
% Elongation	18.22	14.71	8.64	13.86
Tensile Strength	574.16	467.44	561.83	534.48

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Table 2: The mechanical properties of the 16mm (Control) Steel Bar

	Sample 1	Sample 2	Sample 3	Average
D_0	4.51	4.68	4.84	4.68
L_0	25.54	26.41	26.35	26.10
D_f	2.92	4.63	3.05	3.53
L_f	31.51	27.16	33.98	30.88
Load	85.00	82.00	86.00	84.33
% Elongation	23.38	2.84	28.96	26.17
Tensile Strength	532.08	476.69	467.44	492.07

that the building failures is due to lack of adherence to standards (Alabi *et. al.*, 2010).

The low yield strength of 16mm samples agreed with previous works who also reported a low yield strength of steel rods in Nigeria (Alabi and Onyeji, 2010, Chukwudi, 2010). Kutz, 2002 stated that the low yield strength could be as a result of significantly low amount of silicon and manganese in the steels.

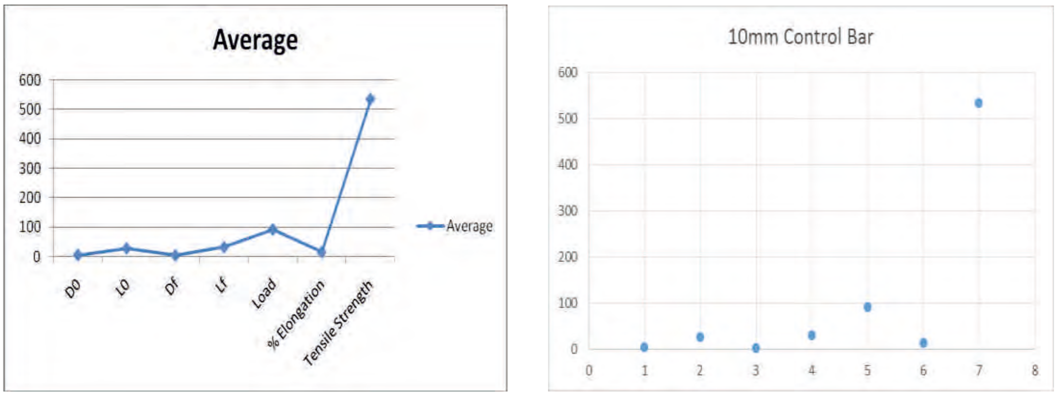

Figure 1: The mechanical properties of the 10mm (Control) Steel Bar

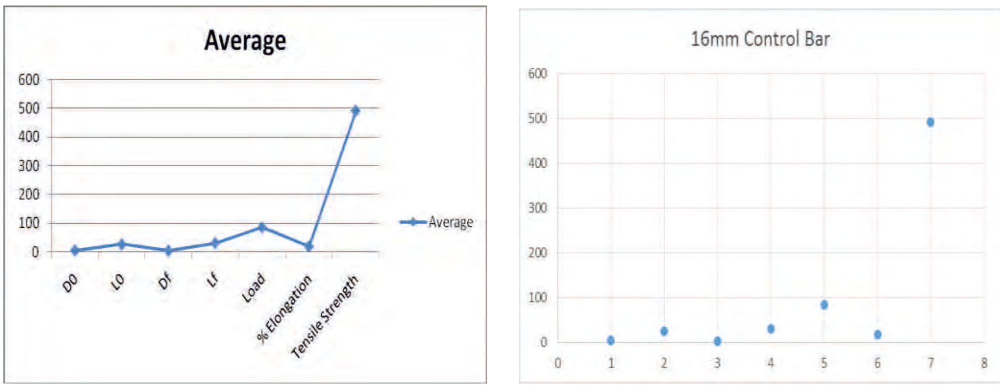

Figure 2: The mechanical properties of the 16mm (Control) Steel Bar

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Table 3: Table showing the mechanical proper ties of the 10mm (Site) Steel Bar

	Sample 1	**Sample 2**	**Sample 3**	**Average**
D_0	4.76	4.85	4.64	4.75
L_0	28.40	27.39	27.31	27.7
D_f	4.09	4.59	3.86	4.18
L_f	32.56	31.88	29.67	31.37
Load	105	105	95	101.67
% Elongation	14.64	16.39	8.64	13.22
Tensile Strength	590.05	568.18	561.83	573.35

Table 4: Table showing the mechanical properties of the 16mm (Site) Steel Bar

	Sample 1	Sample 2	Sample 3	Average
D_0	4.34	4.84	4.32	4.5
L_0	25.34	26.35	25.66	25.78
D_f	2.94	3.05	2.16	2.72
L_f	27.29	33.98	30.71	30.66
Load	75	86	75	78.67
% Elongation	7.70	28.96	19.68	18.78
Tensile Strength	506.99	467.44	511.70	495.38

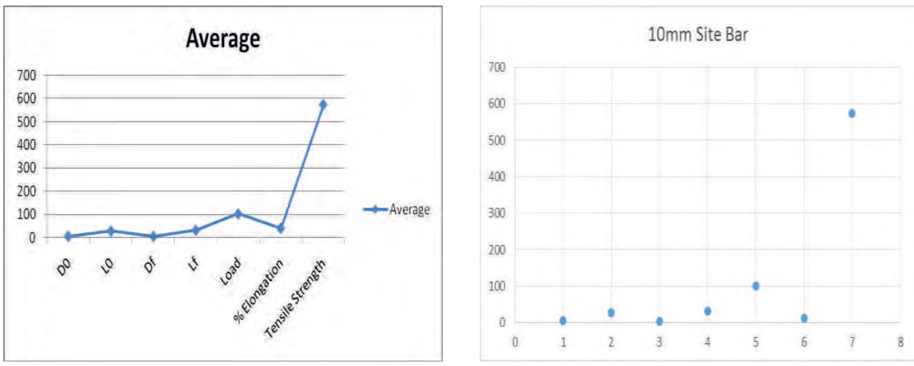

Figure 3: Chart showing the mechanical properties of the 10mm (Site) Steel Bar

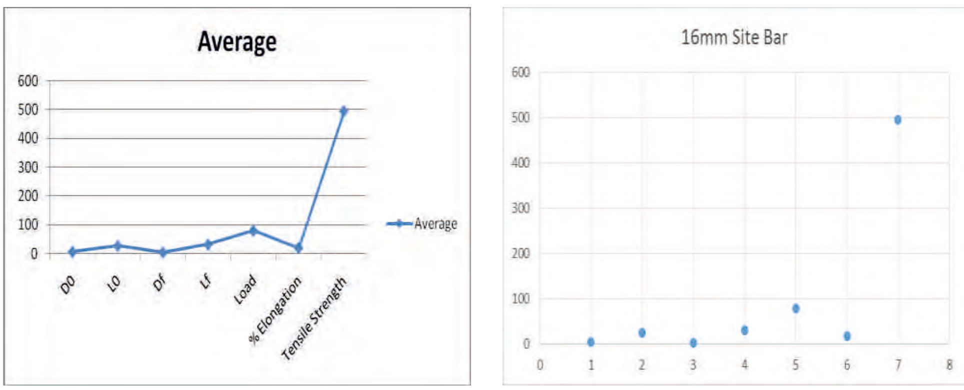

Figure 4: Chart showing the mechanical properties of the 16mm (Site) Steel Bar

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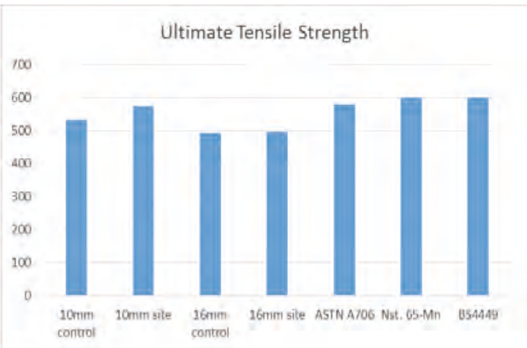
Table 5: Table comparing the mechanical properties of the steels to international standards

Sample	**Ultimate Tensile Strength (N/mm2)**	**Elongation (%)**
10mm control	534.48	13.86
10mm site	573.35	13.22
16mm control	492.07	18.39
16mm site	495.38	18.78
ASTN A706 [25]	580.00	10.00
Nst. 65-Mn [26]	600.00	14.00
BS4449 [24]	600.00	12.00



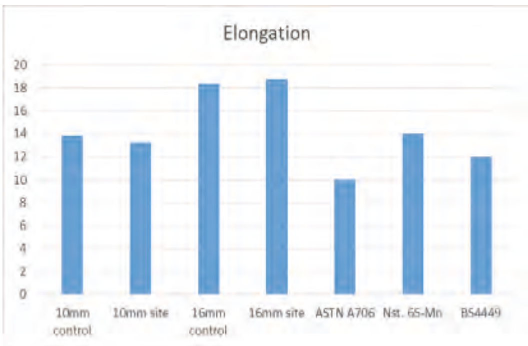


Figure 5: The mechanical properties of the steels compared to international standards.

4.0 CONCLUSIONS

The percent elongation of both samples agreed with the international standard specifications.

The reinforced steel obtained from the shelves of vendors and that from the failed residential building showed similar Tensile strengths for both 10mm and 16mm.

The tensile strengths of the 10mm agreed with the standards while the tensile strength of the 16mm is both lower than the standard. Low yield strength of steels makes it inappropriate for structural load bearing applications like residential buildings.

Generally, there is need for the Standard Organization of Nigeria (SON) to perform adequate and proper assessment on manufactured steel bars to ensure compliance to standards. This will go a long way to reduce failures.

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