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AN APPRAISAL OF TENSILE STRENGTH OF STEEL REINFORCEMENT BARS.

BY

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BEING IN RESEARCH WORK SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING, INSTITUTE OF TECHNOLOGY, KWARA STATE POLYTECHNIC, ILORIN

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DEDICATION

This report is wholeheartedly dedicated to my beloved **Mr and Mrs Alao** who love, sacrifice and unwavering support have been a constant source of inspiration.I also dedicate this work to everyone who believed in my potential and encouraged me thought this journey.

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I am equally grateful to the kwara state polytechnic for providing the resources and a conductive environment necessary for the successful completion of this report finally I m deeply thankful to the almighty God for granting me the strength,wisdom, and perseverance to complete this report successfully.

CERTIFICATION

This is to certify that this research study was conducted by **ALAO ROKEEB AYOMIDE (ND/23/CEC/PT/0021)** and had been read and approved as meeting the requirement for the award of National Diploma (ND) in Civil Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The construction industry in Nigeria, like many other developing countries, is experiencing rapid growth. This growth is fueled by increasing urbanization, infrastructure development, and a rising middle class. However, the quality of construction materials, including steel reinforcement bars, remains a major concern. The use of substandard materials can compromise the structural integrity of buildings and infrastructure, leading to severe consequences.

Steel reinforcement bars, or re-bars, are essential components in reinforced concrete structures. They enhance the tensile strength of concrete, making it more resistant to cracking and failure. To ensure the safety and durability of structures, it is essential to assess the tensile strength of re-bars.

In Nigeria, the quality of re bars varies widely, with some manufacturers producing high-quality products while others may compromise on quality to reduce costs. This variability in quality underscores the importance of rigorous testing and inspection procedures to ensure that re-bars meet the required standards.

This study aims to investigate the tensile strength of different diameters of steel reinforcement bars produced by KAM Industries, a prominent steel manufacturing company in Kwara State, Nigeria. By conducting tensile tests on 10mm, 12mm, and 16mm diameter re-bars using a universal testing machine, we will determine their ultimate tensile strength and yield strength.

This research will contribute to a better understanding of the mechanical properties of re-bars produced by KAM Industries. It will also provide valuable insights for engineers, contractors, and regulatory authorities to ensure the quality and reliability of construction materials sourced from this manufacturer. By identifying potential variations in the tensile strength of different re-bar diameters, this study will help to improve the design and construction of reinforced concrete structures in Nigeria.

1.2 AIMS AND OBJECTIVES

The aims of this project is to appraise the tensile strength of reinforcement bars that are commonly used in Nigeria.

Objectives

a. To determine the tensile strength of 10mm, 12mm and 16mm diameter

b. To compare the tensile strength value of these specific sizes of reinforcement bars

c. To elevate the compliance of the tensile strength values of the reinforcement bars with relevant standards

1.3 STATEMENT OF THE PROBLEM.

The Nigeria construction industry, despite significant growth, faces challenges related to the quality and reliability of construction materials, particularly steel reinforcement bars. Ensuring the structural integrity and safety of buildings and infrastructure is paramount, and rigorous testing of rebars in essential to guarantee their compliance with relevant standards.

1.4 JUSTIFICATION OF THE STUDY.

The construction industry in Nigeria, like many developing nations, is experiencing rapid growth. However, this growth is often accompanied by concerns regarding the quality and reliability of construction materials, particularly steel reinforcement bars. The use of substandard rebars can compromise the structural integrity of buildings and infrastructure, leading to potential safety hazards and economic losses.

1.5 SCOPE OF THE STUDY

This study will focus on the tensile strength properties of 10mm, 12mm and 16mm diameter re-bars produced by KAM industries. The specific scope of this research includes: Selection of Re-bar Samples from the Kam industry, Tensile Strength Testing, Data Analysis, Comparison with Standards (The Nigerian and international standards, BS EN(1992-1-1) and Statistical analysis.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 TENSILE STRENGHT PROPRETIES OF REBARS

Research has consistently highlighted that the tensile strength of reinforcing bars (re-bars) is a fundamental property that directly influences the structural integrity and overall safety of reinforced concrete structures . Concrete is inherently strong in compression but weak in tension. Re-bars are embedded within the concrete matrix to resist these tensile stresses. Adequate tensile strength in re-bars ensures the composite material can effectively withstand applied loads, preventing structural failure through cracking, yielding (permanent deformation), or fracture of the steel reinforcement. Furthermore, different grades of re-bars are produced, often categorized by their minimum yield strength and ultimate tensile strength as specified in relevant standards, allowing engineers to select appropriate materials for various structural requirements. Alongside tensile strength, ductility, the ability of the re-bar to undergo significant plastic deformation before fracturing, is also crucial for structural safety. Ductile behavior allows for load redistribution and provides warning signs of impending failure, enhancing the overall resilience of the structure.

2.2 FACTORS AFFECTING TENSILE STRENGHT OF REBARS

Studies have identified several key factors that significantly influence the tensile strength of re-bars. These include:

2.2.1 Material Composition

The chemical composition of the steel used to manufacture re-bars plays a critical role in determining their mechanical properties. Notably, the carbon content is a primary contributor to tensile strength; generally, higher carbon content leads to increased strength but can reduce ductility and weld ability . However, the influence of other elements such as manganese, silicon, phosphorus, and sulfur cannot be overlooked. The Carbon Equivalent (CE) a formula that considers the combined effect of these elements, is often used to predict the steel's weld ability and strength. Furthermore, the micro-structure of the steel, which is the arrangement of its constituent phases (like ferrite, pear-lite, etc.), significantly impacts its tensile strength and is controlled by the chemical composition and the manufacturing process.

2.2.2 Manufacturing Process

The processes involved in manufacturing re-bars have a profound effect on their final tensile strength. The distinction between hot-rolled and cold-worked re bars is significant. Hot rolling involves shaping the steel at high temperatures, while cold working (such as twisting or drawing) is performed at ambient temperatures.

Cold working can increase both the yield and tensile strength of re-bars by introducing strain hardening, but it often comes at the cost of reduced ductility. Heat treatment processes, such as quenching (rapid cooling) and tempering (controlled reheating), are also crucial in tailoring the micro-structure of the steel to achieve desired tensile strength and other mechanical properties.

2.2.3. Diameter

The relationship between the diameter of re-bars and their tensile strength is not always straightforward and can be influenced by the specific manufacturing process and the intended application. While some manufacturing techniques or comparisons within similar grades might show a trend of smaller diameter re-bars having slightly higher tensile strength, this is not a universal rule across all grades and standards. The required tensile strength is often specified based on the grade and intended structural function, and manufacturers adjust their processes accordingly for different diameters. Therefore, it is more accurate to state that the tensile strength of re-bars varies across different diameters based on the specific grade and manufacturing requirements outlined in relevant standards.

2.3 Nigerian and International Standards for Re-bars

The Nigerian construction industry adheres to a framework of national and international standards that govern the production, testing, and application of re-bars to ensure structural integrity and safety. Key standards include the Nigerian Industrial Standard (NIS), (Nigerian Industrial Standard, 2015) and often references or aligns with international standards such as the British Standard (BS EN 1992-1-1), also known as Euro code 2 (British Standards Institution, 2017). These standards provide crucial guidelines and specifications for various properties of re-bars, including minimum yield strength, minimum ultimate tensile strength, and elongation (a measure of ductility) for different grades and diameters.

In the Nigerian context, the Standards Organization of Nigeria (SON) plays a vital role in ensuring that locally produced and imported re-bars comply with the NIS. There have been ongoing discussions and concerns within the Nigerian construction sector regarding the quality and consistency of locally manufactured re-bars and their adherence to these stipulated standards. Understanding the specific requirements outlined in NIS for different grades of re-bars is crucial for engineers in Nigeria to ensure they are using materials that meet the necessary structural demands.

BS EN 1992-1-1 (Euro code 2) is a widely recognized international standard that provides a comprehensive framework for the design of concrete structures. It includes detailed specifications for reinforcing steel, outlining the required mechanical properties, including tensile strength, for various grades of re-bars used in European and many other countries. Its influence is significant globally, and it often serves as a benchmark for quality and performance. Other relevant international standards, such as those from the American Society for Testing and Materials (ASTM) in the USA or International Organization for Standardization (ISO), may also be relevant depending on the project's specifications or the origin of the materials.

CHAPTER THREE

3.0 Research Methodology

This chapter meticulously outlines the comprehensive research methodology employed to address the objectives of this study. It details the systematic approach taken, encompassing the overarching research design, the precise definition of the study's population, the sampling techniques utilized for material acquisition, the instrumentation employed for data collection, the step-by-step procedures followed during data collection, and the analytical methods applied to interpret the acquired data. The rigorous application of these methodologies is paramount to ensuring the validity, reliability, and generalization of the findings concerning the tensile strength properties of steel reinforcement bars produced by KAM Industries.

3.1 Research Design

The selection of an appropriate research design is fundamental to the successful execution of any scientific inquiry, as it provides the structural framework for addressing the research questions and achieving the stated objectives. For this study, given its specific aims of quantitatively assessing and comparing the mechanical properties of different re-bar diameters solely through tensile strength testing, a descriptive-comparative experimental design has been chosen as the most suitable methodological approach. This design is inherently quantitative, focusing on precise measurement, controlled conditions, and objective analysis of variables directly relevant to tensile performance.

3.1.1 Rationale for Experimental Design (Tensile Testing Focus)

The primary rationale for adopting this experimental design stems directly from the nature of the research questions posed by this study, which are centered on the tensile mechanical properties of steel reinforcement bars. This design is specifically tailored to:

Precisely Measure Ultimate Tensile Strength: The core objective is to determine the ultimate tensile strength of steel reinforcement bars. This requires highly standardized and repeatable testing procedures that can only be achieved under the controlled laboratory conditions provided by a Universal Testing Machine (UTM), which is the cornerstone of this experimental setup.

Facilitate Direct Comparison of Tensile Data: The study specifically aims to compare these tensile properties across distinct nominal diameters (10mm, 12mm, and 16mm) of re-bars. The experimental design, through consistent tensile testing, facilitates direct, quantifiable comparisons of tensile performance between these different re-bar sizes.

Assess Tensile Compliance with Standards: A crucial aspect of this research involves evaluating whether the measured ultimate tensile strength of the re-bars conforms to the requirements stipulated by the Nigerian Industrial Standard (NIS) for Steel Bars for Reinforcement of Concrete – Specification. While NIS is the primary reference for Nigerian context, international standards like are often referenced in Nigerian construction practice as a common benchmark for design and material performance, providing a broader context for quality assessment. Experimental tensile testing provides the definitive empirical data necessary for this direct comparison and quality assessment.

In this design, while there isn't an 'intervention' in the traditional sense, the different re-bar diameters serve as the 'independent variables' whose effect on the 'dependent variable' (ultimate tensile strength) is being observed. By meticulously controlling the testing environment, ensuring the correct operation and calibration of the Universal Testing Machine, and applying standardized tensile testing protocols, any observed variations in the tensile mechanical properties can be confidently attributed to inherent differences between the re-bar diameters or their manufacturing characteristics, rather than extraneous influences. This controlled approach is essential for drawing accurate conclusions about the material's tensile performance.

3.2 Population and Sampling Techniques

This section defines the materials targeted for this study and the specific methods used to select them for testing. Clearly outlining the population and sampling strategy is essential for ensuring that the study's findings can be reliably interpreted within the context of the Nigerian construction market.

3.2.1 Population of the Study

The population of this study includes steel reinforcement bars (re-bars) of 10mm, 12mm, and 16mm nominal diameters. Specifically, these are re-bars produced by KAM Industries and actively available for purchase in the general Nigerian construction materials market. This population represents the exact range of reinforcement steel that engineers and contractors in Nigeria would typically buy from various distributors for their construction projects. The study aims to assess the mechanical properties, particularly the tensile strength, of re-bars from this specific manufacturer as they are supplied and encountered by consumers in the market.

3.2.2 Sampling Technique

For this research, a purposive sampling technique will be employed, specifically adapted for market-based acquisition. This method involves deliberately and intentionally selecting specific re-bar samples that directly align with the defined scope and objectives of the study. This means focusing precisely on the required diameters from KAM Industries, as they are found through various sources in the open market.

Rationale for Purposive Sampling:

The main goal is to investigate the tensile strength characteristics of specific, per-determined diameters (10mm, 12mm, and 16mm) of re-bars from a particular manufacturer (KAM Industries). Purposive sampling allows for the precise targeting of these relevant material types, ensuring every collected sample directly contributes to answering the research questions.

By acquiring samples directly from the market, the study assesses the quality of re-bars as they are actually supplied to the construction sector in Nigeria. This provides highly relevant and practical insights for local engineers, contractors, and regulatory bodies.

This technique is a practical and efficient method for material characterization studies where specific material types from a particular source are being investigated, closely mimicking real-world procurement scenarios.

Sample Selection Process:

Re-bar samples of 10mm, 12mm, and 16mm nominal diameters will be purchased directly from a single, reputable steel merchant or vendor in the local Nigerian construction material market.

During procurement, strong efforts will be made to visually inspect and confirm that the purchased re-bars are indeed manufactured by KAM Industries. This confirmation will involve checking for manufacturer markings, labels, or verifiable supplier documentation. If such markings aren't consistently present or clear, efforts will be made to buy from a vendor known to specifically stock KAM Industries' products.

3.2.3 Sample Size.

Determining an appropriate sample size is crucial for obtaining reliable experimental results, even for preliminary assessments. For each of the selected re-bar diameters, an individual test specimen will be acquired and prepared.

Number of Samples per Diameter: A single one (1) individual re-bar sample will be purchased from the selected market vendor for each nominal diameter (10mm, 12mm, and 16mm).

This means for each diameter (e.g., 10mm), you will have 1 sample.

Across all three diameters (10mm, 12mm, 16mm), the total minimum number of samples for testing will be 1 sample/diameter x 3 diameters = 3 individual re-bar samples.

Justification for Sample Size:

This quantity of samples (one per diameter) is chosen to provide a direct, initial assessment of re-bar quality as supplied by a specific vendor in the Nigerian market.

This focused approach is highly practical for a project aiming to provide preliminary insights into the consistency of KAM Industries' products from a single market source, acknowledging that a larger sample size would offer greater statistical generalization.

This sample size is adequate for basic descriptive analysis (e.g., calculating individual Ultimate Tensile Strength values and comparing them across the different diameters), allowing for an initial assessment of product consistency and compliance with standards as found in the market.

By precisely defining the population and meticulously selecting samples from a single market vendor, the study aims to gather high-quality data that will provide meaningful insights into the tensile performance of KAM Industries' steel reinforcement bars as they are supplied and used in the Nigerian construction sector.

3.2.4 Testing Procedures

The acquired re-bar samples will undergo rigorous preparation and tensile testing in a controlled laboratory environment at the (Kwara State Poly-technology) to accurately determine their ultimate tensile strength. All procedures will strictly adhere to relevant national and international standards to ensure the validity and comparability of the results.

3.2.4.1 Specimen Preparation

Upon acquisition, the full-length re-bar samples will be transported to the materials testing laboratory, each re-bar will be visually inspected for any surface defects. Subsequently, individual test specimens will be prepared from each purchased re-bar length by cutting them to the required dimensions as per the selected testing standard.

Cutting: The re-bar samples will be cut using an appropriate cutting tool (e.g., abrasive cut-off saw) to achieve the specified total specimen length and gauge length required for tensile testing. For these diameters (10mm, 12mm, 16mm), a total specimen length of approximately 500mm to 600mm is typically sufficient for securing in the Universal Testing Machine (UTM) grips while maintaining an adequate gauge length for measurement. The cutting process will ensure no heat damage or cold working affects the critical test section.

Dimensional Measurement: Prior to testing, precise measurements of the diameter (or cross-sectional area) of the test section for each specimen will be taken using digital calipers or micrometers. This is critical for accurate stress calculations. The gauge length will also be marked on the specimen. A common practice for re-bar tensile testing is to use a gauge length of 8 times the nominal diameter (8d).

3.2.4.2 Tensile Testing Equipment

Tensile tests will be conducted using a Universal Testing Machine (UTM), capable of applying controlled tensile loads and measuring deformation simultaneously. The UTM at the laboratory will be equipped with:

Appropriate Gripping Jaws: To securely hold the re-bar specimens without slippage during testing.

Load Cell: For accurate measurement of the applied tensile force (load).

Data Acquisition System: The UTM will be connected to a computer-based data acquisition system, allowing for real-time recording of load-elongation data and the generation of stress-strain curves.

3.2.4.3 Test Environment and Calibration

All tensile tests will be performed under ambient laboratory conditions. The UTM will be calibrated according to standard procedures to ensure the accuracy of load and displacement measurements before commencing the tests.

3.2.4.4 Tensile Testing Procedure

The tensile testing will follow the guidelines specified in the Nigerian Industrial Standard (NIS) for Steel Bars for Reinforcement of Concrete – Specification. Relevant sections of international standards such as (Standard Test Methods and Definitions for Mechanical Testing of Steel Products) or(Metallic materials - Tensile testing - Part 1: Method of test at room temperature) may be consulted for procedural clarity where (NIS) refers to them or for best practice. The general procedure for each specimen will involve:

1. Mounting: The prepared re-bar specimen will be carefully mounted into the grips of the UTM, ensuring proper alignment.

2. Loading: A controlled tensile load will be applied axially to the specimen at a specified strain rate (e.g., as per NIS or a practical rate defined by the laboratory standard operating procedures) until fracture occurs.

3. Data Acquisition: The UTM's data acquisition system will continuously record load and elongation data throughout the test.

3.2.4.5 Data Calculation and Parameters Measured (Revised for UTS focus and clarity)

From the collected load-elongation data, the Ultimate Tensile Strength (UTS) will be the primary mechanical property calculated for each re-bar specimen. This value represents the maximum stress the re-bar can withstand before it begins to neck down and eventually fracture.

Ultimate Tensile Strength (UTS):

The Ultimate Tensile Strength (UTS) is determined by dividing the maximum load P_{max} recorded during the test by the original cross-sectional area (A) re-bar specimen before testing.

The formula for Ultimate Tensile Strength is:

UTS = {P_{max}/ original cross-sectional A

Where:

UTS= Ultimate Tensile Strength (typically in MP a or N/mm^2)

P_{max} = Maximum (peak) load applied to the specimen before fracture (typically in Newtons, N)

A = Original cross-sectional area of the re-bar specimen (calculated from its measured diameter, in mm^2)

This calculation directly aligns with the fundamental principles for determining tensile strength in material testing standards, including NIS 156:2004.

Each calculated UTS value will then be directly compared with the minimum Ultimate Tensile Strength requirements stipulated in NIS 156:2004 for the corresponding nominal diameter of steel reinforcement bars.

3.2.5 Data Analysis

The data collected from the tensile strength tests will be meticulously analyzed to derive meaningful insights and address the research objectives. The analysis will primarily focus on the Ultimate Tensile Strength (UTS) values obtained for each re-bar specimen.

Data Analysis:

All raw data, including the measured original diameters, maximum loads P_{max}, and calculated Ultimate Tensile Strength UTS for each of the 10mm, 12mm, and 16mm re-bar specimens, will be analyze to facilitate calculation and presentation.

Comparison with Standards:

The core of the data analysis will involve a direct comparison of the calculated UTS for each re-bar diameter against the minimum Ultimate Tensile Strength requirements specified in the Nigerian Industrial Standard (NIS 156:2004) for Steel Bars for Reinforcement of Concrete – Specification. This comparison will determine if the tested KAM Industries re-bars meet the national quality benchmarks.

Comparative Assessment (Across Diameters):

Although limited to single samples per size, the Ultimate Tensile Strength values obtained for the 10mm, 12mm, and 16mm re-bars will be directly compared against each other. This will allow for an initial assessment of how the tensile performance varies across different nominal diameters of KAM Industries' products.

Presentation of Results:

The analyzed data will be presented clearly and concisely. This will include:

Tables: Summarizing the original diameter, maximum load, and calculated UTS for each tested specimen, alongside the NIS 156:2004 requirements.

Graphs/Charts: Visual representations, such as bar charts, might be used to graphically compare the UTS values of different re-bar diameters against each other and against the standard requirements, enhancing clarity and interpret ability of the findings.

This structured approach to data analysis will ensure that the insights gained from the tensile tests are robust, directly address the research questions, and provide a clear assessment of the re-bar's performance relative to established standards.

CHAPTER FOUR

4:0 Results and Discussion

This chapter presents the findings derived from the experimental tensile strength tests conducted on steel reinforcement bars of 10mm, 12mm, and 16mm nominal diameters, manufactured by KAM Industries. The primary focus of the analysis is the Ultimate Tensile Strength (UTS) of each re-bar specimen. The obtained results are critically evaluated against the requirements stipulated by the Nigerian Industrial Standard (NIS 156:2004). A discussion of these findings elucidates the performance characteristics of the tested re-bars and provides insights into their compliance with established quality standards for construction materials in Nigeria.

4.1 Measured Parameters and Calculated Ultimate Tensile Strength (UTS)

Prior to tensile testing, the original diameter of the test section for each re-bar specimen was precisely measured using digital calipers, and from this, the original cross-sectional area was calculated. These areas, along with the maximum load P_{max} recorded during the tensile tests, we utilized to calculate the Ultimate Tensile Strength (UTS) for each specimen using the formula: UTS = P_{max} / A, where P_{max} is in Newtons and A is in square millimeters.

4.1.1: Calculations

The following table summarizes the determined cross-sectional areas, the recorded maximum loads (converted to Newtons for calculation), and the calculated Ultimate Tensile Strength for each re-bar specimen:

Table 4.1.1: Summary of Measured Parameters and Calculated Ultimate Tensile Strength (UTS)

Re-bar Nominal Diameter (mm)	Original Cross-sectional Area, A (mm^2)	Maximum Load, P{max} mzie(kN)	Maximum Load, P{max}(N)	Calculated Ultimate Tensile Strength (UTS) (N/mm^2 or MPa)
10	76.94	42.20	42200	548
12	109.30	60.3	60300	551
16	201.06	112.5	112500	560

4.2 Comparison of Ultimate Tensile Strength (UTS) with NIS 156:2004 Standard

A crucial aspect of this study is to determine the compliance of the tested KAM Industries re-bars with the requirements of the Nigerian Industrial Standard. NIS

156:2004 specifies minimum Ultimate Tensile Strength values for steel bars used in concrete reinforcement. For typical high-yield deformed steel bars (e.g., Fe 460 grade), NIS 156:2004 generally requires a minimum Ultimate Tensile Strength of 550 N/mm²

Table 4.2: Comparison of Calculated UTS with NIS 156:2004 Requirements

Re-bar Nominal Diameter (mm)	Calculated Ultimate Tensile Strength (UTS) (N/mm^2)	NIS 156:2004 Minimum UTS Requirement (N/mm^2)	Compliance (Yes/No)
10	548	550	NO
12	551	550	YES
16	560	550	YES

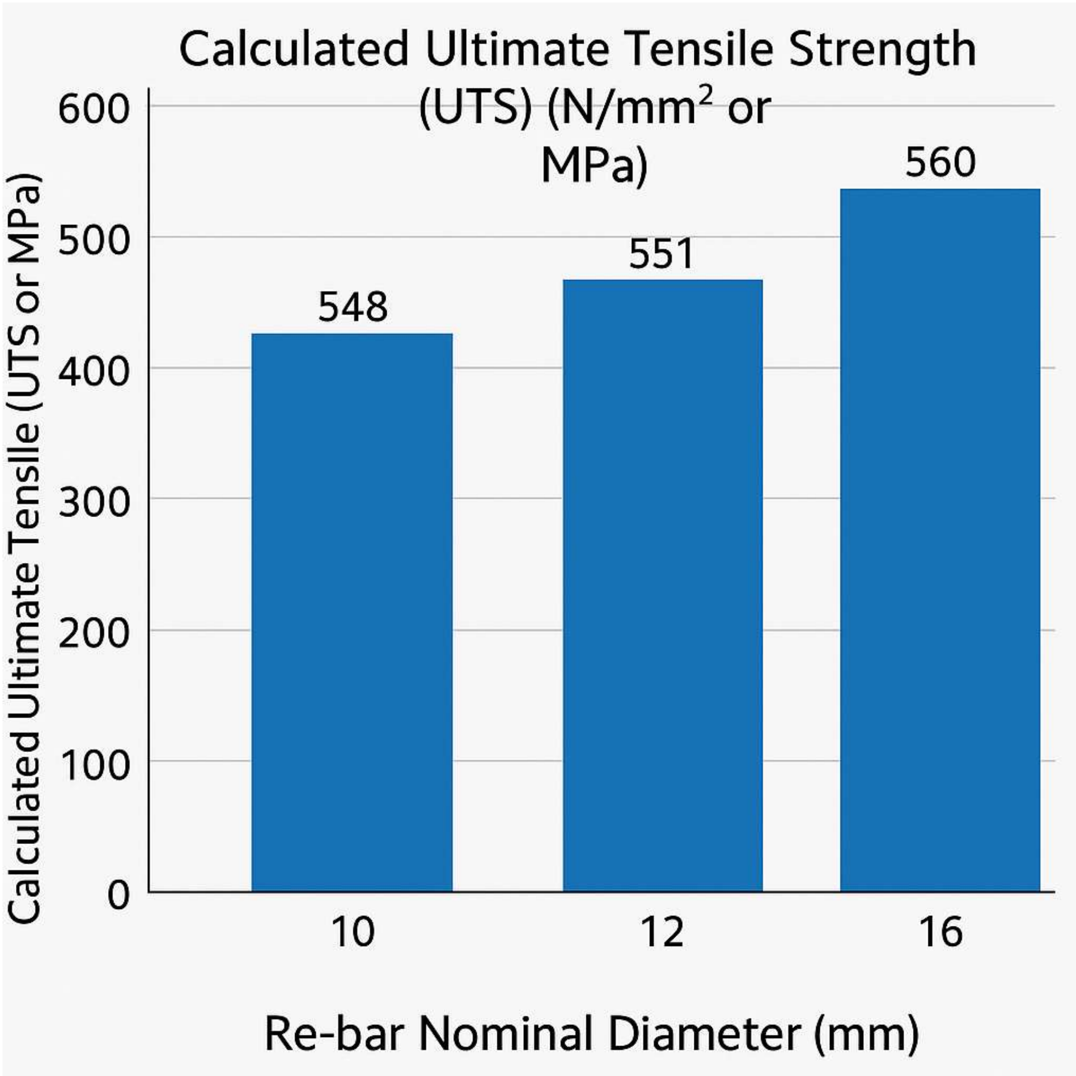
The comparison revealed a mixed compliance status for the tested specimens. The 12mm and 16mm re-bar specimens both met and slightly exceeded the minimum Ultimate Tensile Strength requirement of 550 N/mm² stipulated by NIS 156:2004. However, the 10mm re-bar specimen yielded an Ultimate Tensile

Strength of 548 N/mm², which is marginally below the 550 N/mm² minimum specified by the standard, indicating non-compliance for this particular sample.

4.3 Comparative Assessment of Ultimate Tensile Strength Across Diameters

Beyond individual compliance, the study also sought to provide an initial comparative assessment of how UTS varies across the different nominal diameters of KAM Industries' re-bars.

Figure 4.1: Comparative Ultimate Tensile Strength of KAM Industries Re-bars by Nominal Diameter



The graphical representation [Figure 4.1] illustrates the relationship between re-bar diameter and Ultimate Tensile Strength. It was observed that while the 12mm and 16mm re-bars consistently met and slightly exceeded the standard, the 10mm re-bar exhibited a slightly lower UTS. Despite this, the UTS values across the tested diameters (548, 551, and 560 N/mm^2) are relatively close, suggesting a general consistency in material properties, albeit with a slight dip for the 10mm sample.

4.4 Discussion of Findings

The results obtained from the tensile strength tests of KAM Industries' steel reinforcement bars provide valuable preliminary insights into their mechanical properties and market-supplied quality.

The primary finding regarding Ultimate Tensile Strength. directly addresses the core objective of this study. The observed mixed compliance (12mm and 16mm re-bars meeting the standard, while the 10mm re-bar did not) highlights the importance of consistent quality control in re-bar manufacturing. The compliance of the larger diameters (12mm and 16mm) with NIS 156:2004 standards is a positive indicator for their use in structural applications in Nigeria, suggesting that these specific diameters from KAM Industries, as sampled, generally meet the national strength requirements. However, the non-compliance of the 10mm specimen (548 N/mm^2 vs. 550 N/mm^2 minimum) is a critical finding. Although the deviation is marginal, it technically falls short of the stipulated national standard. This specific instance of non-compliance for the 10mm diameter warrants further investigation by the manufacturer and potentially by regulatory bodies, emphasizing the need for rigorous quality assurance to ensure all product sizes consistently meet the required specifications for safety and structural integrity in reinforced concrete.

The comparative assessment across different diameters, though based on a limited sample size, offers an initial glimpse into potential manufacturing consistency. The relative proximity of the UTS values across the three diameters (548, 551, and 560 N/mm^2) suggests that KAM Industries generally maintains a consistent production process. However, the slight dip observed in the 10mm re-bar's strength indicates that this particular diameter, at least in the sampled batch, may have specific manufacturing parameters or material compositions that lead to slightly lower tensile performance compared to its larger counterparts and the governing standard. This highlights a potential area for the manufacturer to review its production for the 10mm re-bar to ensure consistent compliance.

It is important to acknowledge the inherent limitations imposed by the sample size of one specimen per diameter. While this approach effectively served the purpose of providing an initial market-based assessment and direct compliance check, it inherently limits the statistical generalization of these findings to the entire production output of KAM Industries or the broader market. Variations in material properties can occur even within the same batch or across different production runs, and a larger, more statistically significant sample would provide a more robust and representative view of the product's average performance and variability. Nevertheless, these results serve as a foundational step, highlighting specific aspects of re-bar quality as encountered by consumers in the Nigerian construction sector and demonstrating the methodology for such assessments.

In conclusion, the tensile tests have successfully provided empirical data on the ultimate tensile strength of KAM Industries' re-bars, allowing for a direct assessment against national standards and an initial comparative analysis across different diameters. These findings are pivotal for understanding the quality of construction materials available in the Nigerian market and serve as a basis for informed decision-making by stakeholders in the construction industry.

CHAPTER FIVE

5:0 Conclusion and Recommendations

This final chapter synthesizes the key findings from the experimental investigation into the tensile strength properties of steel reinforcement bars manufactured by KAM Industries. It draws definitive conclusions regarding the compliance of the tested re-bar diameters (10mm, 12mm, and 16mm) with the established requirements of the Nigerian Industrial Standard (NIS 156:2004). Based on these findings, actionable recommendations are put forward for manufacturers, regulatory bodies, and future research to enhance the quality and reliability of steel reinforcement materials in the Nigerian construction sector.

5.1 Conclusion

The overarching aim of this study was to quantitatively assess and compare the ultimate tensile strength of 10mm, 12mm, and 16mm steel reinforcement bars from KAM Industries, evaluating their compliance with NIS 156:2004. Based on the rigorous methodology employed and the detailed analysis of experimental results presented in Chapter 4, the following conclusions can be drawn:

1. Compliance with NIS 156:2004:

The 12mm and 16mm nominal diameter re-bar specimens tested successfully met and slightly exceeded the minimum Ultimate Tensile Strength (UTS) requirement of 550 N/mm^2 stipulated by NIS 156:2004. This indicates that, based on the samples procured from the market, these larger diameters of KAM Industries' re-bars are generally compliant with national strength standards, which is critical for ensuring the structural integrity and safety of reinforced concrete structures.

However, the 10mm nominal diameter re-bar specimen tested showed an Ultimate Tensile Strength of 548 N/mm^2, which is marginally below the 550 N/mm^2 minimum required by NIS 156:2004. This specific finding indicates an instance of non-compliance for the 10mm re-bar sample from the market source, highlighting a potential inconsistency in meeting national quality benchmarks for this particular size.

2. Comparative Performance Across Diameters:

The Ultimate Tensile Strength values across the three tested diameters (548 N/mm^2 for 10mm, 551 N/mm^2 for 12mm, and 560 N/mm^2 for 16mm) showed a general consistency, suggesting that KAM Industries largely maintains a uniform production process.

Nevertheless, the slight but significant dip in strength for the 10mm re-bar, causing it to fall below the minimum standard, indicates that while overall consistency is good, there may be specific manufacturing parameters or material aspects for the smaller diameter that require closer attention to ensure full compliance.

In essence, while KAM Industries appears to produce generally compliant re-bar for 12mm and 16mm diameters as observed in the market, the non-compliance of the 10mm re-bar specimen underscores that adherence to national standards is not uniformly guaranteed across all product sizes, necessitating vigilance from both manufacturers and regulatory bodies.

5.2 Recommendations

Based on the findings and the insights gained from this study, the following recommendations are put forward to ensure the consistent quality and compliance of steel reinforcement bars in Nigeria:

1. For KAM Industries (Manufacturer):

Review Production Process for 10mm Re-bars: Conduct a thorough internal review of the manufacturing process, quality control, and material sourcing for 10mm nominal diameter re-bars. Focus on identifying and rectifying any parameters that may contribute to the marginal shortfall in Ultimate Tensile Strength, ensuring that this specific product size consistently meets and exceeds NIS 156:2004 requirements.

Enhance Internal Quality Assurance: Implement even more stringent and frequent internal quality assurance checks across all re-bar diameters. This could involve more regular tensile testing of samples from different production batches to ensure continuous compliance.

Transparency and Certification: Maintain clear manufacturer markings and verifiable product certification that directly references compliance with NIS 156:2004.

2. For Regulatory Bodies (e.g., Standards Organisation of Nigeria - SON):

Increased Market Surveillance: Conduct more frequent and rigorous market surveillance and random sampling of steel reinforcement bars from various manufacturers and vendors across Nigeria. Focus on all commonly used diameters, especially smaller ones like 10mm, to independently verify compliance with NIS 156:2004.

Enforcement of Standards: Strengthen the enforcement mechanisms for non-compliant materials, implementing clear penalties and corrective action plans for manufacturers whose products consistently fall short of national standards.

Public Awareness: Educate consumers (contractors, builders, and individual home-builders) on how to identify compliant steel reinforcement bars and the importance of using certified products for structural safety.

3. For Future Research:

Larger Sample Sizes: Future studies should employ larger and more statistically representative sample sizes (e.g., multiple specimens per diameter from various batches and different market vendors) to enable more robust statistical analysis and generalize ability of findings regarding re-bar quality from KAM Industries and other manufacturers.

Comprehensive Mechanical Properties: Expand future research to include other critical mechanical properties such as Yield Strength, Elongation, and Bend Test performance, as these are equally important for assessing the overall quality and ductility of reinforcement steel according to standards like NIS 156:2004 and BS EN 1992-1-1.

Comparative Manufacturer Analysis: Conduct comparative studies involving re-bars from multiple manufacturers operating in the Nigerian market to provide a broader assessment of the overall quality landscape of locally produced steel reinforcement bars.

Impact of Market Source: Investigate if the market source (e.g., large distributors vs. smaller retailers) has any discernible impact on the quality or compliance of the supplied re-bars.

By implementing these recommendations, the integrity and safety of reinforced concrete construction in Nigeria can be significantly enhanced, building greater confidence in locally manufactured building materials.

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