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A study on the quality assessment of Steel bar utilised in the Construction sector of Nigeria: A case study of Benin City, Edo State.

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Abstract
This study investigates the diameter characteristics of reinforcement steel bars commonly used in construction. Measurements were taken for both 10mm and 12mm diameter bars obtained from distributors, revealing mean diameters of 9.66mm and 11.46mm, respectively—both falling below industry-standard dimensions. Statistical analysis, with standard deviations of 0.47 and 0.40 for 10mm and 12mm bars, respectively, indicates consistent measurements around the means. While this uniformity is a positive aspect for quality control, the deviation from standard sizes raises concerns about the structural implications and adherence to industry specifications. The undersized bars may compromise load-bearing capacity, necessitating further investigation into manufacturing processes and the implementation of robust quality assurance measures in the construction industry. The findings underscore the critical importance of ensuring construction materials meet established standards for the safety and reliability of built structures.

Keywords: Reinforcement steel bar, Structural integrity, Construction material; Building collapse, Mechanical properties.

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Introduction

The process of designing a building structure starts with the selection of materials based on their properties and the type of stresses to be supported. For the design of reinforced concrete structure, which is one of the most built structures around the world, the choice will fall on concrete and steel reinforcing bars. The quality of concrete and steel reinforcement bars chosen must have adequate strength to guarantee a ductile behaviour expected of reinforced concrete structure, so that the structure will be safe and functional to fulfil the purpose for which it is built. But this is not often the case in Nigeria, where the collapse of reinforced concrete structures has been very frequent (Ede et al., 2015).

Steel exhibits linear elasticity within the elastic limit until yielding occurs. Beyond this point and prior to ultimate failure, stress is no longer proportional to strain. However, a considerable amount of energy is absorbed within the yield plateau and in the strain hardening portion prior to failure. The prevalence of the zone between the yield point and the maximum stress point is a measure of ductility. Steel is widely used in the building construction practice to impart ductility and tensile strength to concrete, being inherently brittle. Ductility in concrete beams means the ability of the member to survive large deformations and its capacity to absorb energy in the event of failure. This failure would be initiated by gradual yielding of the steel while concrete strains are still relatively low. Thus large deflections would be attained before the final collapse occurs so that the members bend and deform substantially but remain intact, providing ample and probably visible warning to occupants (Senfuka, Kirabira and Byauhanga, 2013). Table 1 shows the effect elemental composition on the properties of steel reinforcement bars.

Table 1: Influence of different chemical ingredients in steel on properties of rebars

No	Chemicals	Controlling Property
1	Carbon	Hardness, strength, weldability & brittleness
2	Manganese	Strength and yield strength
3	Sulphur	Brittleness
4	Phosphorus	Strength & brittleness
5	Copper	Strength & corrosion resistance properties
6	Chromium	Weldability & corrosion resistance
7	Carbon Equivalent (CE or Ceq)	Hardness, tensile strength & weldability

It is known that concrete is strong under compression, but is weak in tension. Steel is used for reinforcing concrete structures. In the steel reinforced concrete structure steel and concrete act together to withstand induced forces. For any reinforcing steel rod to be adequate as reinforcing material, it should satisfy basic characteristics such as yield strength, ultimate strength, percentage elongation and nominal diameter (Motra, Hildebrand and Dimmig-Osburg, 2014). Its reasonable cost and strong strength ensure its wide utilization in construction sector. An important drawback of steel is that it corrodes to form rust under common environments (Alo et al., 2017).

Most common mechanical properties of metals including steels used in structural engineering are the stress-strain curve, yield strength, ultimate tensile strength, strain at yield, at maximum stress and failure, and the compressive strength. Although mechanical properties of steels are affected mainly by their carbon contents, their chemical properties and the production processes used also influence their mechanical properties (Alabi and Onyeji, 2010 & Osarenmwinda and Amuchi, 2013).

Researchers usually face with difficulties in determining the ideal steel formulation since steel strength rises are often followed by reduced plastic deformation. To relax the problem, a thorough analysis should be carried out into each component of the alloys measured in steel to determine the stress vs elongation properties. A beneficial aspect about metal recycling is that the material can be processed again and again and do not cause a waste management issue or concern (Osarenmwinda and Amuchi, 2013).

Statement of Problem

It is suspected that one of the causes of structural failure observed in many parts of Nigeria is the use of substandard materials in structural work. Steel reinforcement bars are vital building material needed for construction of structures. The use of substandard steel bars for structural reinforcement is suspected to be the one most causative factor responsible for building failures and collapse. For instance, a study by Baba et al. (2020), reported that about 42% of the 12 mm bars and 46% of 16 mm bars in Lagos State of Nigeria failed to meet the BS code prescription of 460 MPa yield strength and about 28% and 33% of 12 mm and 16 mm bars respectively, failed to meet the Nigeria professional prescription of 410 MPa.

Aim and Objectives

The main objective in this work is to determine the mechanical properties of reinforcing steel bars used in Nigerian building and constructions and compare them with the British standard adopted in Nigeria for structural design as to verify the level of substandard bars used in Nigerian Local building and constructions, as adduced to be one of the causes of structural failure seen in most places.

- Determined the mechanical properties of locally produced reinforcing steel bars.
- Determined the effect of chemical composition on the mechanical properties of local reinforcing steel bars.

Significance of the Study

It is known that concrete is strong under compression, but is weak in tension. Steel is used for reinforcing concrete structures. This work will provide a view on the quality of steel reinforcement bars available within Benin city.

- The results of this investigation shall be relevant in bench marking of our steel production with those of other countries.
- Design engineers can use the result of this study as a guide to improve their design and take more factors of safety, since the bars do not conform always to design specifications.

Literature Review

Buildings is said to collapse when it can no longer satisfy its primary function of being safe, stable, comfortable and satisfying the occupants (Khitab et al, 2015). Building is therefore used to provide adequate shelter and form of protection to her occupants without any fear of being collapsed (Kapliński et al, 2016).Building, therefore, are constructed or built to have desired designed satisfaction, comfort and safety. If any of these becomes vulnerable, then the purpose for which the building was built has been defeated (Olagunju et al, 2013). The study by Emmanuel and Ojo (2009) on Relationship between Building Collapse and Poor Quality of Materials and Workmanship in Nigeria concluded that quality of Nigerian structural building materials is not satisfactory neither is the quality of workmanship of Nigerian workers.

According to Baba et al. (2020), recent increases in the unexpected collapses of residential buildings necessitated an investigation as well as a comparison of the mechanical and chemical properties of local steel bars produced by various firms in Nigeria. A number of tests such as hardness, impact and tensile tests and also chemical compositions were carried out on those steel bars received from Kastina and Sharada steel manufactures. Results revealed that the carbon contents of the samples varied between 0.35 - 0.41 %, i.e. above those limits recommended by the ASTM standards for reinforcing steel bars. The hardness values were found to be more than the estimated standard values and increased with the carbon content. The ultimate tensile strengths and yield strengths were noted as 621.6 MPa and 441.1 MPa for Sharada and 473.7 MPa and 324.5 MPa for Kastina mills, respectively. The ASTM and NQSA standards required ultimate tensile strengths as 620 MPa - 690 MPa and this was fulfilled by the Sharada company. The yield strength of samples from both steel producers were below the recommended values, i.e. 420 MPa – 520 MPa of the standards. It can be recommended that strict laws and regulations are needed to guide and control the production and application of steel reinforcement bars.

As the interaction between reinforcing steel and the surrounding concrete, bond is fundamental for all reinforced concrete structures. For those concrete structures located in an aggressive environment bond may be weakened by corrosion of the reinforcing steel, affecting the serviceability and ultimate strength of concrete elements within the structure. While some researchers think corrosion of a limited degree improves the bond between steel and concrete (Maslehuddin et al., 1990), corrosion is considered one of the main causes for the limited durability of steel-reinforced concrete (Fu and Chung, 1997). The basic problem associated with the deterioration of reinforced concrete due to corrosion is not that the reinforcing steel itself is reduced in mechanical strength, but rather that the corrosion products due to the volume increase cause splitting (Cabrera, 1996).

This research by Joshua et al. (2013), investigated the mechanical properties (yield strength, ductility and the ultimate tensile strength) of 12-mm 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/mm2. The yield strengths obtained range between 337.72 N/mm2 and 569.71 N/mm2. 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.

Fang et al., (2006), studied the effect of steel corrosion on bond between steel bars and the surrounding concrete was investigated for different corrosion levels. Both pullout tests and finite element analysis were used and the results from the two were compared. An electrolyte corrosion technique was used toaccelerate steel corrosion. For confined deformed bars, a medium level (around 4%) of corrosion had no substantial influence on the bondstrength, but substantial reduction in bond took place when corrosion increased thereafter to a higher level of around 6%. It is demonstrated that the confinement supplied an effective way to counteract bond loss for corroded steel bars of a medium (around 4% to 6%) corrosion level. The results of finite element analyses, where it was assumed that rust behaved like a granular material, showed a reasonably good agreement with then experiments regarding bond strength and bond stiffness.

Based on the tensile test conducted and the analysis carried out on 1325 samples collected from construction sites at 10 Local Government in Lagos Nigeria, the following conclusions were made. The characteristic high yield stress of diameter 10 samples tested had a total of 70% above 460N/mm2 conforming to BS4449:1997, 9% was between 410 and 460N/mm2, 21% was below the standard code. The characteristic high yield stress of diameter 12 samples tested had a total of 63% above 460N/mm2 conforming to BS 4449:1997, 12% was between 410 and 460N/mm2, 25% was below the standard code. The characteristic high yield stress of diameter 16 samples tested had a total of 54% above 460N/mm2 conforming to BS 4449:1997, 15% was between 410 and 460N/mm2, 31% was completely below the standard code. The characteristic high yield stress of diameter 20 samples tested had a total of 69% above 460N/mm2 conforming to BS 4449:1997, 15% was between 410 and 460N/mm2, 16% was completely below the standard code. The characteristic high yield stress of diameter 25 samples tested had a total of 95% above 460N/mm2 conforming to BS 4449:1997, 0% was between 410 and 460N/mm2, 5% was completely below the standard code. A large percentage of the bars tested were found to comply with the standard code BS 4449:1997 in the aspect of yield stress at 460 N/mm2 and % elongation at 14%. From the results gathered, Alimosho had the highest percentage of reinforcement meeting the appropriate standard while Bariga had the lowest. More of diameter 12 bars were used during construction for slabs and more of diameter 16 would be used for the beams, columns and foundations. This research recommends that the code specification of 460N/mm2 be enforced and efforts should be geared towards upgrading the code to Euro code since BS codes are no longer renewable codes since 2009. This research studies the strength of steel reinforcing bars used in 10 Local Government Areas of Lagos State, Nigeria. Samples of 10mm, 12mm, 16mm, 20mm and 25mm diameter bars were collected from building sites and tested in the State Laboratory. Results obtained show that an average of 70% of the 1325 samples considered met the BS8110 code specifications (Ede et al., 2015).

The chemical compositions and the microstructures of reinforcing steel bars obtained from three different collapsed building sites were studied. Optical emission spectrometer was used to carry out the chemical analysis, while the microstructure was examined using an optical microscopy. The carbon contents of the steel bars were found to be higher than BS4449 and ASTM706 standards, but they are in close range with the Nst-65-Mn standard. The manganese contents of the steel bars are lower, while the sulphur and phosphorus contents are quite higher than the BS4449, ASTM706 and Nst-65-Mn standards. The hardness values of the investigated bars are higher than recommended BS4449 standard but lower than Nst-65-Mn standard. Brittle globules of Fe3P and FeS were observed within the structure possibly due to higher contents of deleterious sulphur and phosphorus. The results suggest that the investigated reinforcing bars are brittle and thus contributing significantly to the collapse of the building structures (Odusote and Adeleke, 2012).

Steel bars are important engineering materials for structural application. In Nigeria, due to incessant building collapse occurrences, it is important to further investigate some of the mechanical and chemical properties of reinforcing steel bars produced from scrap metals in order to ascertain their compliance with the required standard. Three diameters (10, 12 and 16 mm) of the reinforcing steel bars were chosen from each of the eight steel plants (A–H). Chemical composition analyses and mechanical tests (yield strength, ultimate tensile strength and percentage elongation) were performed using optical emission spectrometer and

InstronSatec Series 600DX universal testing machine, respectively. Hardness values of the samples were obtained by conversion of tensile strength based on existing correlation. The results showed that carbon contents, hardness values, yield and ultimate tensile strengths of some of the steel bars were found to be higher than the BS4449, NIS and ASTM A706 standards. The steel bar samples were also found to possess good ductility with samples from steel plants C and D. By observation, all the 12 mm steel bars from steel plants A to H met the required ASTM and BS4449 standards except samples from plant G. This study revealed that most of the investigated reinforcing steel bars have reasonable yield strength, ultimate tensile strength, ductility and hardness properties when compared with the relevant local and international standards. Therefore, they are suitable for structural applications where strength and ductility will be of paramount interest (Odusote et al., 2019).

An investigation was conducted by Anyanwu, Ekengwu and Utu (2019), on the conformance of the mechanical properties of the reinforcement bars used in local building and construction with the BS8110 design standard adopted in Nigerian considering grade S460 reinforcement bars and using Imo State as case study. In this paper, seven Local Government Areas in Imo State were considered as given in table 3.1. Two samples each of 12mm, 16mm and 20mm ribbed bars were collected from each of the seven Local Government Areas considered. The samples have 100cm gauge length and total length of 114cm each as recommended by the laboratory where they were analysed. Tensile test was conducted on each sample using Universal Testing Machine (Avery Denison), while the chemical analysis was done after the tensile test using a spectrometer (spectromax). The results obtained show that out of 21 average result, only 5(24%) of the samples satisfy yield strength requirement based on the acceptability range of (420 – 475) N/mm2 for grade S460 used, which has standard yield strength of 460N/mm2 according to BS8110 code. 2(10%) satisfy elongation requirement based on acceptability range of (11 – 15) % against 14% for grade S460 steel according to BS4449:1997. (10%) satisfy both yield strength and elongation requirement. It was also observed through the chemical analysis that increase in carbon equivalence increases the strength of the steel but decreases its ductility and for a given carbon equivalence, increase in bar size results to decrease in strength but increase in ductility.

Based on the acceptability indices (420 - 470) N/mm2 yield strength and (11-15) % elongation used in this investigation, just 5% of the whole samples tested have satisfactory strength and ductility. The rest of the samples failed either by low strength, excessive strength, low elongation or excessive elongation. Hence, this result show that most of the reinforcement bars used in Nigeria local building and construction has substandard quality and contributes significantly to structural failure common around.

With particular reference to the locally produced bars, the reality of the consequences of the data in Table 1 had always impacted negatively on local steel industry. Risk of failure of structure(s) in which such bars are used is quite high, giving rise to lack of confidence in the quality of locally made bars. This has made the massive importation of the better quality product an imperative. The result is the neglect and underdevelopment of the local steel industry. These are real engineering problems to which an effective solution must be found.Variations of the strain hardening factor parameters in terms of carbon, copper and the Ceq value are presented in Figure 1. The standard deviation for carbon calculated from the data in Table 2 is 0.09 against the acceptable value of 0.05. Although, mild steel mostly used for structural purposes contain 0.15-0.30 percent carbon, billet compositions in the range 0.15-0.25 percent are preferable. The choice of the low carbon level is to prevent embrittlement of the material during strain hardening and the development of undesirable microstructure in the heat-affected zone (HAZ) of such steel bar during welding (Balogun et al., 2009).

Thus, for weldable steel, Ceq$\leq$ 0.51 while Ceq $>$ 0.51 is indicative of non-weldability (BS 4449, 1988). From Figure 1 it can be seen that five out of seven (71.4%) companies' products tested had Ceq values in the range 0.51 – 0.58 and a standard deviation (σ_{Ceq}) of 0.05 as against the normal 0.02. Thisimplies that most locally produced steel bars are non-weldable.

The British standard yield strength of grade S460 steel is 460N/mm2 with percentage elongation of 14% [BS4449:1997], as adopted in Nigeria for structural design. The permissible range of strength and ductility are taken based on practical experience and looking at the difficulty in producing bars of exact required strength and ductility. Any value in the result found above or below the permissible range fails the test and the material (sample) responsible for such value is substandard (Rao, 1961).

Methodology

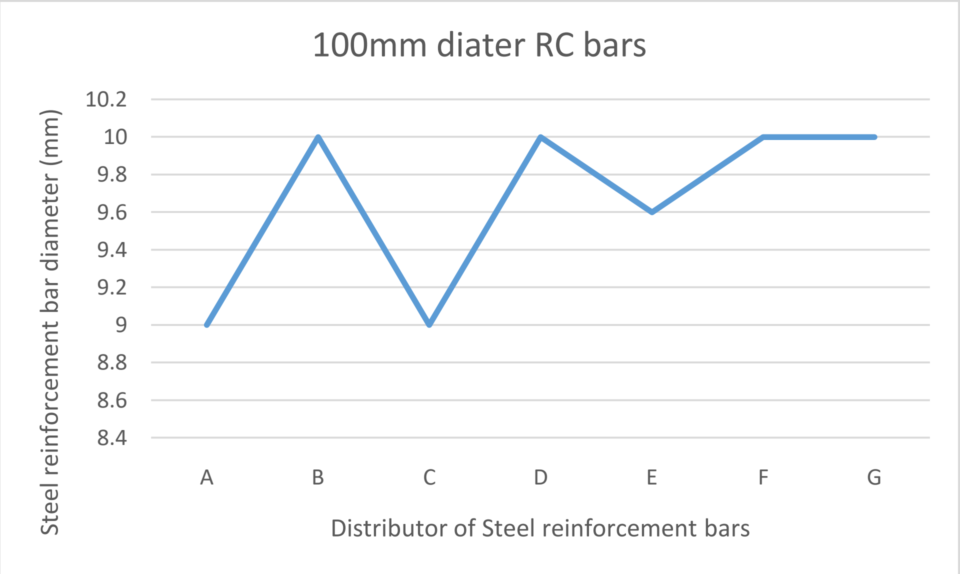
This research was carried out by visiting some major dealers of reinforcement steel bars and other building materials. They sellers or distributors where not confided on the reason of purchasing these rods by the researchers.

The 10mm and 12mm steel bars were purchased and taken to the laboratory for measurement. The measurement was basically to ascertain if the diameters steel bars the distributor sold conformed to their labelled diameter.

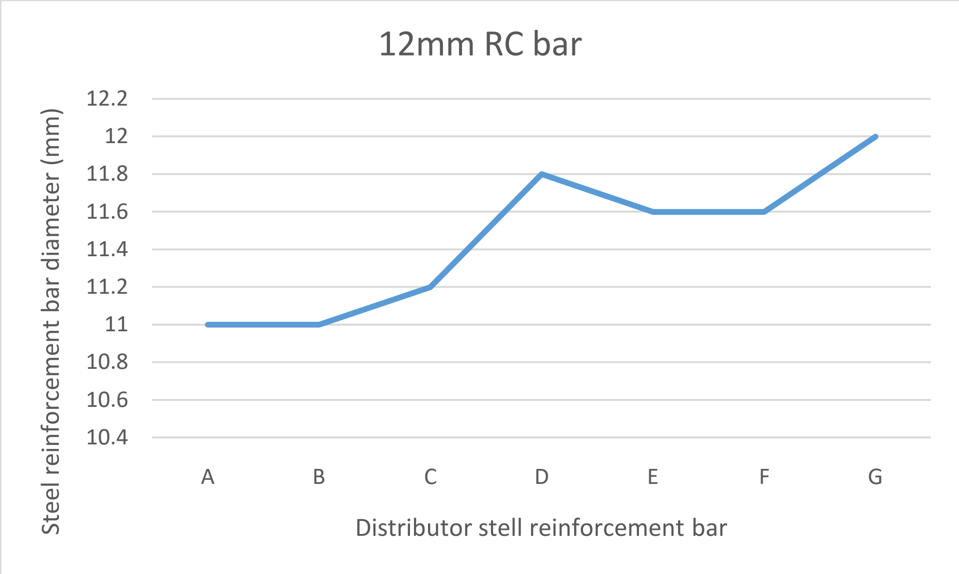
The veneer calliper gauge was used to determine the diameter of the various steel bars. 2 bars were but from seven distributors one 10mm and one 12 mm. the rods specimens were labelled A,B,C,D,E,F and G

Result and Findings

The result of the findings is presented in the graphs below.



Graph 1: the diameters of the 10mm steel reinforcement bars



Graph 2: the diameter of the 12mm reinforcement steel bars.

The arithmetic mean of a given set of numbers, often referred to as the average, is obtained by dividing the sum of the data by the total count of data points.

$$mean = \mu = \frac{\sum x}{n}$$

$$where \sum x \text{ is the sum of all the } x \text{ values and } n \text{ is the number of } x \text{ values}$$

The results provided suggest that the actual diameters of the reinforcement bars obtained from distributors and measured are less than the standard diameters. The standard diameters for the 10mm and 12mm reinforcement bars are 10mm and 12mm, respectively (Graph 1& 2).

The breakdown of the findings:

1. 10mm Reinforcement Bars:
   Standard Diameter: 10mm
   Observed Mean Diameter: 9.66mm
   Interpretation: The mean diameter of the 10mm reinforcement bars obtained from distributors and measured is less than the standard 10mm diameter. This indicates that, on average, the 10mm reinforcement bars examined are undersized.

2. 12mm Reinforcement Bars:
   Standard Diameter: 12mm
   Observed Mean Diameter: 11.46mm
   Interpretation: The mean diameter of the 12mm reinforcement bars obtained from distributors and measured is less than the standard 12mm diameter. Similar to the

10mm bars, this suggests that, on average, the 12mm reinforcement bars examined are undersized.

These findings raise concerns about the conformity of the reinforcement bars provided by the distributors to the specified standards. Undersized reinforcement bars may have implications for the structural integrity and performance of the structures they are used in, as the designed strength and load-bearing capacity could be compromised.

The standard deviation, denoted as σ, quantifies the extent of dispersion of data with respect to the mean. A low standard deviation implies that the data points are closely grouped around the mean, while a high standard deviation suggests that the data points are more widely dispersed. A standard deviation that is close to zero suggests that the data points are in close proximity to the mean, while a high or low standard deviation indicates that the data points are situated above or below the mean, respectively.

$$\sigma = \sqrt{\frac{\sum(x - \mu)}{n}}$$

The standard deviation is a measure of the amount of variation or dispersion in a set of values. A lower standard deviation indicates that the values in the dataset are closer to the mean, suggesting less variability.

1. 10mm Diameter Reinforcement Steel Bars:
   Standard Deviation: 0.47
   Interpretation: A standard deviation of 0.47 for the 10mm diameter reinforcement steel bars suggests that the measured diameters of these bars tend to cluster relatively closely around the mean diameter of 9.66mm. This implies that there is not a significant amount of variability in the diameters of the 10mm bars; they are relatively consistent in size.

2. 12mm Diameter Reinforcement Steel Bars:
   Standard Deviation: 0.40
   Interpretation: Similarly, a standard deviation of 0.40 for the 12mm diameter reinforcement steel bars indicates that the measured diameters of these bars tend to cluster around the mean diameter of 11.46mm. This suggests that, on average, the 12mm bars exhibit less variability in diameter compared to the mean. The values are relatively close to each other.

In both cases, the low standard deviations suggest that the diameter sizes of the reinforcement bars are relatively consistent and do not deviate significantly from the mean values. This can be considered a positive aspect in terms of quality control because it indicates that the measurements are not widely scattered, and the bars are more uniform in size. However, it's important to note that while low standard deviations indicate consistency, they don't provide information about whether the measured values are close to the desired standard diameter. This is where the mean values and the comparison to the standard diameters become crucial for assessing the quality of the reinforcement bars.

It is observed that the Mean diameter for the 10mm reinforcement bar bought from distributors and measured was 9.66mm. This shows that the reinforcement steels did not meet the normal 10mm diameter.

While for the 12mm diameter steel reinforcement bars, the Mean was 11.46mm and this also fall short of the normal 12mm diameter.

The results suggest that the actual diameters of the reinforcement bars obtained from distributors and measured are less than the standard diameters. The standard diameters for the 10mm and 12mm reinforcement bars are 10mm and 12mm, respectively.

Here's a breakdown of the findings:

10mm Reinforcement Bars:

Standard Diameter: 10mm
Observed Mean Diameter: 9.66mm
Interpretation: The mean diameter of the 10mm reinforcement bars obtained from distributors and measured is less than the standard 10mm diameter. This indicates that, on average, the 10mm reinforcement bars examined are undersized.
12mm Reinforcement Bars:

Standard Diameter: 12mm
Observed Mean Diameter: 11.46mm
Interpretation: The mean diameter of the 12mm reinforcement bars obtained from distributors and measured is less than the standard 12mm diameter. Similar to the 10mm bars, this suggests that, on average, the 12mm reinforcement bars examined are undersized.

These findings raise concerns about the conformity of the reinforcement bars provided by the distributors to the specified standards. Undersized reinforcement bars may have implications for the structural integrity and performance of the structures they are used in, as the designed strength and load-bearing capacity could be compromised.

It would be advisable to investigate further, possibly by examining more samples or consulting with the distributors to understand the reasons behind the deviation from standard diameters. This information is crucial for ensuring the quality and safety of structures that use these reinforcement bars.

The result of the standard deviation of 0.47 for the 10mm diameter reinforcement steel bars shows that the samples diameter sizes revolves around the mean value. The same can be said for the 12mm steel reinforcement bar which have a standard deviation of 0.40 (see graph 2).

The standard deviation is a measure of the amount of variation or dispersion in a set of values. A lower standard deviation indicates that the values in the dataset are closer to the mean, suggesting less variability.
10mm Diameter Reinforcement Steel Bars:

Standard Deviation: 0.47
Interpretation: A standard deviation of 0.47 for the 10mm diameter reinforcement steel bars suggests that the measured diameters of these bars tend to cluster relatively closely around

the mean diameter of 9.66mm. This implies that there is not a significant amount of variability in the diameters of the 10mm bars; they are relatively consistent in size.
12mm Diameter Reinforcement Steel Bars:

Standard Deviation: 0.40
Interpretation: Similarly, a standard deviation of 0.40 for the 12mm diameter reinforcement steel bars indicates that the measured diameters of these bars tend to cluster around the mean diameter of 11.46mm. This suggests that, on average, the 12mm bars exhibit less variability in diameter compared to the mean. The values are relatively close to each other.

In both cases, the low standard deviations suggest that the diameter sizes of the reinforcement bars are relatively consistent and do not deviate significantly from the mean values. This can be considered a positive aspect in terms of quality control because it indicates that the measurements are not widely scattered, and the bars are more uniform in size. However, it's important to note that while low standard deviations indicate consistency, they don't provide information about whether the measured values are close to the desired standard diameter. This is where the mean values and the comparison to the standard diameters become crucial for assessing the quality of the reinforcement bars.

Conclusion:
Based on the results of the measurements and statistical analysis of the reinforcement steel bars, several key conclusions can be drawn:

i. Deviation from Standard Diameters:
Both the 10mm and 12mm diameter reinforcement steel bars exhibit mean diameters (9.66mm and 11.46mm, respectively) that fall below the standard specifications of 10mm and 12mm. This indicates a deviation from the expected dimensions, raising concerns about the adherence of the obtained bars to industry standards.

ii. Consistency in Diameter Measurements:
The low standard deviations for both the 10mm (0.47) and 12mm (0.40) bars suggest that the measured diameters tend to cluster closely around their respective mean values. This consistency in measurements is a positive aspect in terms of quality control, indicating that the bars are relatively uniform in size.

iii. Undersized Bars Pose Structural Concerns:
The observed undersized diameters of the reinforcement bars have potential implications for the structural integrity of constructions using these materials. Undersized bars may compromise the designed load-bearing capacity and overall strength of structures, necessitating careful consideration and potential adjustments in construction plans.

iv. Further Investigation Recommended:
To fully understand the reasons behind the observed deviations from standard diameters, further investigation is recommended. This could involve a larger sample size, collaboration with distributors to identify potential sources of variation, and a comprehensive review of manufacturing processes.

v. Quality Assurance Measures:
The findings underscore the importance of robust quality assurance measures in the procurement and use of reinforcement steel bars. Ensuring that construction materials meet industry standards is crucial for the safety and performance of structures.

In conclusion, while the measured reinforcement steel bars demonstrate consistency in diameter measurements, the deviation from standard diameters raises significant concerns regarding their suitability for structural applications. Addressing these concerns requires a comprehensive examination of manufacturing and distribution processes, as well as a commitment to quality control measures to ensure the safety and reliability of construction projects.

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