ASSESSMENT OF THE QUALITY STEEL REINFORCEMENT BARS AVAILABLE IN NIGERIAN MARKET.

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ABSTRACT.

The use of substandard and steel reinforcement rods in the construction of structural steel concrete elements of a building, most especially in floor slabs has been identified as one of the most important causes of structural failures in buildings in Nigeria. This research investigated the mechanical properties (yield strength, ductility and the ultimate tensile strength) of 12mm diameter steel bars commonly used in reinforcing floor slabs using an extensometer. Results obtained from the tests showed that only three (3) brands out of a total of nine (9) tested most commonly used brands of sampled rods showed yield strengths greater than 460N/mm^2. The yield strengths obtained range between 337.72 N/mm^2 and 569.71 N/mm^2. The study confirmed that the wide usage of substandard steel reinforcement bars in the Nigerian market is a major contributing factor to increasing incidences of structural building failures in the country when viewed from the angle of variability in material quality.

Key words: Nigerian-steel, Rebars, Reinforcements and Steel-bars.

BACKGROUND TO STUDY.

From pilot survey in Lagos, it was discovered that over ninety percent (90%) of storey buildings in Nigeria are structures whose structural frame/elements are made of reinforced concrete. The place of reinforced concrete in the Nigerian construction industry cannot be over emphasized and in fact, bulk of her construction industry revolve around the use of concrete, be it in dams, bridges, buildings and all other civil engineering works.

According to Ede (2010), the occurrence and casualties of building collapse from the year 2000-2010 was alarming. Of the three (3) states in Nigeria with the highest number of building collapse, about 80% of the collapse and 65% of the casualties (deaths) occurred in Lagos state with forty (40) and one hundred seventy five (175) collapse and deaths respectively. Over 95% of the collapse occurred in over two (2) storey buildings.

Oni (2011) also used the predictive linear trend equation to show that an average of ninety-one (91) storey buildings will collapse between the years 2007-2017 with an average of nine (9) collapses annually.
Also, Oke and Abiola-Falemu (2009) showed that poor material and workmanship contributes about 52% to the overall causes of building collapse in Nigeria.
Ogunsemi (2002) also showed that poor workmanship amount to about 18.4% of the total causes of building collapse while the use of sub-standard materials amount to 18.4% of building collapse in Nigeria but Oke and Abiola-Falemu (2009) asserted that their study of 52% overrides others because they based theirs on a greater number of building collapse data than the others.
It can be deduced from the above percentages from Ogunsemi (2002) and Oke and Abiola-Falemu (2009) that about 26% of building collapse occurred as a result of the use of substandard materials.

Holistically, buildings can never collapse until the structural component(s)/systems fails or begin to fail and since over 90% of the structural components/systems in Nigeria are made of concrete, it can be deduced that the greatest percentage of collapse is as a result of concrete failure and 26% of this failure is as a result of the use of substandard material.
Reinforced concrete star materials are cement, aggregates (fine and coarse) and steel reinforcement rods.
There arises a need to study the qualities of these star materials in an attempt to curb or reduce to the nearest minimum the menace of collapse due to the use of substandard materials.

Building.

According to the United States Building Seismic Safety Council and the Federal Emergency Management Agency (2010), a building is simply an enclosure intended for human occupancy and or other uses. This enclosure ranges from simple bungalows to multi-storey buildings with over a hundred numbers of floors. It further divides buildings into two main broad components which includes the structural component which bears the whole weight of the building and effectively transmit it to the ground, e.g. slabs, beams, columns and foundation; and non-structural components that simply bears its own weight and transmit its weight to the structural components, e.g. partition walls, electrical and mechanical installations, windows, doors, etc.

An example is the tallest building in the world, Burj Khalifa with reinforced concrete as its primary supporting structure. The building is 829.84m high with 163 floors and structural concrete supports the floors to the 156th floor above which the remaining supporting structure to the top is mainly of steel.

It can be seen that the role of reinforced concrete as a structure cannot be over emphasized.

Basic Functional Requirements of Building Structural Components.

Olusola *et' al* (2011) summarized the basic requirements that a structure must satisfy and they include the following:

1. Each and every member of a structural system should be able to resist, without failure or collapse, the applied loads under service conditions. In other words, it must possess adequate strength. This demands that the material that make up the structure, like concrete, steel sections or wood, must be adequate to resist the stresses generated by the loads and the shape and size of the structure must be adequate.

2. Every component of the structure should be able to resist deformation under loading conditions. Deformation implies a change in size or shape when a body is subjected to stress. Excessive deformations that are deformations exceeding specified acceptable limits will impair the functional performance of a structure and any attached services. This demands that the stiffness of a beam or column is a measure of its resistance to bending or buckling. It should be noted that a component may be strong and not stiff, and vice-versa.

3. Every component of a structure must be stable otherwise the whole structure is assumed to be unstable. Structural stability is needed to maintain shape. It is the ability of a structure to retain, under load its original state of equilibrium. It can mean anything from resistance to a minor degree of movement to resistance to sliding overturning partial or complete collapse. Any phenomenon (which will be a potential source of load) that can alter the load-carrying behaviour of a structure, if not properly taken care of can lead to instability, a condition in which the support reaction is less than applied load. Thus to ensure stability, loads must be balanced by reaction, and the moments due to loads must be balance by the moments due to reactions.

As it can be observed from the above that in the event of failure in the structural component(s) of a building, the failure of such building is inevitable. The structural components define the strength and stability of the building.

Reinforced Concrete as a Structural Material in Nigeria

The four (4) main materials that these structural components are made up of are masonry (load bearing walls), timber, steel and plain/reinforced concrete (Garrison, 2011). Some structural elements derive their nomenclature by the materials they are made from, e.g., reinforced concrete beam, steel columns, timber joists, etc.

From previous survey within Lagos, it was observed that over ninety percent (90%) of storey buildings (buildings with floor(s) above the ground floor) are structures whose structural system/elements are made of reinforced concrete. The place of reinforced concrete in the Nigerian construction industry also cannot be over emphasized and in fact, bulk of her construction industry revolves around the use of concrete.

Also, structural materials are components capable to bear load due to their ability to resist stresses. Structural material are components that determines the strength of a building, they are responsible for the stability of the structure.

There are several structural materials like timber and masonry-network but when buildings needs to go higher, they are simply incapable of bearing the resulting stresses due to the imposed/dead loads and this limits structural components to two major materials which are steel and reinforced concrete.

Steel is a material that is good in resisting both compressive and tensile stresses but unlike steel, concrete is only good in resisting compressive stresses but structural components are concurrently subjected to both tensile and compressive stresses and for concrete to serve as a very good structural material, it must be able to resist tensile load and to achieve this, it is usually reinforced with materials that are good in resisting tension and these materials include fibre usually sourced from plants, glass fibres and steel. This introduces concrete to a composite referred to as reinforced-concrete in which the concrete resist the compressive stresses and the other composite resisting the tensile stresses in the tensile zone of the component under its service load.

In building construction today, steel bars are the most widely used reinforcing material in concrete largely because concrete bonds well with steel and both expand and contract to about the same degree with temperature changes (Committee E-701, 2006). And probably also because it has more strength and durability advantages than others.

In light of the above, the study of structural materials in this study will be limited to reinforced concrete.

The Role of Component Materials Quality on the Performance of Structural Reinforced Concrete.

It is widely recognized that reinforced concrete strength depends on the strength of cement paste, on the cement paste-aggregate bond, on the aggregate strength and on the strength of its reinforcing material. For ordinary concrete, the strengths of paste and the paste-aggregate bond control concrete strength (Lamond and Pielert, 2006).

The factors that can greatly affect the strength and durability of reinforced concrete are the quality of its constituent materials and production.

The use of low quality materials results in low quality concrete and even when high quality materials are used but combined in wrong proportions, badly produced, it can result in the production of undesirable reinforced concrete properties.

The material make-up/components of reinforced concrete include:

- Cement
- Aggregate (fine and coarse)
- Admixtures (Chemical and Mineral) and
- Water and
- Steel reinforcement.

But this study will be limited to the contributions of steel rebars on the properties of reinforced concrete in Nigeria.

Roles of reinforcing steel in concrete property.

- **Strength**
  Concrete is best at compression and its resistance to tension is negligible and therefore, in reinforced concrete structural elements under service conditions, concrete resist only compressive stresses and the steel rebars resist both tensile and compressive stresses in the tensile and compression zones of the stress block respectively. The greater the yield strength of the rebars, the greater the strength of the reinforced concrete structure.

- **Ductility.**
  All structures need ductility, as well as strength. In reinforced concrete, it is the reinforcing steel that induces ductility into the structural element. Ductility of the structural reinforced concrete element is its ability to fail by deflection or extensive cracking in an overload situation, without sudden catastrophic collapse. This failure mode saves lives by giving adequate warning before collapse. The ductility property of reinforced concrete structure is imputed by the steel rebars. Concrete is considered a brittle material but when reinforced with steel (reinforced concrete), it exhibits some measure of ductility. The level of ductility of reinforced concrete structural element is determined by the ductility (elongation) of the rebars.

The factor that undermines the effects of reinforcing steel rods in reinforced concrete includes:

- When the steel bar strength is below the designed yield and ultimate strength;
- Ductility of the rebars (usually measured by elongation).
- Corrosion of the reinforcing steel rods under its service load; and
- Loss of bond between the steel rods and concrete.

These factors can be ameliorated by controlling the chemical composition of the rebars from the manufacturing process as the properties of rebars are influenced by the chemical composition of the steel from which it is manufactured. Table 1.2 shows the influence of the various rebars chemical components on the resulting steel (Prabir C. B. *et al*, 2004).

Deficiency in the main chemical components and level of impurities can result in the production of substandard steel rebars.

Reinforced concrete design assumptions.

The design of reinforcement in concrete to BS 8110:1997, the yield strength of steel is taken to be 460N/mm^2 and the current EuroCode2 (EC2) now states that the yield strength of steel be 500N/mm^2. The specification for steel reinforcement for concrete to BS4449:2005 states that the minimum steel yield strength be 500N/mm^2. The Nigerian standard as specified by the Nigerian Industrial Standard, NIS 117:2004 specify the yield strength of steel Grade 420 to be 500N/mm^2

If steel reinforcements in reinforced concrete are designed based on these design values and the actual steel available for constructions falls below these strength values, the failure of such structures is almost certain. It is on this premise that the need arose to study the quality of steel reinforcement in the Nigerian market to ensure it's not one of the factors contributing to building failures/collapse in Nigeria.

Table 1.2: Influence of different chemical ingredients in steel on properties of rebars (Prabir *et al*, 2004).

S/N	Chemical	Effect on rebar	
		Controlling property	Actual effect
1	Carbon (C)	Hardness, strength, weldability and brittleness	Higher carbon contributes to the tensile strength of steel, that is, higher load, bearing capacity and vice versa. Lower carbon content less than 0.1 percent will reduce the strength. Higher carbon content of 0.3 percent and above makes the steel bar unweldable and brittle.
2	Manganese (Mn)	Strength and yield strength	The manganese content in steel is not specified as per IS: 1786. However higher manganese content in steel increases the tensile strength and also the carbon equivalent property.
3	Sulphur (S)	Present as an impurity in steel which increases its brittleness	Presence of sulphur should be limited as per IS: 1786. Presence of higher sulphur makes the bar brittle during twisting, as higher sulphur content brings the hot shot problem during rolling.
4	Phosphorus (P)	Present as an impurity which increases strength and brittleness	Higher phosphorus content contributes to the increase in strength and corrosion resistance properties but brings brittleness due to the formation of low euctoid phosphicles in the grain boundary. Also lowers the impact value at sub zero temperature level (transition temperature).
5	Copper (Cu)	Strength and corrosion resistance properties	Being a pearlite stabiliser, it increases the strength and corrosion resistance property.
6	Chromium (Cr)	Weldability and corrosion resistance	Present as an impurity from the scrap and influences carbon equivalent; weldability and increases corrosion resistance property.
7	Carbon Equivalent (CE or Ceq)	Hardness, tensile strength and weldability	This property is required to set the cooling parameters in Thermo Mechanically Treated (TMT) process and a slight variation in carbon equivalent may alter the physical properties. In case Of Cold Twisted Deformed (CTD) bars, carbon equivalent has a maximum limit of 0.42 percent but there is no lower limit prescribed. As such, as long as the chemical composition and physical properties of raw materials are within specified limits, the variation in carbon equivalent as in the case of TMT bars.

METHODS

Sampling and Testing

The method of sampling these rebars is by market survey to identify the steel brands used in Lagos, purchased three cuts of 12mm diameter rebars for each identified steel brand from three different shops. The cuts were labeled and sent to the laboratory for tests. 12mm diameter bar size was chosen because it is the most used in structural design work in Nigeria.

Nine (9) steel brands were identified denoted as Brands 1-9 as shown in Fig. 1-3. The tests conducted include tensile yield and ultimate strengths and elongation; and prices per standard market length of the identified brands were also surveyed. The results are as shown in Fig. 1-3.

RESULTS

The tensile strength test and elongation were conducted on each sample with the extensometer and the results are tabulated in Fig.1-3.

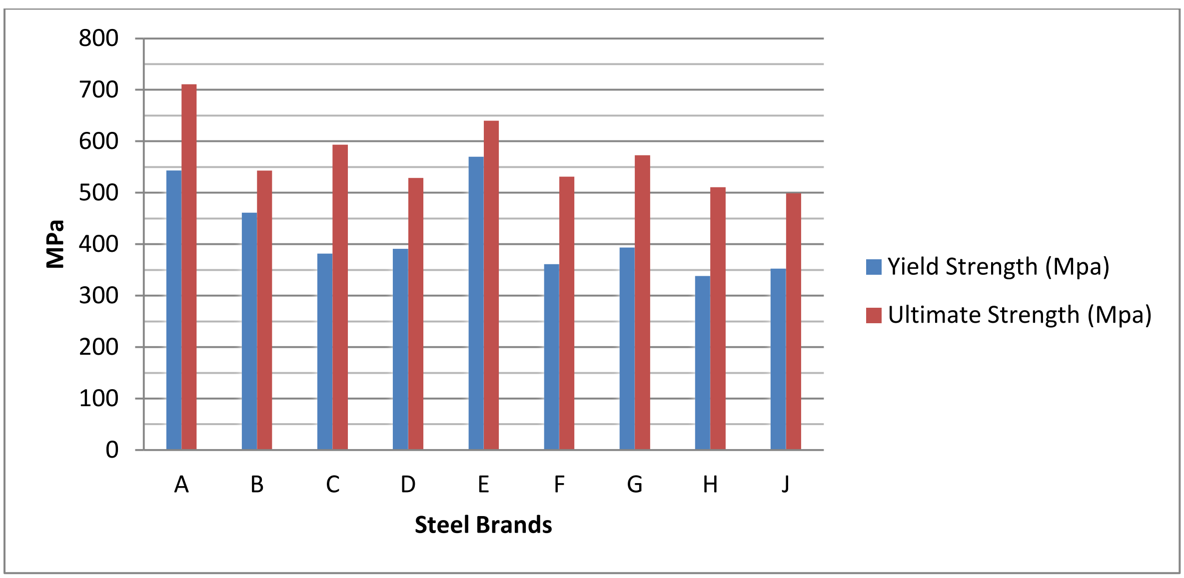

Figure 1: Steel Brand’s yield and ultimate strengths.

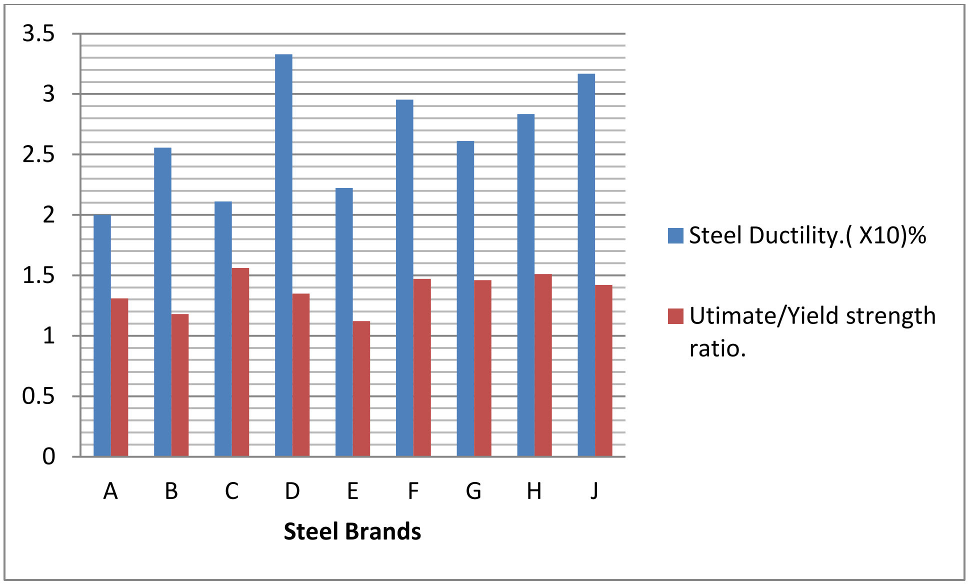

Figure 2: Ductility and Ultimate/Yield strength ratio of different steel brands.

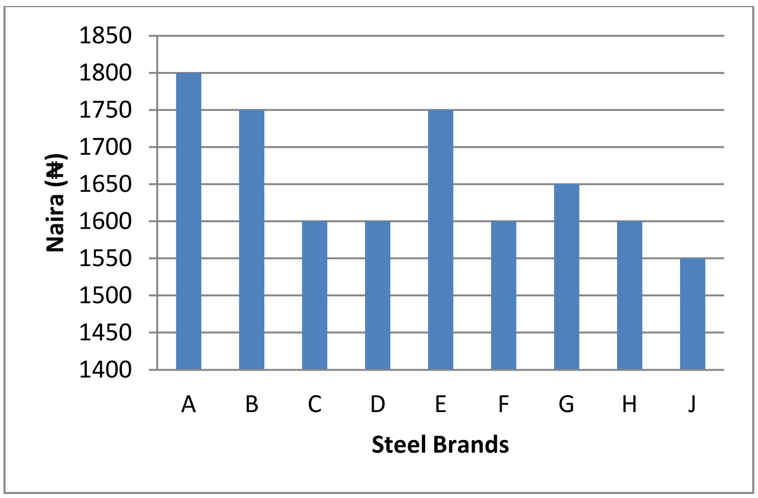

Figure 3: Cost of standard length (12m) of the different steel brands.

CONCLUSIONS.

1. All identified steel brands satisfy its specified diameters if 12mm.

2. By local and foreign standards, only three (3) of the nine (9) identified steel brands meet the required yield strength of between 460-500 MPa as design value in BS 8110:1997 and minimum values in NIS 117:2004 and BS 4449:2005. See Fig. 1.

3. All steel brands satisfy the required minimum percentage elongation of 7.5% as specified in BS4449:2005. As seen in Fig.2, the least elongation is 20%. Prabir *et al* (2004) asserts that the greater the elongation, the better.

4. Four (4) of all identified steel brands satisfy the ultimate to yield strength ratio of between 1.15-1.35 while the rest of the brands are greater than 1.35 as seen in Fig. 2. Almost all brands that meet this requirement also met the yield strength requirement.

5. All steel brands that falls short of strength requirements are relatively cheaper than the ones that met the standard as seen in Fig. 3. They also didn't meet the ultimate to yield strength ratio of 1.15-1.35 as specified in BS4449:2005.

6. Conclusion No. five (5) above tend to agree with BS4449:2005 that a relationship exist between the ultimate/yield strengths and their ratios that confirm a good quality steel. Since the best steel brands that satisfy the ultimate to yield strength ratio range also satisfies the strength requirement.

7. The steel marketers admit that though the standard length is 12m (40ft), it's usually less but always greater than 38ft.

RECOMMENDATIONS.

1. It is highly recommended that all steel batches be randomly sampled and tested to ensure compliance before being used in construction work.

2. Standard regulatory agencies within the country should undertake periodic market survey to identify substandard product and discipline erring brands.

3. In calculating accurately the number of reinforcements needed for a project by Quantity Surveyors (QS), it is recommended on the interim that lengths be based on market dimension of 38ft and not the usual 40ft pending when regulatory authorities are able to enforce compliance on the manufacturers to produce 40ft standard bars for proper on-site steel scheduling.

4. Nigerian Structural design Engineers should either base their designs on 340 MPa or use greater factors of safety when designing for structures in rural areas that have restricted access to laboratories to ameliorate the effects of these margins from the standard strength.

5. Building contractors should be careful with cheap reinforcements and other practices that seems to "reduce cost", these mostly results in the purchase of sub-standard steel materials as shown in Fig.3 that the cheaper ones are substandard bars.

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