INVESTIGATION OF CEMENT MORTAR AND STEEL USED IN REINFORCED CONCRETE IN NIGERIA

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INVESTIGATION OF CEMENT MORTAR AND STEEL USED IN REINFORCED CONCRETE IN NIGERIA

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Abstract

"INVESTIGATION OF CEMENT MORTAR AND STEEL USED IN REINFORCED CONCRETE IN NIGERIA"

The study explores the investigation of the chemical composition, microstructure and mechanical properties of steel and cement mortar used in reinforced concrete. The compositions and mechanical properties of the locally produced steel were analyzed to ascertain their potential for applications for construction.

Two samples of construction steels produced and used in Nigeria were studied along. The chemical compositions of these steels were determined using Solaris CCD techniques. The microstructure of the steels was characterized using an Optical microscopy.

Similarly, two of the cement samples that are produced and commonly used in the Nigerian market were studied. The chemical compositions of the cements were determined using X-ray Fluorescence and X-ray Diffraction techniques. The cements were mixed with standard river sand to produce mortar with well controlled mixed proportions .The setting time and soundness of the mortar were determined along with their compressive and flexural strengths. The implications of the results were discussed for the development of manufacturing of steel and cement and construction codes that could significantly improve the safety and reliability of African buildings.

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DEDICATION

I dedicate this work to God the Father, God the son, and God the Holy Spirit . You gave me knowledge and understanding which led to the success of this research. Without You Lord, I would have not been able to accomplish anything. My heart-felt gratitude to You, Lord.

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CHAPTER ONE: BACKGROUND AND INTRODUCTION

1.1 INTRODUCTION

Engineering failure of buildings has been a general concern to civil, structural and materials engineers. Studies have shown that some of these causes are as the results of bad designs, Faulty construction, Foundation Failure, Over Loads, Fatigue, and Thermal environmental effects on concrete. However, most of the failures are frequently are also attributed to the misuse of materials. The major constituents of materials used in reinforced concrete are cement, steel and aggregates. These materials are essential components of enhancing better mechanical properties and the durability of said reinforced concrete.

In virtually every construction project the safety and durability of the finished structure are critical to its success. Essential to achieving this, is the implementation of effective quality control procedures of construction materials such as steel and cement. Steel and cement are the two very essential construction materials of this century. The construction industry is largely dependent on these materials for durable and quality structures.

Ever since steel began to be used in the construction of structures, it has made possible some of the grandest structures both in the past and also in the present day .

For instance, Considerable progress has been achieved through the use of steel-fiber reinforced concrete (SFR) to enhance structures.

The fundamental properties of SFRC using these new materials have been investigated and compare with those of standard/ imported .

The tensile strength is important for concrete structures as a basic mechanical property and factor of good durability. Since concrete is generally weak and brittle in tension compared to its capacity in compression, steel –fiber reinforcing is a practical means developed for a better control of the tensile performance of concrete.

According to studies, Steel- fiber reinforced concrete (SFRC) has various excellent properties as a composite material; for instance, flexural strength, tensile strength, shear strength, toughness, impact resistance etc are improved by the used of steel fiber.

In order for this properties to be achieved, the production of the steel serving as a fiber must highly be considered [1].

1.2 STEEL

The chemical composition of steel is not the only mechanistic means to control the properties of structural steel. The chemical composition is linked to processing and microstructure for the overall quality of the steel. Most properties depend on the microstructure for a specific steel composition. For example, Yield strength and hardness of the steel are microstructure dependent. Such properties are described as microstructure-sensitive.

In order to achieve the desire microstructure, the steel is processed. Through processing of steel, the means of developing and controlling the microstructure is obtained, hence mechanical properties. For example, hot rolling, quenching, normalizing and so forth. It cannot be over-emphasized that the microstructure plays a primary role in providing the properties desired for application. It is therefore glaring that the properties of a material can be tailored by its chemical structure and microstructural manipulations [2].

Several studies have been done to investigate the quality of locally produced construction steel bars used for concrete reinforcement. Most of these studies have focused on chemical composition of the bars and relate the composition to the mechanical properties.

According to a report, high carbon concentration of locally produced steels from scraps is noticed in Nigerian products. The source reported that this could be one aspect of structural failure as these bars contained high carbon content [3].

Furthermore, cement is another component of the concrete. It is a paste that holds concrete ingredients (steel, sand and aggregates) together. Without cement, none of these ingredients of concrete can successfully combine to achieve desired structural support.

1.3 CEMENT

Cement is defined as an adhesive material that is good at holding fragments of solid matter together and make it rigid over time [4].

When cement is mixed with water, cement functions by performing plastic paste with water which grows very rigid(sets) and gradually grows in compressive strength through reactions that occur chemically. This is said to be the hydration reaction of cement. The material is categorized hydraulic when it is store in water such as hardened cement and increases in strength [5]. Portland cement is pre-eminent based on its balanced of composition and excellent performance. As it has been said, processing plays a major role in the manufacturing of any material.

The properties of the final products of Portland cements are reliant on the chemical and morphological composition of gypsum, clinker and other additives introduced during the process of grinding. However, changes in cement properties could occur during subsequent storage in different environments. The quality of cement can be extremely reliant on the quality of clinker which means that any consideration of this characteristic requires basic knowledge of the factors the control the quality of processing clinker [6].

According to Ashby, concrete as a particulate composite held together by an adhesive-the cement paste. Cement contains flaws and cracks when it is made, with a low fracture toughness: K_{IC} is about 0.3MPa $m^{1/2}$ [7].

However, Plain unreinforced cementitious materials(mortars) are likewise characterized by low tensile strength, and low tensile strain capacities, that is, they are brittle materials. They thus require reinforcement before they can be used extensively as construction materials. The livelihoods of the structure is promoted when reinforced with quality steel, as the reinforcement remains the main portion that bears the loads.

Therefore, to ensure sustainable and reliable structures, construction materials such as steel and cement should be designed with the concept of quality and durability rather than strength alone.

1.4 UNRESOLVED PROBLEMS

While structural collapse remains challenging in our environment today, studies have been conducted to ensure that these failures are minimize. These studies have shown that, faulty construction, poor designs, substandard materials, inadequate application of materials and poor construction methods etc, are amongst impediments of such failures.

However, construction materials such as steel bars may appear as “fit” for application even when subjected to so-called quality checks. External quality does not account for the internal and durability of structures. Equality, chemical compositions, strength, hardness are amongst properties that contribute to the properties of a material. But these properties are empirical to the overall properties of the structural materials. Generally, the chemical structure and the microstructure of a material control its properties**.** An important difference between the two is that while the chemical structure is relatively fixed, the microstructure depends strongly on how the material is made and can thus be controlled. Hence, the microstructure gives information why the properties of a material change. Thus the microstructure provides a link between processing (how a material is made) and properties (how a material behaves).These relationships significantly influence the quality of the material. The below paradigm of materials science depicts this relationship:

PROCESSING **MICROSRUCTURE** PROPERTIES

The microstructure of a material depends on the way that it is processed, and the properties depend on the microstructure. If these relationships are understood, the material properties can be controlled, predicted, and improved.

The solutions to these problems such as maintaining the Quality of locally construction materials-steel and cement, and the microstructure of steel as it relates to its mechanical properties are the reasons of this paper. It aims at the development of manufacturing and construction codes that could significantly improve the safety and reliability of African buildings and steel structures?

1.5 OBJECTIVES

The aim of this work is as follows:

- To analyze chemical composition & microstructure of locally produced cement and steel
- To relate the microstructure to mechanical properties of steel reinforced concrete
- To investigate cement-strength

- To improve on locally produced materials for the construction industry

1.6 SCOPE OF WORK

This paper investigates the chemical composition, microstructure and mechanical properties of locally produced steel and cement .The paper then relates the implications of the results to reinforced concrete for the construction industry.

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CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

The onset of the nineteenth century witnessed the transformation of structural materials with better mechanical behavior. This is of no exception to the construction industry. The construction industry uses concrete to enhance the strength and thereby improve the durability of the structure. Concrete is a composite which constitutes steel, cement and aggregate. Thus, contemporary concrete is reinforced with steel to enhance appropriate mechanical properties.

The appearance and strength of concrete can directly affect the final structure. The two major constituents of concrete are cement and steel bars in modern structures such as buildings, bridges, tunnels and etc. These structural materials must be produced with some level of sanctity for applications in the construction industry.

On the contrary, with the use of these new materials, the fact still exists that structures mentioned still suffer from various failures. In some parts of the World such as Europe, the Americas and Asia suffer structural losses as a result of natural disasters such as earthquakes, storm (e.g. typhoons, hurricane), flood etc. unlike Africa where most of such disasters are uncommon and rare. Yet, in the past two decades, there has been an alarming report of structural failures especially in one of Africa's most populated country of Nigeria[1] .

According to a source , The World's second largest continent-Africa with 53 nations, about 750 million people, with the highest population growth and with diversified natural resources looks forward at the beginning of the twentieth century for real development in all fronts. Africa needs to apply technology wisely, needs to comprehend the lessons of its predecessors examples in Europe, America and more recently in Asia. As per an estimate by 2050 more than 75% of the African population will live in urban areas. To meet and serve these frequent and far reaching changes, large quantities of materials are required for the construction of shelters and infrastructures. Concrete due to obvious reasons lends itself as the only feasible material capable of meeting these needs [2].

The amount of materials needed for decent living is unimaginable. Concrete being the most important material for construction Worldwide plays a predominant role in any society. In fact, concrete consumption is a real indicator of social progress and development in any country. There is a clear need for materials of better quality to address this concern [p3]. Therefore some of these materials include cement and steel which should be of good quality to address these requirements.

2.1.1 STEEL

An addition of carbon in small quantities generates steel. The influence of carbon on mechanical properties of iron is much larger than other alloying elements. Varying the amount of alloying elements and the form of their presence in the steel (solute elements, precipitated phase) controls qualities such as the hardness, ductility, and tensile strength of the resulting steel. Steel with increased carbon content can be made harder and stronger than iron, but such steel is also less ductile than iron.

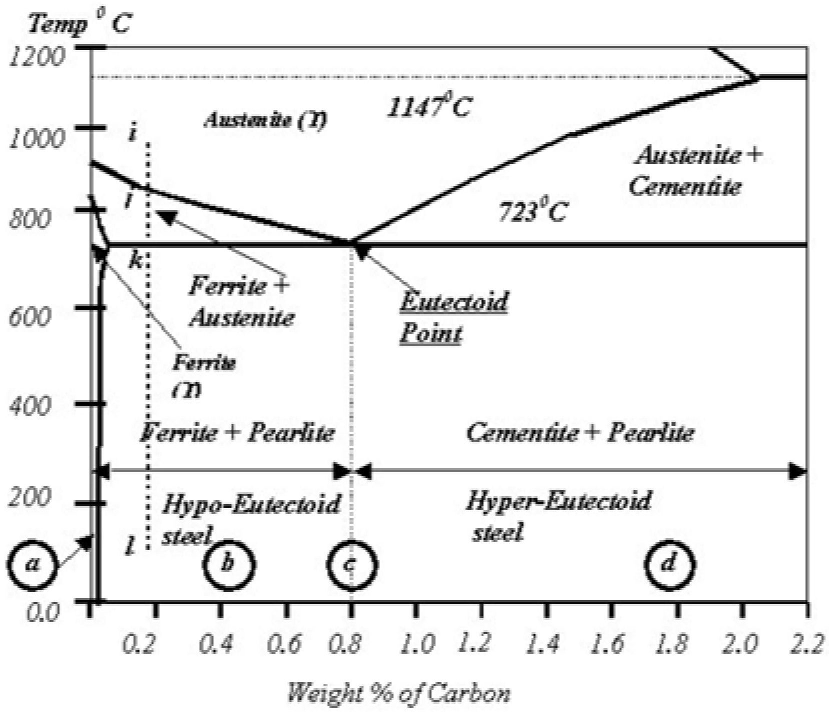

Figure 2.1: *The iron–iron carbon phase diagram*

Increase in carbon content is not the only way to obtain increased strength of steels. Mechanical strength and ductility of steel can be improved even with low carbon content when proper processing mechanism is explore. The iron-iron carbon phase equilibrium diagram in figure 2.1 is a plot of transformation of iron with respect to carbon content and temperature.

2.1.2 IMPORTANT PHASES

(I) Ferrite (α): usually pure iron and is stable at all temperatures up to 9100^0C and the solubility of carbon is dependent on temperature. Ferrite is soft and ductile.

(ii) Pearlite: A fine mixture of ferrite and cementite arranged in lamellar form. It is stable at all temperatures below 723oC. Pearlite is hard and imparts mechanical strength to steel. The higher the carbon content, the higher would be the pearlite content and hence higher mechanical strength. Conversely, when the pearlite content increases, the ferrite content decreases and hence the ductility is reduced.

Below in figure 2.2 are the different stages of Pearlite formation:

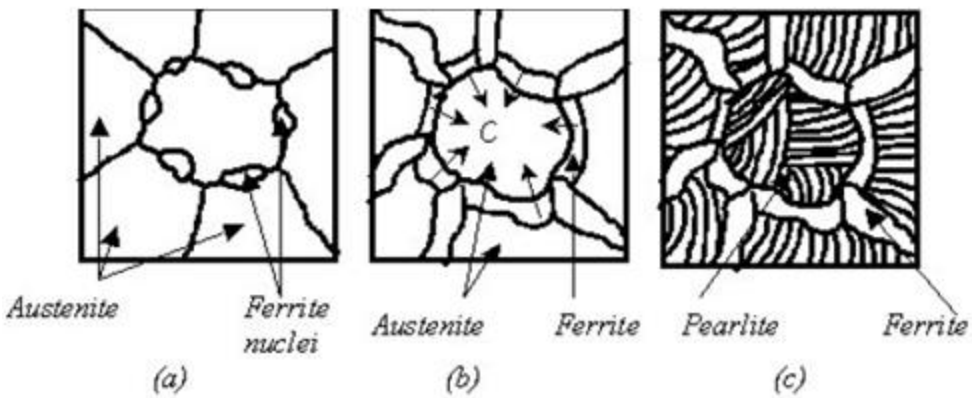

Figure 2.2: *Different stages of pearlite formation*

(iii) Austenite (γ): Austenite is a face centered cubic structure (fcc). It is stable at Temperatures above 723oC depending upon carbon content. It can dissolve up to 2% Carbon.

(iv) Cementite: iron carbide (Fe3C), a compound iron containing high carbon.

The Fe-C phase diagram shows which phases are to be expected at metastable equilibrium for different combinations of carbon content and temperature. The steel portion of the Fe-C phase diagram covers the range between 0 and 2.08 wt. % C. The cast iron portion of the Fe-C phase diagram covers the range between 2.08 and 6.67 wt. % C. [3]

2.1.3 Classification of steel

Steel may be classified in many ways. Structurally, steel is classified into:

(i) **Low alloy steels:** which possess slowly cooled microstructures namely pearlite, pearlite + ferrite, or pearlite + cementite.

(ii) **High alloy steels:** which possess slowly cooled microstructures, consisting either of martensite, austenite or ferrite + carbide particles?

2.1.4 Effects of alloying elements on steel

Steels contain alloying elements and impurities that must be associated with austenite, ferrite and cementite. The combined effects of alloying elements and heat treatment produce an enormous variety of microstructures and properties. Alloying elements can be divided into two categories according to the interaction with carbon in steel:

(i) **Carbide-**forming elements, such as Mn, Cr, Mo, W, V, Nb, Ti, and Zr. They go into solid solution in cementite at low concentrations. At higher concentrations, they form more stable alloy carbides, though Mn only dissolves in cementite.

(ii) Non-carbide-forming elements, such as Ni, Co, Cu, Si, P, and Al. They are free from carbide in steels.

CARBON

The amount of carbon (C) required in the finished steel limits the type of steel that can be made. As the C content of rimmed steels increases, surface quality deteriorates. Killed steels in the approximate range of 0.15–0.30% C may have poorer surface quality and require special processing to attain surface quality comparable to steels with higher or lower C contents. Carbon has a moderate tendency for macro-segregation during solidification, and it is often more significant than that of any other alloying elements. Carbon has a strong tendency to segregate at the defects in steels (such as grain boundaries and dislocations). Carbide forming elements may interact with carbon and form alloy carbides. Carbon is the main hardening element in all steels except the austenitic precipitation hardening (PH) stainless steels, managing steels, and interstitial-free (IF) steels. The strengthening effect of C in steels consists of solid solution strengthening and carbide dispersion strengthening. As the C content in steel increases, strength increases, but ductility and weldability decrease.

MANGANESE

Manganese (Mn) is present in virtually all steels in amounts of 0.30% or more. Manganese is essentially a deoxidizer and a desulfurizer. It has a lesser tendency for macro-segregation than any of the common elements. Steels above 0.60% Mn cannot be readily rimmed. Manganese favorably affects forgeability and weldability. Manganese is a weak carbide former, only dissolving in cementite, and forms alloying cementite in steels.

Large quantities (>2% Mn) result in an increased tendency toward cracking and distortion during quenching. The presence of alloying element Mn in steels enhances the impurities such as P, Sn, Sb, and As segregating to grain boundaries and induces temper embrittlement.

SILICON

Silicon (Si) is one of the principal deoxidizers used in steel making; therefore, silicon content also determines the type of steel produced. Killed carbon steels may contain Si up to a maximum of 0.60%. Semi-killed steels may contain moderate amounts of Si. For example, in rimmed steel, the Si content is generally less than 0.10%. Silicon dissolves completely in ferrite, when silicon content is below 0.30%, increasing its strength without greatly decreasing ductility. Beyond 0.40% Si, a marked decrease in ductility is noticed in plain carbon steels.

If combined with Mn or Mo, silicon may produce greater hardenability of steels. In heat-treated steels, Si is an important alloy element, and increases hardenability, wear resistance, elastic limit and yield strength, and scale resistance in heat-resistant steels. Si is a non-carbide former, and free from cementite or carbides; it dissolves in martensite and retards the decomposition of alloying martensite up to 300ºC.

PHOSPHORUS

Phosphorus (P) segregates during solidification, but to a lesser extent than C and S. Phosphorus dissolves in ferrite and increases the strength of steels. As the amount of P increases, the ductility and impact toughness of steels decrease, and raises the cold-shortness. Phosphorus has a very strong tendency to segregate at the grain boundaries, and causes the temper embrittlement of alloying steels, especially in Mn, Cr, Mn–Si, Cr–Ni, and Cr–Mn steels. Phosphorus also increases the hardenability and retards the decomposition of martensite-like Siin steels. High P content is often specified in low-carbon free-machining steels to improve machinability. In low-alloy structural steels containing ~0.1% C, P increases strength and atmospheric corrosion resistance. In austenitic Cr–Ni steels, the addition of P can cause precipitation effects and an increase in yield points. In strong oxidizing agent, P causes grain boundary corrosion in austenitic stainless steels after solid solution treatment as a result of the segregation of P at grain boundaries.

SULPHUR

Increased amounts of sulfur (S) can cause red- or hot-shortness due to the low-melting sulphide eutectics surrounding the grain in reticular fashion. Sulfur has a detrimental effect on transverse ductility, notch impact toughness, weldability, and surface quality (particularly in the lower carbon and lower manganese steels), but has a slight effect on longitudinal mechanical properties. Sulfur has a very strong tendency to segregate at grain boundaries and causes reduction of hot ductility in alloy steels. However, sulfur in the range of 0.08–0.33% is intentionally added to free-machining steels for increased machinability.

Sulfur improves the fatigue life of bearing steels, because (1) the thermal coefficient on MnS inclusion is higher than that of matrix, but the thermal coefficient of oxide inclusions is lower than that of matrix, (2) MnS inclusions coat or cover oxides (such as alumina, silicate, and spinel), thereby reducing the tensile stresses in the surrounding matrix.

ALUMINUM

Aluminium (Al) is widely used as a deoxidizer and a grain refiner. As Al forms very hard nitrides with nitrogen, it is usually an alloying element in nitriding steels. It increases scaling resistance and is therefore often added to heat-resistant steels and alloys. In precipitation-hardening stainless steels, Al can be used as an alloying element, causing precipitation-hardening reaction. Aluminium is also used in maraging steels. Aluminium increases the corrosion resistance in low-carbon corrosion-resisting steels. Of all the alloying elements, Al is one of the most effective elements in controlling grain growth prior to quenching. Aluminium has the drawback of a tendency to promote graphitization.

CHROMIUM

Chromium (Cr) is medium carbide former. In the low Cr/C ratio range, only alloyed cementite (Fe3Cr)C forms. If the Cr/C ratio rises, chromium carbides would appear. Chromium increases hardenability, corrosion and oxidation resistance of steels, improves high-temperature strength and high-pressure hydrogenation properties, and enhances abrasion resistance in high-carbon grades. Chromium carbides are hard and wear-resistant and increase the edge-holding quality. Complex chromium–iron carbides slowly go into solution in austenite; therefore, a longer time at temperature is necessary to allow solution to take place before quenching is accomplished.

Chromium is the most important alloying element in steels. The addition of Cr in steels enhances the impurities, such as P, Sn, Sb, and As, segregating to grain boundaries and induces temper embrittlement.

NICKEL

Nickel (Ni) is a non-carbide-forming element in steels. Nickel raises hardenability. In combination with Ni, Cr and Mo, it produces greater hardenability, impact toughness, and fatigue resistance in steels. Nickel dissolving in ferrite improves toughness, decreases FATT50% (ºC), even at the sub-zero temperatures. Nickel raises the corrosion resistance of Cr–Ni austenitic stainless steels in non-oxidizing acid medium.

MOLYBDENUM

Molybdenum (Mo) is pronounced carbide former. It dissolves slightly in cementite, while molybdenum carbides will form when the Mo content in steel is high enough. Molybdenum can induce secondary hardening during the tempering of quenched steels and improves the creep strength of low-alloy steels at elevated temperatures. The addition of Mo produces fine-grained steels, increases hardenability, and improves fatigue strength. Alloy steels containing 0.20–0.40% Mo or V display a delayed temper-embrittlement, but cannot eliminate it. Molybdenum increases corrosion resistance and is used to a great extent in high-alloy Cr ferritic stainless steels and with Cr–Ni austenitic stainless steels. High Mo contents reduce the stainless steel's susceptibility to pitting. Molybdenum has a very strong solid solution strengthening in austenitic alloys at elevated temperatures. Molybdenum is a very important alloying element for alloy steels.

TUNGSTEN

Tungsten (W) is a strong carbide former. The behavior of W is very similar to Mo in steels. Tungsten slightly dissolves in cementite. As the content of W increases in alloy steels, W forms very hard, abrasion-resistant carbides, and can induce secondary hardening during the tempering of quenched steels. It promotes hot strength and red-hardness and thus cutting ability. It prevents grain growth at high temperature. W and Mo are the main alloying elements in high-speed steels. However, W and Mo impair scaling resistance.

COPPER

Copper (Cu) addition has a moderate tendency to segregate. Above 0.30% Cu can cause precipitation hardening. It increases hardenability. If Cu is present in appreciable amounts, it is detrimental to hot-working operations. It is detrimental to surface quality and exaggerates the surface defects inherent in re-sulfurized steels. However, Cu improves the atmospheric corrosion resistance (when in excess of 0.20%) and the tensile properties in alloy and low-alloy steels, and reportedly helps the adhesion of paint. In austenitic stainless steels, a Cu content above 1% results in improved resistance to H2SO4 and HCl and stress corrosion [4].

When these elements are added in their appropriate quantities and properly controlled microstructure, quality steel is produced. The major issues with steel production now are that the raw materials are the recycle scraps.

2.2 EFFECT OF MANUFACTURING PROCESS ON REBAR CHARACTERISTICS

According to Basu et al, Production of high-strength bars are achieved through

three stages:

(i) Manufacturing of billets

(ii) Rolling of billets into rebars, and (iii) process to impart further strength.

All the stages have significant influence on the characteristics of rebars. In general, both the quality of basic materials used in rolling the rebars and its manufacturing process are important. Quality of metal scrap has utmost impact on the performance of rebars when re-rollables are used. The so called mild steel rebars are rolled from general carbon steel billet without adopting any special measures or imparting further strength. For example in India, more than 50 percent of the rebars are manufactured from the re-rollables manufactured from the scrap materials such as scrap rails, automobile scrap, defense scrap, defectives from steel plants, and scrap generated from ship breaking or discarded structures .All these conflicting aspects indicate that certain level of refinement of the composition of steel is necessary. The desired refinement can be suitably achieved with the use of an electric arc furnace, which unfortunately is not being employed now-a-days due to prohibitive cost of production. Induction furnace is mostly used in India for manufacturing of rebars from scraps. It is well known that induction furnace cannot yield sufficient refinement of molten scrap to produce billets of desired quality [5].

Likewise in West Africa, large quantities of rebars are now producing from scraps. The manufacturing industries continue to encounter challenges for the quality of these bars. According to studies the bars, mostly produced by hot rolling, constitute the bulk (90% by weight) of all structural steel profiles commonly employed in construction and allied engineering works [6].

A direct correlation exists between steel’s microstructures and its mechanical properties [7].

Hence, the development of a relevant structure – property model in steel is therefore, one of the effective methods of improving its mechanical properties [8].

Empirical analyses of methods of producing hot rolled steel bars indicate a radical departure from the conventional rolling practices. Against the sole dependence on chemical composition adjustment, emphasis is currently placed on the development of relevant structural property that guarantees enhanced strength characteristics.

Through skillful manipulation of metallurgical factors, higher strengths are induced in the bar on the basis of better corresponding microstructures developed.

According to report, it is regrettably said that, mild steel bars produced in Nigeria and some West African countries particularly Ghana exhibit terribly low strength characteristics and has high carbon [9]. According to a report, the world's average specification for high yield steel bar is 460-500MPa [10].

A Comparison of other relevant strength parameters with locally produced bars is presented in table 2.1

Strength Characteristics	**International Standard (min.)**	**Nigeria Bars**
Yield Strength (MPa)	460	250 - 350
UTS (Mpa)	600	410 - 500
Elongation	10 -25	9 -14

Table 2.1: *Strength Characteristics Specification Comparison*

Adapted from Balogun, 2009

Name of company	Carbon composition (wt. %C)
Sun Flag(SF)	0.530
Unique Steel(US)	0.398
Spanish Steel(NS)	0.383
African Steel (AS)	0.483
Imported Steel (IS)	0.306

Table 2.2: *Carbon composition of locally produced steel bars*
Adapted from Alabi et al. (2010)

With particular reference to the locally produced bars, the reality of the consequences of the data in Table 2.1 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. He further said that 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 [9].

Therefore, steel is one of the most essential material for building structures with higher strength compare to the concrete in which it is embeded. Most steel structures are designed to be ductile and robust to withsatnd severe loading.

Finally, good quality control is essential to ensure proper fitting of the various structural elements and microstructure.

2.3. CEMENT

Cement is the gray powder that is a principal strength giving component of concrete. It is a high quality building material and a key component of construction projects throughout the World. It is a concrete binder.

According to the report of

China is the World's highest producer of cement followed by Japan and United states second and third respectively. In 2005, it was reported that Cement production is estimated to reach 2 billion tons annually. A corresponding to growth in cement production is projected as its consumption increases due to population growth and migration in urban settlements.

Cement as concrete ingredients is now produced by several African Countries. Table 2 shows the cement production for industrialized and developing countries in Africa.

country	**Kg/capita**	**country**	**Kg/capita**
Libya	674	Senegal	132

Tunisia	449	Ghana	97
Egypt	325	Benin	80
Algeria	280	Sudan	57
South Africa	268	Tanzania	39
Morocco	256	Congo	38
Namibia	153	Kenya	37
Gabon	150	Nigeria	36
Swaziland	144	Cameron	35

Table 2.3: Cement producing countries in Africa, Symposium 2005 statistics

2.3. 1 COMPOSITION OF PORTLAND CEMENT

Portland cement, also known as a calcium silicate cements are used throughout the world than any other types of cements.

According to Rompps Chemie- Lexikon (1987), the elements that are more abundantly present (>.5%) in cement clinker are the major elements. These are calcium (Ca), silicon (Si), aluminum (Al), iron (Fe), and oxygen (0). Carbon (C) and nitrogen (N), because of their abundance in the raw material and the earth atmosphere respectively, can also be regarded as major elements. In clinker and cement analyses,

Ca, Si, Al, and Fe are expressed as the oxides form (CaO, SiO_2, $A1_2O_3$, and Fe_2O_3. However, they eventually exist as more complex compounds. The approximate formulae of these compounds, also known as clinker phases, are tricalcium silicate (3CaO.SiO_3or C3S); dicalcium silicate (2CaO.SiO_2 or C_2S); tricalcium aluminate (3CaO.Al_2O_3 or C_3A,) and tetra calcium aluminoferrite (4CaO.Al2O3.Fe2O3 or C_4AF)[11] .

2.3.2 THE FOUR ESSENTIAL MINERALS OF CEMENT

The mineral composition of cement is more useful than its oxide composition. As reported by Taylor, table 2.3 lists the composition of these minerals with their theoretical compositions of the pure minerals as found in Portland cement clinker. The values in parenthesis are for the pure minerals. All values are in weight percent (wt.%) [12].

	C	S	A	F
C_3S	71.6(73.7)	25.2(26.3)	1.0(0)	0.7(0)
C_2S	63.5(65.1)	31.5(34.9)	2.1(0)	0.9(0)
C_3A	56.6(62.3)	3.7(0)	31.3(37.7)	5.1(0)
C_4AF	47.5(46.2)	3.6(0)	21.9(21.0)	21.4(32.9)

Table 2.4: *Typical composition of cement minerals along with theoretical values, Taylor*, 1997

2.3.3 THE ROLE OF THE MINERALS IN CEMENT

- **C_3S**-Tricalcium silicate(alite) - Hydrates & hardens rapidly Responsible for initial set and early strength

- **C_2S**-Dicalcium silicate(belite)-Hydrates & hardens slowly Contributes to later age strength (beyond 7 days)

- **C_3A**-Tricalcium aluminate-Liberates a large amount of heat during first few days; Contributes slightly to early strength development ;Cements with low %-ages are more resistant to sulfates

- **C_4AF**-Tetracalcium aluminoferrite (ferrite)-Reduces clinkering temperature; Hydrates rapidly but contributes little to strength. It is responsible for the color(gray) due to ferrite hydrates.

C = CaO ; S= SiO_2 ; A= Al_2O_3 ; Fe_2O_3 [13].

2.3.4 PORTLAND CEMENT AS A STANDARD FOR OTHERS

Modern Portland cements come in a wide variety of subcategories, in order to optimize the properties for specific applications and environmental conditions.

The American Society of Testing Materials (ASTM) specifies five distinct types of Portland cement for general use, designated by the Roman numerals I-V. These types are called the "ordinary" Portland cements, widely abbreviated "OPC". The primary differences between the various OPC types are the relative proportions of the four main cement minerals and the fineness to which the cement is ground. While chemical reactions, microstructure, and general properties of cement pastes made are quite similar [14].

Similarly, The European Standard presents three normal types of cement:

1. Cement 1: composition, specifications and confirmative criteria for common cements CEM II/AL 42.5R, produced with a moderate aluminate and alkali content that can be used to produce concrete with enhance mechanical performances also over the short term and suitable for use in moderate aggressive environment, CEM I 42.5 Portland($C_3A\approx0$) and CEM IV pozzolanic($C_3A\approx0$), both these cements are high sulphate and consisting low alkali content.EN-197-1.[15].

Most cement producing industries in Africa follow any of the standards.

Finally, Modern concrete has been around for more than 150 years, and there are many examples of structures lasting for more than one hundred years with little signs of deterioration. However, there are many other cases when the durability of these materials that make up the concrete is questioned based on their quality.

Cement and steel can make structures to last for years or much more under almost any conditions if they are properly processed for the right applications such as buildings.

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CHAPTER THREE: MATERIALS AND METHODOLOGY

3.1 INTRODUCTION

Two samples of locally produced steel bars were analyzed along with two samples of locally manufactured cement.

3.2. STEEL:

Samples of construction steel bars produced and used in Nigeria were 12mm and 16mm diameter reinforced steel bars. These samples were obtained from the local market in Dei-dei, Abuja FCT. The bars were products of one of Nigeria's biggest steel producing industry- Prism Steel Rolling Mill (PSM).Two specimens each of 335mm length were collected on each of the diameter for tensile test, and 15 mm of each length was used for chemical analysis. The chemical analysis was conducted using a Solaris CCD Plus spectrometer at the Scc Laboratory, Abuja FCT. Mechanical properties which include yield strength, ultimate tensile strength, percentage elongation , hardness and one unidirectional bending tests were investigated at the same Mechanical laboratory of Scc. . Figgures 3.1 show prepared samples and tensile equipment. It also show the polished steel samples and the equipment used to determine the chemical composition of the steel. The Vickers hardness test was used to study the hardness of the steel samples.

Additionally, the microstructure of the steels was characterized using an Optical microscopy at Akure, Ilesia. The grain sizes of the phases were determined using the Gwyddion Software and the volume fraction of the phases was determined using the Lever rule.

$$V\%(\alpha) = \frac{0.76 - 0.26}{0.76 - 0.08} \times 100\% = X$$

V% Pearlite = 100-X

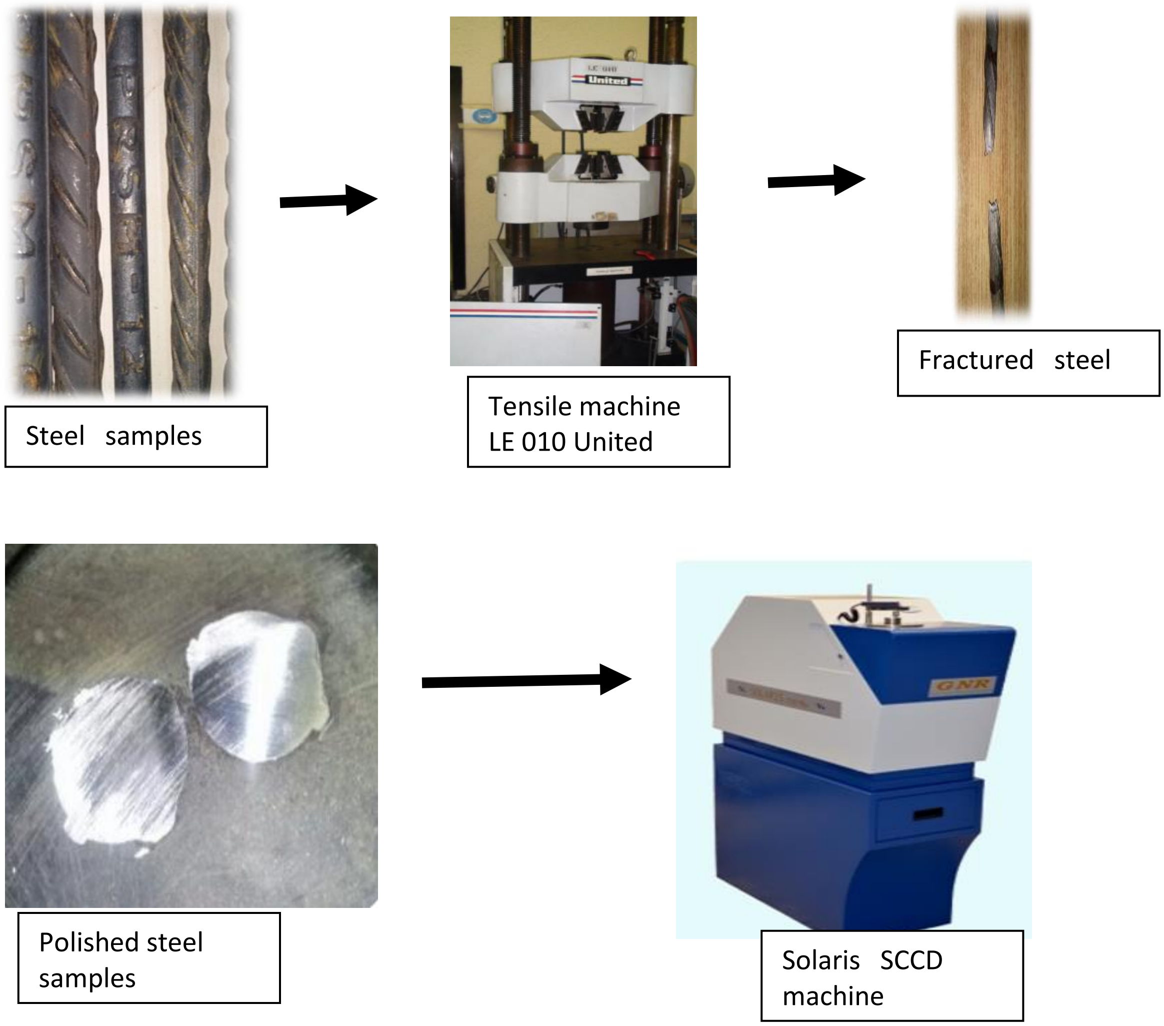

Figure 3. 1: Showing Samples, Tensile testing machine, polished sample and the Solaris SCCD chemical composition machine respectively.

3.3 CEMENT

Similarly, two samples of cement were used in this work. They were the Supaset cement (labelled No. 01) and Dangote 3X cement-42.5R (labelled No.02). The Dangote 3X is manufactured by the Dangote Company, Obajana, Kogi state while Supaset Elephant is produced by Lafarge Wapco located in Ikeja, Lagos, Nigeria.

The two samples are necessary for comparative investigation and analysis. The samples were acquired from a local dealer -Ogah Blocks, situated along Suncity Estate Road, Galadimawa, and Abuja, Nigeria. The chemical analysis of the cement samples was carried out using X-ray Fluorescence(XRF) and X-ray diffraction (XRD) equipment at the Chemical laboratory of the Engineering Materials Development institute, Akure, Ondo State.

The XRF is EDX 300B Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer; Made in china. While the XRD is EMMA 0141GBC; Made in Australia.

The mechanical properties tests of the cements were determined at the Julius Berger Company (quarry yard), Mpape, and Abuja. The cements were mixed with standard river sand and water to produce mortar with well controlled mix proportions. The compressive and flexural strengths were determined . Setting time and soundness tests of the mortar were also determined.

3.3.1 SAND

Natural siliceous sand of Germany was used in this Work with Standard Specification of EN 196-1 1994 requirement [1]. The Nigerian river sand could not be used due to the mud content which would have resulted to unexpected results. The mud content diminishes the strength of the mortar.

3.3.2 PREPARATION OF SAMPLES TO DETERMINE FLEXURAL AND COMPRESSIVE STRENGTHS

The European standard EN 196 -1 standard [1] was used for samples preparation .

Figure 3.1a-f shows material sand below is the mixed ratio.

Constituents of Mortar: sand, cement and water.

Preparation of mortar: These specimens were cast from a batch of plastic mortar containing one part by mass of standard sand with a water cement ratio of 0.50

Each batch for three tests specimens consisted of

Wt. of empty cylinder = 77.0g

Wt. of Cement = 450g

Wt. Of sand = 1350g, with diameter ≈ 0.4

Volume of water 225ml

The specimens were immediately moulded using standard jolting apparatus. The total time of mixing was 180s (3 minutes).

For each sample, three prismatic test specimens 40mm x 40 mm x 160 mm were cast.

The specimens in the mould were stored in a moist atmosphere for 24 hrs. and then demoulded and stored under water at 20 ^{0}C until strength testing at 2, 7, 14, 21 and 28 days.

For flexural testing, the three-point loading method was explored by applying the load vertically, by means of the loading roller till it breaks into two. Figure 3.3 show the flexural testing.

Each prim half was tested by loading its side faces for compressive strength. A total of 20 specimens were cast and 40 (2 X 20) were tested for the compressive strengths.

The mortar was prepared by mechanical mixing and was compacted in a mould using a standard jolting apparatus.

Summary of samples preparation for compressive and flexural testing.

Figure 3. 2: *Materials for mortar preparation.*

Mix proportion by mass

Cement	+ sand +	water
2	6	1

Compressive and Flexural Tests

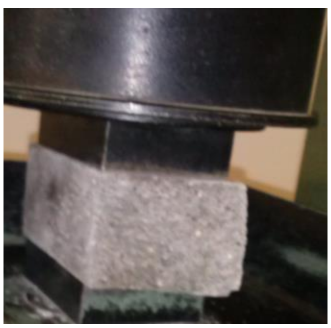

Figure 3. 4:
Compressive Testing

Figure 3. 3:
Flexural Test

3.3.3 PREPARATION OF SAMPLES FOR SETTING TIME

Apparatus: Balance, graduated cylinder, Vicat apparatus, hard rubber mould, and mixer

The hard rubber mould was in a truncated conical form 40.0 mm deep with internal diameters at top and bottom of 70mm and 80 mm respectively. It was provided with a plane glass base-plate larger than the mould with thickness of 2.5mm.

Materials: distilled water and cement

Procedure:

The Vicat needle was used as test method to determine the initial and final setting time of Hydraulic cement, according to EN 196-3 [2]. Figure 3.3 displays the vicat procedure.

Figure 3. 5: *Setting time testing (Vicat apparatus)*

Excess of paste was immediately transferred into the mould in one layer by using hand trowel. The top of the mould was smoothened and levelled. The mould was placed under the initial set needle of cross-sectional area of 1mm and the needle was covered gently onto the surface of the paste and was quickly released by allowing it to sink to the bottom. These tasks were repeated several times at regular intervals of 15 minutes in different positions of mould until the paste has stiffened sufficiently for the needle not to penetrate deeper than 4mm above the bottom of the mould.

The time interval between the addition of water and the initial setting time was recorded. Finally, the needle was replaced with a 1mm square needle fitted with a metal annular attachment and this probe was allowed to come gently with contact with the surface of the cement paste at an interval of 15 minutes. The final set was reached when the needle makes an impression on the surface but annular cutting edges fail to do so.

3.3.4 SOUNDNESS:

This test method determination of the autoclave expansion cement and is conducted according to EN 196-3 [2]. Figures below 3.4a and b display the Le Chatelier empty mould and mould filled with mortar respectively.

Figure 3. 7: *Mortar sample*

Figure 3. 6: *Le Chatelier mould*

The cement paste was prepared as of a standard consistency and filled in to the expansion mould, or Le Chatelier mould (Le Chatelier 1904), placed on a glass plate. The split end of the mould was gently fastened with a rubber band as the operation was being carried out. The surface of the paste was well smoothened and levelled with the blade of a gauging trowel and was covered with another piece of glass as seen in figure 3.4b and was immediately placed in a stream tank.

After 24 hours, the mould was removed from the tank and the distance between the pointers measured by using a meter rule. The mould was immersed in water and was brought to boiling point within 30 minutes and afterwards allowed to boil for two hours. This material was then kept in the water and allowed to cool. The distance between the pointers was measured. The difference between the two measurements represents the value for soundness. The mortar was prepared under the temperature of 22^0C

3.5 REFERENCES

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CHAPTER FOUR: RESULTS AND DISCUSSION.

Two samples of each component (steel and cement) were studied and analyzed.

4.1. STEEL

Tables 4.1a and 4.1b show the results of the chemical compositions of the 12mm and 16mm iron rods investigated. Iron (Fe) with the composition of 98.127 and 98.254 percent for the 12mm and 16mm respectively is the element with the highest composition. According to sources [1], the higher the carbon content in steel, the greater the hardenability, the strength, hardness and wear resistance of the steel. But high carbon content in steel decreases weldability, ductility and toughness.

However, the steel samples studied have a maximum carbon contents compare to the standards [2].

As seen on Table 4.1a, the carbon content is 0.209 and 0.262 for the 12mm and 16 mm respectively. Table 4.1c shows the standard composition of structural steels.

sample	C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%	Nb%	Al%	Cu%	Co%
12mm	0.209	0.094	0.410	0.033	0.032	0.145	0.001	0.040	0.002	0.001	0.133	0.005
16mm	0.262	0.137	0.676	0.041	0.049	0.162	0.002	0.073	0.004	0.001	0.267	0.006

Table 4. 1: Chemical composition of 12mm & 16mm samples

sample	W%	Mg%	Ca%	Ce%	La%	As%	Pb%	Sn%	Sb%	Zn%	Fe%
12mm	0.004	0.0006	0.0020	0.001	0.005	0.006	0.002	0.009	0.009	0.0074	98.127
16mm	0.005	0.0012	0.0040	0.002	0.005	0.011	0.003	0.015	0.011	O.001	98.254

Table 4. 2: Chemical composition of 12mm and 16 mm steel

Element	*Grade 250 (% Max.)*	*Grade 460 (% Max.)*	*Deviations (% Max.)*
Carbon	0.25	0.25	0.02
Sulphur	0.060	0.050	0.005
Phosphorus	0.060	0.050	0.005
Nitrogen	0.012	0.012	0.001

Table 4. 3 : Chemical Composition of Steel Grades (BS 4449) standards*
** Grades are given in term of the minimum yield strength: Grades 460 are for hot rolled high yield deformed bars while grades 250 are for low yield plain bars. Balugon 2009*

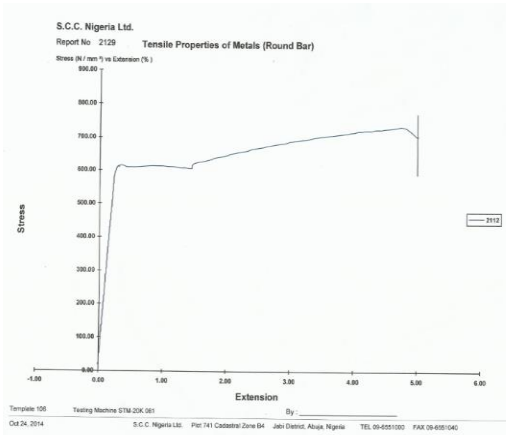


Figure 4. 2: *stress –strain curve for 16mm*

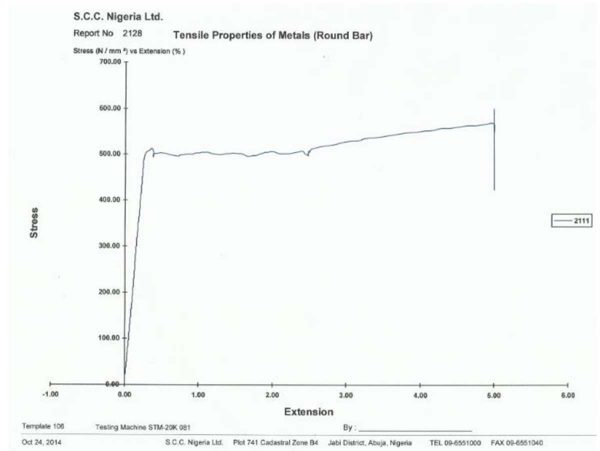


Figure 4. 1: *stress-strain curve for 12mm*

Table 4.2 shows the mechanical properties (yield strength, ultimate tensile strength, percentage strain and hardness) of the steel samples investigated.

Both samples show preferable tensile properties because of their higher manganese content. Manganese improves the tensile properties such as ductility and toughness in steel. From the tensile test results, the yield strength of the 12mm and 16mm steel rods respectively is 501.43Mpa and 610.25Mpa for the rods. The investigated rods met the minimum standard requirement for medium carbon which is 415N/mm^2 [3].

The ultimate tensile strength results from Table **4.2** shows that the values for the 12mm and 16mm rods respectively are 599.60Mpa and 771.32 Mpa. These steel rods ultimate tensile result exceed the minimum standard requirements of 580N/mm^2 [3]. An iron rod with a high ultimate tensile strength does not necessarily have a good ductility or a good plastic deformation. The percentage elongation and the one-sided bent test results proved that the samples are very ductile having all their values greater than the required minimum value of 10% of the standard [3]. The percentage elongation values for 12mm and 16mm steel rods respectively are 31.81% and

43.64%. Since percentage elongation is a measure of the material's ductility and thus, it toughness. Thus, the samples show high ductility which could be as a result of the maximum magnesium content. Figures 4.1 and 4.2 show the trend of stress and strain of the samples. This trend also indicates that the samples have high modulus and are ductile.

The hardness value for 12mm and 16mm steel rods respectively are 181.0Hv and 198 Hv respectively. These look like ferrite pearlite microstructures with similar fractions of pearlite and ferrite. Furthermore, the microstructure of the samples was similar so one is display in figure 4.3. The ferrite- pearlite microstructures grain sizes were estimated. The ferrite and pearlite grain sizes were 7.11μm and 6.35 μm respectively. The difference of 0.76μm, indicating higher content of ferrite. Similarly, the volume fraction of the phases was calculated. From the calculations, there 73.53% ferrite and 26.47% pearlite. This also shows higher content of ferrite in the steel. Ferrite is ductile and soft. Therefore, the steel is more ductile but not tough. Based on this microstructure, the steel is not totally reliable. The ductility was shown during one-sided bent and tensile tests. From this microstructural analysis, it can be said that the steel was improperly processed .

Sample	Yield stress (Mpa)	Ultimate Tensile stress-UTS(Mpa)	Modulus	Total Elong %	Vickers Hardness
12mm	501.43	559.60	188, 218.90	31.81	181
16mm	610.25	77.32	254,103.80	43.64	198

Table 4. 4: Mechanical properties of samples

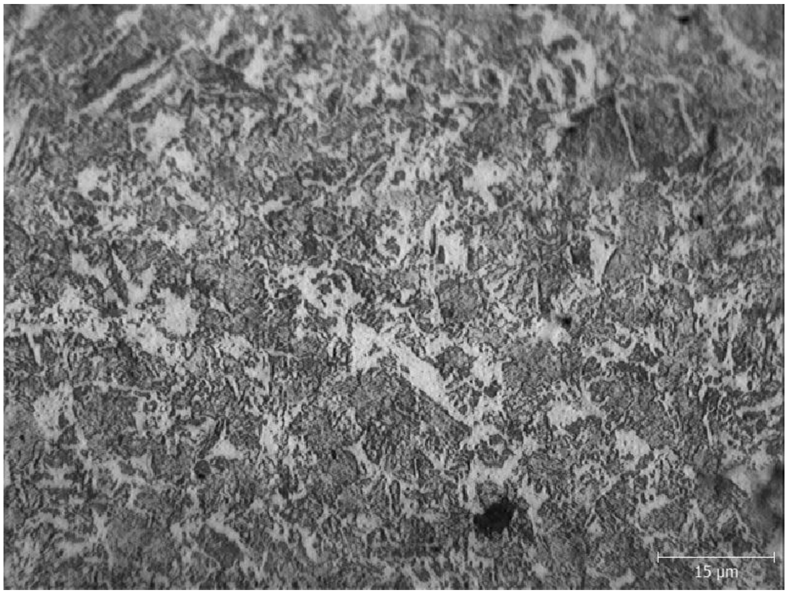


Figure 4. 3: Microstructure of the steel

4.

CEMENT

The results obtained from the experimental work are analyzed and studied. This study Includes initial and final setting time, soundness, compressive and flexural strengths at (2, 7, 14, 21 28) days. The chemical composition of the samples was also analyzed. Two samples of cement were used for this investigation.

4.2.1 SETTING TIME

Tables 4.3a and 4.3b show the results of the setting time.

The setting time was determined by observing the penetration of the needle into the cement according to the EN197-1 [6]

SETTING TIME		
	Supaset Elephant	**Dangote 3X**
Initial Time	120 minutes	250 minutes
Final Time	250 minutes	260 minutes

Table 4. 5: Setting time of cement samples

SOUNDNESS	
Supaset Elephant	2.5mm
Dangote 3X	3.00mm

Table 4. 6: Soundness of cement samples

The initial setting time of the two samples lies in the range of 120-130 minutes while the final setting time occurs between 250-260 minutes. There is unique difference of 10 minutes both between the initial and final setting times. According to EN 197-1 [4] standards requirements, initial setting time should be higher than 60 minutes. This difference may be as a result of the selective hydration of C_3A and C_3S and is accompanied by temperature rises in the cement paste according to [5] However, the two samples of cement are within limits stated by EN standards. Final setting times should be less than 600 minutes according to old BS12 [6] requirements. However, No value is specified for Final setting time in EN standards.

4.2.2 SOUNDNESS

Table 4.3 (c) shows the soundness result according to EN 197-1 [4]

The samples analyzed show soundness (expansion) of 2.5 mm and 3.00mm respectively for Supaset and Dangote 3x respectively. A difference of o.5mm observed. But EN requirement for soundness is not more than 10mm. Therefore, the samples fall within the required standard. The difference of 0.5mm higher soundness of Dangote over Supaset may be associated with high CaO free content (Sosman and Merwin 1916).

4.3 STRENGTH.

The results of compressive and flexural strength at (2, 7, 14, 21 and 28) days for cement types are shown in Tables 4. 10 to 4.14. Likewise, Figures 4.4 to 4.8. show the graph of strength development with time.

SUPASET ELEPHANT	No. of samples	2 days (48hrs)	7 days	14 days	21 days	28 days	Ave. Error
Weight of prism-W [kg]	4	588.0	579.8	582.7	589.7	587.2	
Reading of gauge - F [KN]	4	67	121.5	134	144	150	
Strength(Compressive) σ = F/A [N/mm^2]	4	26.8	48.6	53.6	57.6	60	
Error±		±1.34	±2.43	±2.68	±2.88	±3	±2.466

Table 4. 7: Average compressive strength of Supaset elephant cement

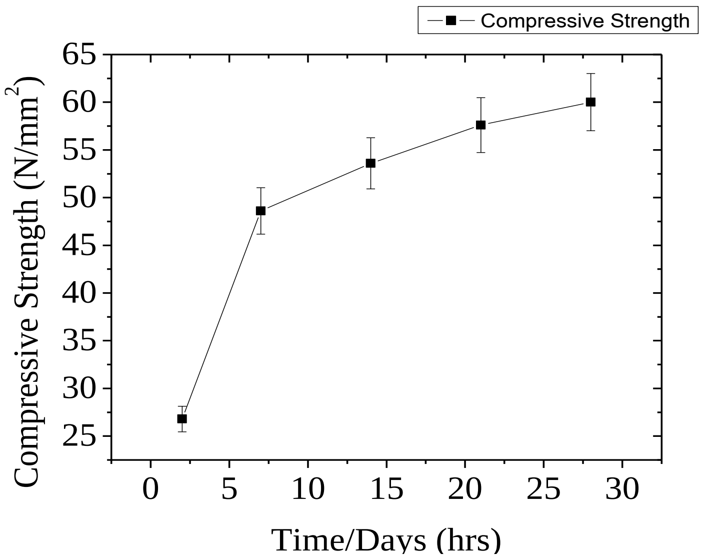


Figure 4. 4**:** *Compressive strength of Supaset Elephant graph*

DANGOTE 3X	No. of samples	2 days (48hrs)	7 days	14 days	21 days	28 days	**Ave. error**
Weight of prism-W [kg]	4	582.8	578	582	582.1	581.7	
Reading of gauge - F [KN]	4	52.5	99.5	104	115	129.5	
Strength(compressive)σ = F/A [N/mm^2]	4	21.0	39.8	41.6	46.0	51.8	
Error ±		±1.05	±1.99	±2.08	±2.3	±2.59	±2.002

Table 4. 8: Average compressive strength Dangote 3x cement

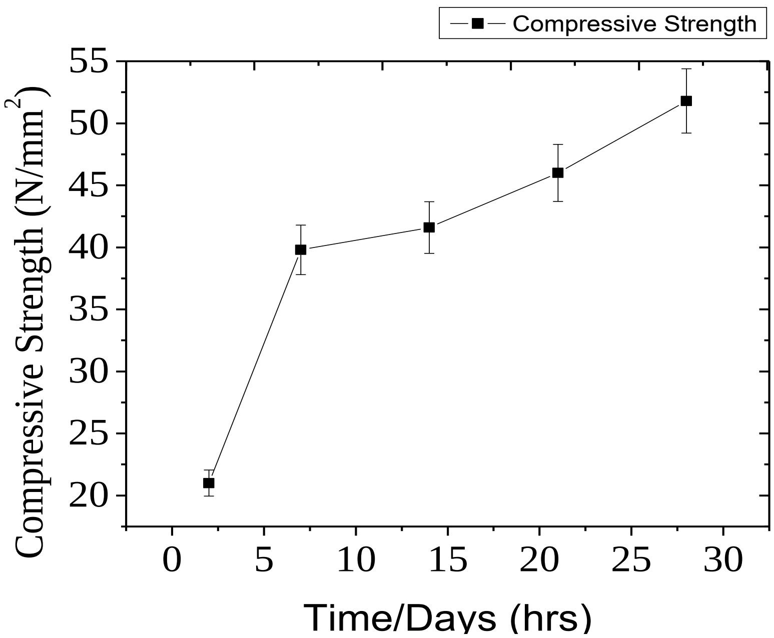
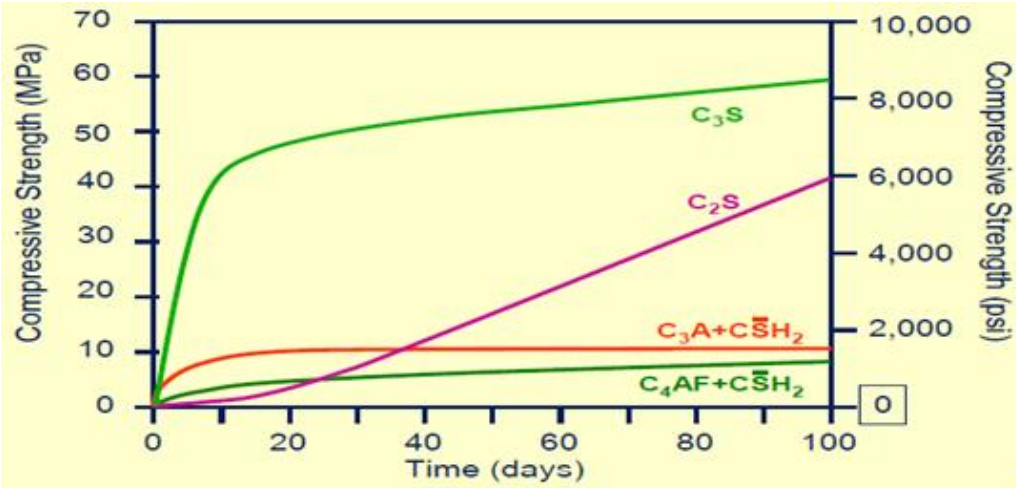


Figure 4. 5: *Compressive strength of Dangote 3X graph*

Strength class	Compressive strength MPa				Initial setting time	Soundness (expansion)
	Early strength		Standard strength			
	2 days	7 days	28 days		min	mm
32,5 N	–	≥ 16,0	≥ 32,5	≤ 52,5	≥ 75	≤ 10
32,5 R	≥ 10,0	–				
42,5 N	≥ 10,0	–	≥ 42,5	≤ 62,5	≥ 60	
42,5 R	≥ 20,0	–				
52,5 N	≥ 20,0	–	≥ 52,5	–	≥ 45	
52,5 R	≥ 30,0	–				

Table 4. 9: Mechanical and physical requirements given as characteristic values, EN 197-1 standard for cement



C = CaO
S = SiO_2
A = Al_2O_3
F = Fe_2O_3

Figure 4. 6:*Compressive Strength development in pastes of pure cement compounds (Adapted from Mindess et al, 2003)*

	No. of samples	2 days (48hrs)	7 days	14 days	21 days	28 days	Ave. error
Weight of prism-W [kg]	2	588.0	579.8	582.7	589.7	587.2	
Reading of gauge -F [KN]	2	2.60	3.40	4.0	4.05	3.65	
Strength(flexural) σ = F x A [N/mm^2]	2	6.09	7.96	9.36	9.48	8.54	
Error		±0.3045	±0.398	±0.468	±0.474	±0.425	±0.4139

Table 4. 10 :Average flexural strength Supaset elephant cement

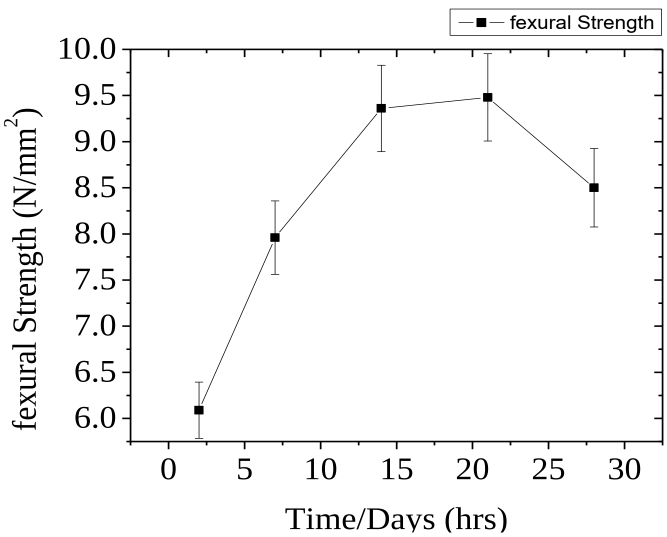


Figure 4. 7: *Flexural strength of Supaset*

	No. of samples	2 days (48hrs)	7 days	14 days	21 days	28 days	Ave. error
Weight of prism-W [kg]	2	582.8	578.0	582	582.1	581.7	
Reading of gauge - F [KN]	2	2.10	3.05	3.65	3.45	3.60	
Strength(flexural)σ= F x A [N/mm^2]	2	4.91	7.14	8.54	8.07	8.42	
Error ±		±0.2455	±0.357	±0.427	±0.4035	±0.421	±0.3708

Table 4. 11: Average flexural strength of Dangote 3X cement

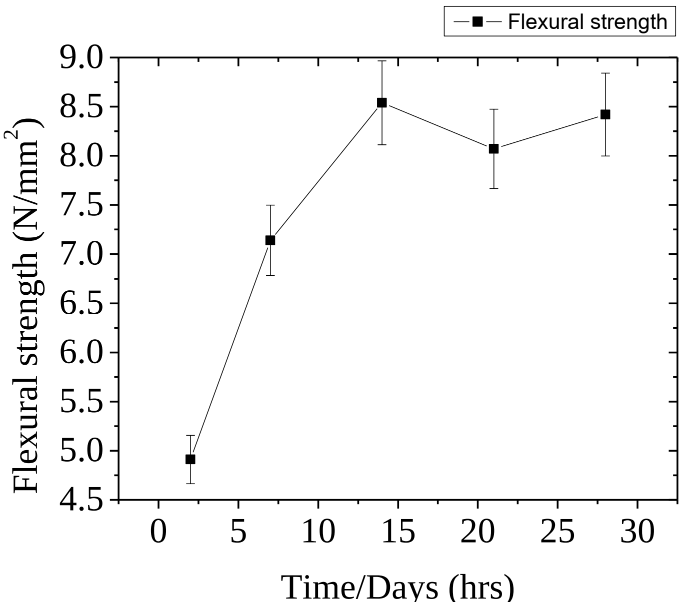


Figure 4. 8: *Flexural strength of Dangote 3x*

4.3.1 COMPRESSIVE STRENGTH

According to EN 197 tables 4.10 and 4.11 , early compressive strength of mortar at 2 days should be more than or equal to 10MP; standards compressive strength at 28 days should be between 42.5 MPa and 62.5PMa for one of the cement sample-(Dangote 3x) while the other is within the range of 32.5Mpa and 52.5 Mpa(Supaset). There are no limitations specified for 7 , 14 and 21 days except for 32.5 N which is ≥16 Mpa at day 7. However, in practice, it is preferable to consistently check for those days. The 7th day strength is checked to understand the behavior of strength development [7],[8]. Similarly, to understand the strength development, the 14th and 21 days were also checked during this investigation. According to the Nigerian standards, most locally produced cements derived EN standards, only two strength classes (32.5 and 42.5) are allowed for structural concrete especially for housing purposes. 32.5 is restricted to plastering and not for weight-bearing components on any structure while 42.5 is specified for the entire concrete work or all general construction works. The two samples of cements chosen for this study are 32.5 and 42.5 classes.

All cements show similar early strength development patterns during the 2 and 7 days period. The both samples early strength development is within the EN standard specification. Tables 4.10 and 4.11 show 39.8 and 48.6 for Dangote 3x and Supaset respectively at the seventh day . However, the Supaset shows higher strength within 7 days . This could be as the result of high C_3S, C_2S and C_3A content.

From figure 4.4 , there was slow strength development between day 14th and 21 for the Dangote 3x. and between day 21 to 28, there was increment in strength. But for the Supaset , as seen on figure 4.4, there was uniformity of strength development over time. From day 14 up to day 28, this cement displayed higher compressive strength development above standards. It exceeded the required standard specifications by 1.1, 5.1 and 7.5 Mpa for days 14, 21 and 28 respectively. This could be as a result of its Tricalcium Aluminate(C_3A) content which is not healthy for construction especially over time.

According to Ashby and Jones(1998), The hardening reaction of CA is as follows: CA + 10 $\rightarrow$ CAH + heat

Since this cement is produced and distributed in West Africa, temperature and environment needs to be considered with such high compressive strength . The cement may deteriorate abruptly without warning by converting the metastable CAH10 to more stable C_3AH_6 (as formed in Portland cement). This leads to substantial reduction in volume, which causes porosity and results in sudden decrease in strength. This is prevalent in warm and wet environment.

4.3.2 FLEXURAL STRENGTH

Tables 4.13 d and 4.14 show flexural strength of the samples. According to [12], cement mortar is a composite technically speaking. This means that the mortar is weak in tension as seen from the tables but higher strength in compression as discussed above. From figure 4.6, the Supaset samples shows unique strength development up to days14. But there was very little increment(almost steady) at day 21. But there was sharp decrease at day 28 . Figure 4.7 shows the fluctuating flexural strength development of the Dangote 3x. The strength increased up days 14, decreases on days 21, and increases at days 28. Irrespective of the sharp decrease in strength, the Supaset samples shows higher flexural strength. I t can be concluded that the mortar is weaker in flexure as a composite material.

4.4 CHEMICAL COMPOSITION

Tables 4.16 an 4.15 show elemental and oxide compositions of the samples studied.

Element	Supaset ele.	Dangote 3X
Mg	0.2146	0.0039
Al	0.2292	0.2055
Si	0.2601	02171
P	0.2589	0.2315
S	0.6948	0.8676
K	0.0000	0.0515
Ca	59.4504	53.4070
fe	3.0948	2.9137

Table 4. 13 : Elemental composition of cement

Structural formula	
	Supaset Ele.
Oxide	Weight %
CaO	54
SiO_2	16
$Al2O_3$	1
MgO	1

Table 4. 12: oxides composition

From the elemental compositions in Tables 4.5, it is observed that the Supaset elephant has higher elemental composition over the 3x. This could be some of the reasons for inconsistency in properties. It can be assumed that all cement samples has high Tricalcium Silicate (C_3S) content and low Dicalcium Silicate (C_2S) content which lead to much faster hydration rate, contributes to higher early strength as well. Thus, cement with a higher proportion of C_3S, as it is the case with most of today's cement, will tend to have a higher early strength, and allow for early form removal or post tensioning. On the other hand, cement with higher C_3S will cause issues due to heat of hydration specially in mass pouring [18],[19]. Tricalcium Aluminate (C_3A) liberate a large amount of heat during the first few days of hardening, and together with C_3S and C_2S may somewhat increase the early strength of hardening cement. Low percentage of C_3A in cement is more resistant to sulfates. Tetracalcium Aluminoferrite (C_4AF) contributes very slightly to strength gain and contribute to the color effects that

Makes cement gray [11]-[13].

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CHAPTER FIVE: CONCLUSION AND FUTOURE WORK

5.1 CONCLUSION

Based on the investigation and experimental results, the following conclusions are made: That the steel manufacture by PRISM Company nowadays is much better as compare to the past years. It appears that improved processing methods have been put into practice. Thus, the steel mechanical properties indicate its fitness for the construction industry. However, when it is wrongly applied in structures, it may lead to structural failure.

Likewise, the cement samples showed early compressive strength up to standards which could be attributed to the tricalcium Silicate ($3CaO.SiO_2$) contents. This indicates that consumers can remove forms in early days after casting.

However, the supaset cement exceeds standard strength of 28 days specifications and needs further investigations. Such a high strength might cause catastrophic failure with age without prior warnings. The flexural strength of the mortar shows its weakness, hence needs fiber reinforcement for optimum strength in flexure.

Finally, the steel produce by PRISM Company and the Dangote 3x cement investigated might not cause adverse effect on structures based on their properties.

5.2 SUGGESTIONS FOR FUTURE WORK

The following recommendations are necessary for further improvements on the quality of the locally produced construction materials:

There is need to investigate the alkali and corrosion effects of locally produced cement on steel-reinforced concrete.

A comprehensive study of locally produced steels and cements to include, microstructure and processing techniques.

The high strength of Supaset cement requires further investigations because of its excessive strength shown beyond standards.

And local materials (cement and steel) should be designed for durability rather than for strength alone.