UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

ASSESSMENT OF THE QUALITY OF REINFORCING BARS IN THE GHANAIAN MARKET: A CASE STUDY OF THE WESTERN REGION

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A Dissertation in the Department Of CONSTRUCTION AND WOOD TECHNOLOGY EDUCATION, Faculty of TECHNICAL EDUCATION, Submitted to the School of Graduate Studies, University of Education, Winneba in Partial fulfillment of the requirements for the Award of Master of Technology (Construction) Degree

JULY, 2016

DECLARATION

STUDENT`S DECLARATION

I, MOSES EMMANUEL AKO HAYFORD, declare that this Dissertation with the exception of quotations and reference contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole for another degree elsewhere.

SIGNATURE…………………………………………….

DATE…………………………………………………….

SUPERVISOR`S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of Thesis as laid down by the University of Education, Winneba.

NAME OF SUPERVISIOR: **DR. PETER PAA- KOFI YALLEY**

SIGNATURE…………………………………………….

DATE…………………………………………………….

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ABSTRACT

Building materials are the main component of the construction industry hence its quality and characteristic are essential. It is expected that building professionals select materials with adequate properties that are fit for purpose and meet acceptable local and international specifications. A study in a Nigeria ranked substandard building materials as the second leading causes of building collapse in Lagos. Hence this study seeks to assess the quality of the mechanical properties of local and foreign reinforcement bars (12mm 16mm and 20mm diameter) in the opening market of Sekondi-Takoradi. Samples were sourced from three major retail companies namely K. Ofori, B5 Company and Sethi Takoradi Limited. Samples were cut to a length of 500mm and tested for their tensile properties at the mechanical laboratory of Ghana Standard Authority in Accra. The result indicated that, the average yield strength for mild steel rods was 318N/mm² which was greater than the minimum provision. All 16mm and 20mm diameter high tensile steel bars exceeded the minimum yield strength; however 12mm did not meet the required yield strength. Both mild steel and high tensile steel samples recorded ultimate tensile steel values greater than the BS 4449 & GS 788-2 minimum provision. Similarly both mild steel and high tensile steel samples recorded an average elongation of 29% and 25% respectively. Mild steel samples recorded ductility of 1.24 while high tensile steel recorded a ductility of 1.44. 12mm and 20mm diameter samples were approximate to the standard nominal size provided by the BS 4449 & GS 788-2 specification. Meanwhile all the high tensile steel samples were below the nominal diameter provision of area of steel. The research conclude that mild steel rods may not be the causes of building collapse, while high tensile steel bars results suggest inconsistent qualities standard. All high tensile steel samples did not meet the required nominal area of steel and may partly be responsible for the collapse of buildings.

CHAPTER ONE

INTRODUCTION

1.1 Background

Physical infrastructural development of developing countries hinges on the construction industry, in a typical modern society, around half of all physical assets are created by the construction industry generating about 5-10% of national wealth (Gross Domestic Product). Thus the Ghanaian Construction Industry (GCI) if well exploited could be very strategic in championing the accelerated growth that would help take millions of the citizenry out of poverty. However, after 50 years of existence of the formal industry, very little has consciously been done towards tapping its full potential in the National Development Agenda (Ahadzie, 2010).

(Moavenzadeh & Rossow, 1976) emphasize this in their report that in developing countries the construction of physical facilities make up more than one half of gross Domestic investment and tends to be concentrated on basic infrastructure in agriculture, mining, transportation communication and utilities. They added that construction direct contributions to development are significant and it also stimulates a sizeable amount of economic growth through backward and forward linkages.

(Moavenzadeh., 1978) as cited in (Elkhalifa A. A., 2011) stated that, the importance of the construction industry stems from the role the industry plays in satisfying the demand made by its sisters in the economy for construction output. In that sense, the construction industry is very much like a service industry, and thus contributes significantly to economic development.

The (World Bank, 1984) reported that construction provides a stimulus for growth throughout the whole economy and vanguards nations' development. It contributes to economic development by satisfying some of the basic objectives of development including output generation, employment creation and income generation and redistribution (Moavenzadeh., 1978).

In order to realize tangible results in terms of improvement in the performance of, and prospects for, the construction industry, several other issues require attention (Ofori, 1993).

The construction industry is important because of the outputs and outcomes of its activities. It contributes to national socio-economic development by providing the buildings which are used in the production of all goods in the economy. The items built also offer social and welfare benefits. For example, housing fulfills one of the most basic needs of people by providing shelter from the physical elements. Built items also offer people the opportunity to improve their living standards. The construction industry can influence the competitiveness of enterprises within the economy. Construction can also affect the ability of the nation to attract foreign investment. This is important in this era of globalization as all nations are competing nations to position to attract foreign investment (Ofori, 2012).

The (Government of Ghana (GOG), 2005) Growth and Poverty Reduction Strategy report, reported that the construction industry contributed 8.8% to GDP in 2003 and 2004, ranking third behind agriculture 35.99% and government services 9.98% (Laryea., 2010). In addition (Anaman. & Osei-Amponsah., 2007) wrote that Ghana has experienced stable patterns of real GDP economic growth rate of around 7.2%. Further economic growth is predicted in particular with the recent discovery of oil in Ghana (as revealed in a study on links between the growth of the construction industry and the growth of the marco-economy).

Construction industry development is a deliberate process to improve the capacity and effectiveness of the construction industry in order to meet the demand for building and civil engineering products, and to support sustained national economic and social development objectives. (CIB, 1999).

(Spence & Kultermann, 2011) define construction industry as a brawny, hearty giant stretching to embrace all kinds of construction activity from the erection of towering skyscrapers, construction of an interstate highway, or the establishment of a massive dam on a wilderness river, to major maintenance and alterations. (Moavenzadeh, 1978) cited in (Elkhalifa A. , 2011) defined the construction industry as: The sector of the economy which, through planning, design, construction, maintenance and repair and operation, transforms various resources into constructed facilities. The types of public and private facilities produced range from residential and non-residential buildings to heavy construction.

A wide range of materials is used by the Construction Industry for new buildings, maintenance and civil engineering. Some materials like cement and bricks are produced exclusively for construction purposes. Other materials, although construction may be the largest user of the industry‘s products, are nevertheless produced for a wide range of uses, e.g. iron, steel, and wood-based products (Elkhalifa & Shaddad, 2008) cited in (Elkhalifa A. , 2011).

A complete understanding and knowledge of the real behavior of construction material is of prime importance for the proper behavior of engineering structures. The physical properties of structural material are expected to meet the demand of the fundamental assumptions underlying structural codes of practice on which designs are based (Kankam & Adom-Asamoah, 2002).

Basic materials used in civil engineering construction projects include wood, cement and concrete, reinforcing bars, structural steels, plastic etc. Knowledge of their properties, performance, availability, aesthetics, and cost is essential in selecting a suitable material for a particular situation. Proper assessment of the properties of these materials is vital to ensure the quality and durability of the structure that is made with them (Savitha, 2001).

―Reinforced Concrete" refers to any approved concrete mixture reinforced by steel of any shape, the steel being inserted into the concrete in such a manner that the former will take up the tensile stresses and assist in the resistance to shear. The steel used for this purpose generally consists of one or a combination of the following: - Expanded metal, iron rods, with or without stirrups, joists, or straight or twisted steel bars. It has been used for the former in connection with the construction of railways, bridges, retaining walls, dams, reservoirs, conduits, sewers, wharves, jetties, lighthouses, and a score of other engineering works; and its use in connection with building construction include the erection of all heavier structures, such as warehouses, factories, hotels, business premises, public buildings, etc. Its extensive use has been due to the fact that its strength, rigidity, durability, and fire-resisting properties have proved to be unsurpassed by any other material. Added to these good qualities is the fact that it is an economical material to use; and last, but not least, is the rapidity with which works can be executed where this material is employed.

1.2 Statement of the Problem

Recent collapse of building is becoming frequent in Ghana just as other countries; these building collapses also involves loss of precious life and property. The (Journal, 2013) cited in (Agbenyega, 2014) reported that in Bangladesh a Government investigation established that extremely poor quality construction materials coupled with series of violations caused the collapse of a garment factory building now regarded as the worst garment-industry disaster in history. (Beaumont, 2008) reported that 93 people were killed and 150 injured in the collapse of a school building in Petionville, Haiti. (Ibrahim, 2013) cited various building collapses in Africa especially in Nigeria indicating the trend of building collapses. (Danso & Boateng, 2013) focused on Ghana and reported that more than 10 different cases have happened in Ghana in recent times, claiming 39 lives and 91injured between 2009 and 2013.

Again some Southern and Eastern (China & Ukraine) countries have taken advantage of trade among nations such as Ghana to flood their market with sub-standard materials in the name of reducing construction cost.

According to (Danso & Boateng, 2013) sub-standard (poor quality) materials such as cement, reinforcing bars, timber and aggregate are some of the major causes of building collapse worldwide.

They recommended further research on the quality of other building materials such as reinforcement bars, timber and aggregate, hence this study seek to assess the quality of reinforcing bars in strength and sizes in the local market because of the effect of building failure to lives, properties and the environment.

1.3 Aim of the Study

The aim of the project is to assess the mechanical properties of reinforcing bars in the local market.

1.4 Specific Objective

The specific objectives of the research are to:

Assess the tensile strength properties of reinforcing bars manufacture in Ghana (Mild Steel).

Assess the tensile strength properties of imported reinforcing bars in the local market.

Assess the ductility of reinforcing bars in the market.

Investigate which manufactured products (local and foreign) dominate the market.

Assess the sizes of the reinforcing bars in the market.

1.5 Significance of the Study

Quality assurance of building materials is very essential in order to build strong durable and cost effective structures. Hence this study will be relevant for all stakeholders of the construction industry. The findings will enhance the credibility of the construction industry for upholding standards compared to any other developed country.

It will better inform the general public steps being taken to ensure monitoring and evaluation of the building materials being used in the industry to assure all and sundry the quality of building deliveries.

1.6 Scope of the Study

Geographically this study will be conducted in the third largest city in Ghana, which is known as Sekondi-Takoradi. Due to the discovery and production of oil in commercial quantities it is expected that more infrastructure will be built to meet the demand that is associated with oil production.

The study will focus on the major retail outlet of reinforcement bars in the capital of the Western Region, Sekondi-Takoradi.

1.7 Organization of the Dissertation

The dissertation has been grouped into five chapters. The first chapter provides background information of the study which includes introduction, problem statement, objectives, significance of the study and scope of the study. Chapter two is the literature review and was based on other researchers‘ findings on the topic.

Sample collection, sample labeling, sample preparation and procedure for conducting the tests are captured in chapter three. Chapter four is the Presentation of results and its Analysis. Chapter five contains Summary, Conclusions and Recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Building Materials

Building materials constitute the single largest input to construction, accounting for 50% to 80% of its total value (UNCHS, 1986). A wide range of materials is used by the construction industry for new buildings, maintenance and civil engineering. Some materials like cement and bricks are produced exclusively for construction purposes. Other materials, although construction may be the largest user of the industry`s product, are nevertheless produced for a wide range of uses, e.g. iron, steel, and wood-base products (Elkhalifa & Shaddad, 2008).

2.1.1 Building Materials and Sustainability

Building materials play an essential role in increasing the sustainability of buildings and contributing to economic prosperity. The usage of building materials has a substantial impact on the environment, mainly because of the large quantity of non-renewable resources with the potential for depriving future generations of their use (Ofori., 2002); Godfaurd *et al.*, 2005 as cited in (Akadiri, 2011).

Moreover, all building materials affect the environment during their life cycles. From extraction of raw materials to disposal of demolition waste, various forms of pollution are created, with adverse effects on the atmosphere, land, and water system. The raw materials are processed before becoming suitable for use within buildings; this process often involves consumption of large amounts of energy. Construction practitioners have begun to pay attention to controlling and correcting the environmental damage due to their activities. The selection of materials has attracted scrutiny. In the past the factors further influencing the choice of building materials were predominantly cost, availability and appearance. However, these days environmental suitability of materials is another important factor that is being acknowledged by construction practitioners (Asif *et al.* 2007) as cited in (Akadiri, 2011).

Due to the great diversity in the usage of buildings and installations and the various processes of production, a great variety of requirements are placed upon building materials calling for a very wide range of their properties: strength at low and high temperatures, resistance to ordinary water and sea water, acids and alkalis etc.

The importance of standardization requires the quality of materials and manufactured items to be not below a specific standard level. To develop products of greater economic efficiency, it is important to compare the performance of similar kinds of materials under specific service conditions. Expenditures for running an installation can be minimized by improving the quality of building materials and products.

Building industry economists are thus required to have a good working knowledge, first, of the building materials, second, of their optimum applications on the basis of their principal properties, and third, of their manufacturing techniques, in order that the buildings and installations may have optimum engineering, economic performance and efficiency. Having acquired adequate knowledge, an economist specializing in construction becomes an active participant in the development of the building industry and the manufacture of building materials (Duggal, 2008).

Among a variety of construction materials available, the most largely used are crushed rock, sand, cement, asphalt, wood, clay, steel, aluminum, plastics etc. In order to select the significant ones, the materials are screened through the criteria; Purpose, Suitability to the Project, Commonly Used and Data Availability (Nirmal, 2012).

2.1.2 Stones

Stone has been used in the construction of most of the important structures since prehistoric age. Most of the forts world over, the Taj Mahal of India, the famous pyramids of Egypt and the Great Wall of China are but a few examples. Stone has also been extensively used in almost all the elements of building structures, as load carrying units as well as for enhancing the beauty and elegance of the structure. As building material stone has gradually lost importance with the advent of cement and steel. Secondly, the strength of the structural elements built with stones cannot be rationally analyzed. Other major factors in overshadowing its use are the difficulties in its transportation and dressing which consume a lot of time resulting in slow pace of construction.

A good building stone should have the following qualities; Appearance, Structure, Strength, Weight, Hardness, Toughness Porosity and Absorption. The rest are Seasoning, Seasoning, Weathering, Workability, Fire Resistance and Thermal Movement.

Use of stone as building material depends upon the nature of the work, type of the structural element in which it is to be used and its quality, availability and transportation cost. For structural purpose, granite, gneiss, trap, sandstone, limestone, marble, quartzite and slate are most useful. On the basis of the method of manufacture, items and materials from natural stones are classified as Sawn obtained either from massive rocks by stone-cutting and stone-splitting machines (large stones) or from semi-product blocks by appropriate working (facing slabs, windows sill slabs, etc.); Split—obtained by splitting and finishing blocks (curb stones, paving blocks, etc.); Roughly split—manufactured by oriented splitting of blocks (bedded stone); Fractured—produced by blasting rocks and separating finer sizes (quarry stone); Crushed—produced by crushing and screening (crushed stone, artificial sand) and; Ground—obtained by grinding rocks (ground mineral powder, stone powder).

Quarrying and cutting have a great bearing on the weathering properties of stones. Stone from top ledges of limestone, granite and slate and from the exposed faces of the rock bed is likely to be less hard and durable. Highly absorbent stone should not be quarried in freezing weather since the rock is likely to split. The method of blasting and cutting also influences the strength of the stone and its resistance to freezing and temperature changes.

The conditions which govern the selection of stone for structural purposes are cost, fashion, ornamental value and durability, although the latter property is frequently overlooked or disregarded. Cost is largely influenced by transportation charges, difficulties in quarrying and cutting, the ornamental features, and the durability of stone (Duggal, 2008).

2.1.3 Wood

Wood is a hard and fibrous substance which forms a major part of the trunk and branches of a tree. Wood has many advantages due to which it is preferred over many other building materials. It is easily available (this will not be true after some years) and easy to transport and handle, has more thermal insulation, sound absorption and electrical resistance as compared to steel and concrete. It is the ideal material to be used in sea water. Wood is a good absorber of shocks and so is suitable for construction work in hilly areas which are more prone to earthquakes. Finally, since wood can be easily worked, repairs and alterations to wood work can also be done easily.

Owing to the above mentioned advantages, wood is very widely used in buildings as doors, windows, frames, temporary partition walls, etc. and in roof trusses and ceilings apart from formwork. The principal characteristics of timber of concern are strength, durability and finished Appearance (Duggal, 2008).

1. Narrow annual rings, closer the rings greater is the strength.
2. Compact medullary rays.
3. Dark colour.
4. Uniform texture.
5. Sweet smell and a shining fresh cut surface.
6. When struck sonorous sound is produced.

7. Free from the defects in timber.

8. Heavy weight.

9. No woolliness at fresh cut surface.

2.1.4 Aggregate

Aggregates are the materials basically used as filler with binding material in the production of mortar and concrete. They are derived from igneous, sedimentary and metamorphic rocks or manufactured from blast furnace slag, etc. Aggregates form the body of the concrete, reduce the shrinkage and effect economy. They occupy 70-80 per cent of the volume and have considerable influence on the properties of the concrete. It is therefore significantly important to obtain the right type and quality of aggregates at site. They should be clean, hard, strong, durable and graded in size to achieve utmost economy from the paste. Earlier aggregates were considered to be chemically inert but the latest research has revealed that some of them are chemically active and also that certain types exhibit chemical bond at the interface of aggregates and cement paste. To increase the bulk density of concrete, aggregates are used in two markedly different sizes—the bigger ones known to be coarse aggregate (grit) and the smaller ones fine aggregate (sand). The coarse aggregate form the main matrix of concrete and the fine aggregate form the filler matrix between the coarse aggregate (Duggal, 2008).

2.1.4.1 Fine Aggregate

Sand (> 0.07 mm) is used as a fine aggregate in mortar and concrete. It is a granular form of silica. Sand used for mix design is known as standard sand (IS: 650). In India Ennore Sand is standard sand and in U.K. it is Leighton-Burrard Sand. The standard sand should be obtained from Ennore, Tamil Nadu. It should be quartz, light grey or whitish variety and should be free from silt. It should (100%) pass through 2-mm IS sieve and should be (100%) retained on 90- micron IS sieve. Sand used in mortars for construction purposes should possess at least 85 per cent of the strength of standards and mortars of like proportions and consistency.

Sand may be classified on the basis of source, mineralogical composition, size of the particles and particle size distribution. Depending upon the source, sand may be classified as natural sand—resulting from natural disintegration of rocks or deposited by streams; crushed stone sand—produced by crushing hard stones and, crushed gravel sand—produced by crushing natural gravel. Based on mineralogical composition, sand is divided into quartz, felspar and carbonaceous varieties. Depending upon its size sand is classified as coarse sand—fineness modulus (F.M.) 2.90-3.20; medium sand—F.M.: 2.60-2.90 and; fine sand—F.M. : 2.20-2.60.

The functions of sand are to achieve economy by its use as adulterant in mortar, prevent shrinkage and development of cracks in mortar, furnish strength to mortar against crushing and allow carbon dioxide from the atmosphere to penetrate the fat lime mortars necessary for its air hardening.

2.1.4.2 Coarse Aggregate

These may be uncrushed, crushed or partially crushed gravel or stone most of which is retained on 4.75 mm IS sieve. They should be hard, strong, dense, durable, clear and free from veins and adherent coatings; and free from injurious amounts of disintegrated pieces, alkali, organic matter and other deleterious substances. Flaky, coriaceous and elongated aggregate should be avoided. The functions of coarse aggregate are almost same as that of fine aggregate.

2.1.4.3 Cinder Aggregate

They are well-burnt furnace residue obtained from furnaces using coal as fuel and are used for making lime concrete. They should be clean and free from clay, dirt, wood ash or other deleterious matter. They are classed as A, B and C. Class A is recommended for general purposes, class B for interior work not exposed to damp conditions, and class C for precast blocks. Sulphate content should not exceed 1 per cent when expressed as sulphur trioxide and loss on ignition 10 per cent for class A, 20 per cent for class B, 25 per cent for class C.

2.1.5 Cement

Cements in a general sense are adhesive and cohesive materials which are capable of bonding together particles of solid matter into a compact durable mass. For civil engineering works, they are restricted to calcareous cements containing compounds of lime as their chief constituent, its primary function being to bind the fine (sand) and coarse (grits) aggregate particles together.

Cements used in construction industry may be classified as hydraulic and non-hydraulic. The latter does not set and harden in water such as non-hydraulic lime or which are unstable in water, e g. Plaster of Paris. The hydraulic cement set and harden in water and give a product which is stable. Portland cement is one such. Cement can be manufactured either from natural cement stones or artificially by using calcareous and argillaceous materials. The examples of natural cements are Roman cement, Puzzolana cement and Medina cement and those of artificial cement are Portland cement and special cements. Today cement finds extensive use in all types of construction works; in structures where high strength is required e.g. bridge piers, light houses, lofty towers, and large structures such as bridges, silos, chimneys. And also in structures exposed to the action of water, e.g. reservoirs, dams, dock yards etc. Cement mortar, concrete, reinforced brick work, artificial stones, plastering, pointing and partition walls are routinely used in buildings. Some of the cements available in the market are as follows; Portland Cement, Rapid Hardening Portland, High Alumina, Super sulphate, Sulphate Resisting Portland and Low Heat Portland Cement (Duggal, 2008).

2.2 Impacts of Building Materials Involved in Construction

Building materials before being used in the construction, are found in the natural impure form (e.g., from ores as raw materials). Using the final product of these raw materials involves an energy consuming process and in addition also produces waste (Asif., Muneer., & Kelly., 2007). This extraction process is done in steps and these steps can be grouped into phases involved in the product‘s life cycle. At each stage, there are associated impacts on the environment.

Morel conducted a research on analyzing how materials used in a building construction can reduce the environmental impact, if they are resourced locally rather than importing them from a distant site. This concept was validated by comparing the energy consumption of two houses (a) built with locally resourced materials and (b) a typical concrete house. The analysis concluded that the amount of energy and the impact of transportation used in building type (a) is decreased by a significant ratio compared to building type-(b) [Morel et. al., 2000] cited in (Nirmal, 2012).

Extensive study has been conducted by many researchers on comparing wood with other alternative building materials focusing on the impacts on environment. Petersen and (Petersen. & Solberg., 2003) analyzed the impacts concentrating mostly on the greenhouse gas emissions, economics and methodological issues. The study, after a complete review on comparing wood with other building materials like steel, concrete, vinyl, etc., concluded that wood stands as the best alternative in terms of low GHG emissions, less SO2 emissions and less waste generation (Petersen. & Solberg., 2003) as cited in (Nirmal, 2012).

One particular research study by (Nicoletti 2002) compared two materials, applicable to only a single component of a building. A comparative Life Cycle Assessment (LCA) between two flooring materials was carried out and the one with better environmental profile was identified. Out of these two materials; marble and ceramic tiles was found to have a significant role in relevant harmful gas emissions, whereas the energy consumption was almost equal in both the types of materials [Nicoletti, 2002] as cited in (Nirmal, 2012).

Material testing is a must in all industries, particularly the building sectors. This is because an incorrect assessment of a material would ultimately be harmful to people and the environment (Savitha, 2001). The author concluded that testing of construction materials provides an assurance to the user on the reliability of the material hence testing laboratories and research work make a useful contribution to national development through the estimation of the quality of construction materials.

2.3 Steel

Steel is the common name for a large family of iron alloys which are easily malleable after the molten stage. Steel is the most common alloy of iron. Alloy steels contain varying amounts of carbon as well as other metals, such as chromium, vanadium, molybdenum, nickel, tungsten etc. Steels are commonly made from iron, coal and limestone. When these raw materials are put in to the blast furnace, the result is a pig iron (Higgins., 1993).

Steel has been part of some of the greatest achievements in the history of man‘s discovery. It was the 'iron horse ' and steel rails that helped carve a nation out of the frontier. Steel is the backbone of bridges, the skeleton of skyscrapers, and the framework for automobiles. Steel continue to revolutionize the way we live even in the twenty first century, it is the high-strength lighter-than plastic frames for eyeglasses. It is the stronger and the more durable frame in the construction buildings; it is the high technological alloy used in the Space Shuttle's solid fuel rocket motor cases; and it is the precise surgical instruments used in hospital operating rooms around the world (Dzogbewu., 2010).

2.3.1 History and Production of Steel

The exact date at which people discovered the technique of smelting iron ore to produce usable metal is not known. The earliest iron implements discovered by archaeologists in Egypt dates from about 3000 BC and iron ornaments were used even earlier; the comparatively advanced technique of hardening iron weapons by heat treatment was known to the Greeks about 1000 BC.

The alloys produced by early iron workers and all the iron alloys made until about the 14th century would be classified today as wrought iron. They were made by heating a mass of iron ore and charcoal in a forge or furnace having a forced draft. Under this treatment the ore was reduced to the sponge of metallic iron filled with a slag composed of metallic impurities and charcoal ash. This sponge of iron was removed from the furnace while still incandescent and beaten with heavy sledges to drive out the slag and to weld and consolidate the iron.

The iron produced under these conditions usually contained about 3 percent of slag particles and 0.1 percent of other impurities. Occasionally, this technique of iron making was produced by accident, a true steel rather than wrought iron. Iron workers learned to make steel by heating wrought iron and charcoal in clay boxes for a period of several days. By this process the iron absorbed enough carbon to become true steel.

After the 14th century the furnaces used in smelting were increased in size, and increased draft was used to force the combustion gases through the ―charge,” the mixture of raw materials. In these larger furnaces, the iron ore in the upper part of the furnace was first reduced to metallic iron and then took on more carbon as a result of the gases forced through it by the blast. The product of these furnaces was pig iron, an alloy that melts at a lower temperature than steel or wrought iron (Rolf, 2006) as cited in (Dzogbewu., 2010). Pig iron (so called because it was usually cast in stubby, round ingots known as pigs) was then further refined to make steel. Over the years various countries have excelled in making steel. During the eighteenth century a relatively small amount of steel was made, but Sweden was the main producer. In the nineteenth century, Great Britain became dominant. In the twentieth century the United States was the largest steel producer in the world until about 1970, when it was surpassed by the Soviet Union. At the start of the twenty-first century, China led the world in steel production (Dzogbewu., 2010).

2.4 Iron

Iron is a chemical element. It is a strong, hard, heavy gray metal. Among all the metals, iron is second only to aluminum in natural abundance, making up 4.7 percent of the earth's crust, and occurring mainly in its various oxides, it is also found in meteorites. Iron is also found combined in many mineral compounds in the earth's crust. Iron rusts easily. It can be magnetized and is strongly attracted to magnets. It is used to make many things such as gates and railings. Iron is also used to make steel, an even harder and tougher metal compound. Steel is formed by treating molten iron with intense heat and mixing it (alloying) with carbon. Steel is used to make machines, cars, tools, knives, and many other things .The main product made from iron is steel, the least expensive and most widely used of all metals (Dzogbewu., 2010).

2.4.1 Iron Rods

Iron rods belong to a large family of iron alloys called steel. Which are easily malleable after the molten stage. Iron rods are obtained after the ingot is rolled into rods of different diameters at the rolling mills. They are used in buildings and heavy constructional works (AWS., (American Welding Society), 2008).

2.4.2 Reinforcement of Concrete with Steel Bars (Iron Rods)

The introduction of steel concrete also known as ferroconcrete, or reinforced concrete is generally attributed to Joseph Monier, a French gardener, who about the year 1868 was anxious to build some concrete water basins. Concrete has considerable compressive or crushing strength, but is somewhat deficient in shearing strength, and distinctly weak in tensile or pulling strength. Steel, on the other hand, have a good tensile strength and is easily procurable in simple forms such as long bars. If a concrete slab be "reinforced" with a network of small steel rods on it‘s under surface where the tensile stresses occurs, its strength will be enormously increased.

A steel bar should be capable of being bent cold to the shape of the letter U without breaking. The structures in which steel concrete is used normally are: walls, columns, piles, beams, slabs and arches. The effect of reinforcing walls with steel is that they can be made much thinner. The steel reinforcement is generally applied in the form of vertical rods built in the wall at intervals, with lighter horizontal rods which cross the vertical ones, and thus form a network of steel which is buried in the concrete. These rods assist in taking the weight, and the whole network binds the concrete together and prevents it from cracking under a heavy load. To meet tensile stresses the steel is nearly always inserted in the form of bars running along the beam (Dzogbewu., 2010).

2.4.3 Important Characteristics of Reinforcement

Good strength, bond with concrete, thermal expansion characteristics (similar to concrete) and bendability are prime attributes which make steel rods most effective reinforcing material for engineering of RC structures. Besides strength, the durability of the structure depends upon rebar quality. Durability is the ability of the structure to maintain safety and serviceability criteria during its design life. Durability is dependent on the condition of concrete and reinforcement. Corrosion of reinforcement is one of the main factors that could impair durability. Corrosion can be either due to chloride intrusion or due to the effect of carbonation. Chemical composition of reinforcement plays an important role in this respect. Two characteristics of reinforcement bars, namely, bendability and weldability are important for construction. Bendability is essential from giving requisite shape to the rebar to suit the demand of the structures (Prabir., Shylamoni., & Roshan., 2004).

2.4.4 Bond with Concrete

The bond between rebar and concrete depends upon many factors, such as shape, and geometry of ribs. Steel bars are generally round in cross section. To restrict longitudinal movement of the bars relative to the surrounding concrete, lugs or protrusions called deformations lugs or ribs are rolled on to the bar surface. For appropriate bond strength, the deformations of ribs of rebar should satisfy certain specifications. The prime objective of such deformation is the enhancement of bond with concrete by mechanical interlock.

Steel is the time proven match for reinforcing concrete structures. Reinforced concrete structure is designed on the principle that steel and concrete act together to resist induced forces. The properties of thermal expansion for both steel and concrete are approximately the same. This along with excellent bendability property makes steel the best material as reinforcement in concrete structures. Another reason steel works effectively as reinforcement is that it bonds well with concrete. When passive reinforcement (steel bars) is employed, the structure is known as reinforced concrete (RC) structure. In pre-stress concrete structure, the reinforcement (steel wire) is stressed prior to subjecting the structure to loading, which may be viewed as active reinforcement. Passive steel reinforcing bars, also known as rebars, should necessarily be strong in tension and, at the same time, be ductile enough to be shaped or bent (Prabir., Shylamoni., & Roshan., 2004).

2.4.5 Resistance Against Corrosion

Resistance of rebars against corrosion depends upon its chemical composition. Corrosion of rebars in reinforced concrete structure is a complex phenomenon. Corrosion of steel occurs due to a number of initiating causes that expose the rebars to moisture and oxygen either by carbonation or chloride intrusion. During the process of cement hydration, a thin protective alkaline passive film is formed around rebars. Corrosion process is initiated when this protective film is broken. Though good quality concrete is a prerequisite for the corrosion resistance of RC structure, the quality of rebars has also a significant influence on it (Prabir., Shylamoni., & Roshan., 2004).

2.4.6 Mechanical Properties of Steel

It is the mechanical properties of a material that reveal its elastic and inelastic behavior when a force is applied thereby indicating its suitability for mechanical applications, e.g. modulus of elasticity, tensile strength, percentage elongation, hardness and fatigue limit. The mechanical properties of steels are almost always requirements of the specification used to purchase the product. For flat rolled products the properties usually specified are tensile strength, yield stress (or proof stress), elongation and Brinell or Rockwell hardness. These properties give a guarantee that the material in question has been correctly produced, and are also used by engineers to calculate the working loads or pressures that the product can safely carry in service (Dzogbewu., 2010).

2.4.6.1 Tensile Test

Tensile properties indicate how the material reacts to forces being applied in tension. It measures the force required to pull something such as rope, wire, or a structural beam to the point where it breaks. It is measured in units of force per unit area. In the SI system, the units are Newton per square millimeter or mega Pascal. Specially, the tensile strength of a material is the maximum amount of tensile stress that it can be subjected to before failure. The definition of failure can vary according to material type and design methodology. This is an important concept in engineering, especially in the fields of material science, material engineering and structural engineering. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the tensile strength, toughness, and modulus of elasticity, elastic limit, elongation, yield point and other tensile properties.

Tensile strength is an intensive property and, consequently, does not depend on the size of the test specimen. However, it is dependent on the preparation of the specimen and the temperature of the test environment and material (Rollason, 1973) as cited in (Dzogbewu., 2010).

2.4.6.2 Types of Mechanical Strength

There are three typical definitions of tensile strength:

i. Yield strength: The stress at which a material strain changes from elastic deformation to plastic deformation, causing it to deform permanently.
ii. Ultimate strength: The maximum stress a material can withstand when subjected to tension. It is the maximum stress on the stress-strain curve.
iii. Breaking or Failure strength: The stress coordinate on the stress-strain curve at the point of rupture.

2.5 Overview of Quality Management

Quality is one of the aims of standardization. The quality of a product or a complete building or other constructions is the totality of its attributes that enable it to perform a stated task or to fulfill a given need satisfactorily for an acceptable period of time. For a building and civil engineering work, a satisfactory product, although essential in itself, is not on its own sufficient. It must be incorporated in the design and construction in a correct manner. In buildings, more defects and failures arise from inadequacies in the treatment of products in design and construction than from shortcomings in the products themselves (Atkinson, 2005). In their work, (Harris, McCaffe, & F.Edum-Fotwe, 2006) stated that Quality Management has seen a transition from reacting to the outcome of site production activities to becoming a strategic business function accounting for the raison d'etre of construction companies. Unless a construction company can guarantee its clients a quality product, it cannot compete effectively in the modern construction market.

2.5.1 The Concept of Quality Management

The concept of quality has existed for many years, but its meaning has changed and evolved over time. Before the early twentieth century, quality management meant inspecting products to ensure that they met specifications. This is evident in the Egyptian wall painting circa of 1450BC which showed evidence of measurement. Stones used in the pyramids which were cut so well that a knife could not go between them (Evans and Lindsay, 2008 as cited in (Sabah, 2011). According to them, around 1940s, during World War II, quality became more statistical in nature. Statistical sampling techniques were used to evaluate quality, and quality control charts were used to monitor the production process. In the 1960s, with the help of so-called ―quality gurus," the concept took on a broader meaning. Quality began to be viewed as something that encompassed the entire organization, not only the production process. All functions were responsible for product quality and shared the costs of poor quality. However, in the 1970s and 1980s many U.S.

industries had to make changes to their quality policies when they lost market share to foreign competition particularly in the auto industry. Many hired consultants instituted quality training programs for their employees (Reid and Sanders, 2007 cited in (Sabah, 2011)).

(Hoonakker, Carayon, & Loushine, 2010) established in their study that many of the management practices used to support construction organizations are being challenged. The industry‘s clients are moving forward. Clients demand improved service quality, faster buildings and innovations in technology. In (Kaufmann & Wiltschko, 2006), Quality Management Concept is said to be structured in general according to the ―International Organization for Standardization" ISO 9000-series and the ―Plan, Do, Check, Act" PDCA-cycle. It further illustrated the two main structures stated above as follows;

ISO 9000-series**:** According to EN ISO 9000 quality management is defined as ―coordinated activities to direct and control an organization with regard to quality". Direction and control with regard to quality generally includes establishment of the quality policy and quality objectives, quality planning, quality control, quality assurance and quality improvement:

- Quality planning is focused on setting quality objectives and specifying necessary operational processes and related resources to fulfill the quality objectives
- Quality control is focused on fulfilling quality requirements

- Quality assurance is focused on providing confidence that quality requirements will be fulfilled
- Quality improvement is focused on increasing the ability to fulfill the quality requirements

2.5.2 PDCA-Cycle

An important mindset of quality management is the PDCA-cycle. This cycle including the four components as Plan, Do, Check and Act (PDCA), was originally conceived by Walter Shewhart in the 1930`s, and later adopted by W. Edward Deming. The model provides in general a framework for the improvement of a process or system and is an iterative four-step quality strategy (Deming,1982) as cite in (Kaufmann & Wiltschko, 2006).

- **Plan:** Establish objectives and processes necessary to deliver results in accordance to specification
- **Do:** implementation of processes
- **Check:** Monitor and evaluate processes and results against objectives and specifications.
- **Act:** Take actions to the outcome for necessary improvement (e.g. improve, standardize).

2.5.3 Quality Management Systems

If properly implemented, formal quality management systems provide a vehicle for achieving quality (i.e. conformance to established requirements). As defined by ANSI, a quality system is –the organizational structure, responsibilities, procedures, processes, and resources for implementing quality management" (Arnold, 1994 as cited in (Battikha., 2002a). In other words, Quality management systems refers to the set of quality activities involved in producing a product, process, or service, and encompasses prevention and appraisal (Burati., Farrington., & Ledbetter., 1992). It is ~~a~~ management discipline concerned with preventing problems from occurring by creating the attitudes and controls that make prevention possible" (Crosby, 1979 as cited in (Battikha., 2002a)). Quality activities include the determination of the quality policy, objectives, and responsibilities and implementing them through quality planning, quality control, quality assurance, and quality improvement, within the quality system (ASQC, 1997 as cited in (Battikha., 2002a)) (Agbenyega, 2014).

Other views expressed by (www.abahe.co.uk, 2016) is that, a quality management system is a management technique used to communicate to employees what is required to produce the desired quality of products and services and to influence employee actions to complete tasks according to the quality specifications. In like manner, (Businessballs.com, 2016) also explained quality management system as a set of co-ordinated activities to direct and control an organization in order to continually improve the effectiveness and efficiency of its performance. These activities interact and are affected by being in the system, so the isolation and study of each one in detail will not necessarily lead to an understanding of the system as a whole. The main thrust of a QMS is in defining the processes, which will result in the production of quality products and services, rather than in detecting defective products or services after they have been produced. The paper continued to say that a fully documented QMS will ensure that two important requirements are met:

- The customers‘ requirements – confidence in the ability of the organization to deliver the desired product and service consistently meeting their needs and expectations.
- The organization‘s requirements – both internally and externally, and at an optimum cost with efficient use of the available resources – materials, human, technology and information.

2.5.4 Purpose of Quality Management in the Construction Industry

The (U.S. Army Corps of Engineers, 2004) states that Construction Quality Management ―CQM" is the performance of tasks, which ensure that construction is performed according to plans and specifications, on time, within a defined budget, and a safe work environment. For purposes of this study, quality is defined as conformance to properly developed requirements. For a construction project, quality begins with requirements carefully developed, reviewed for adherence to existing guidance and ultimately reflected in criteria and design documents which accurately address these needs. Therefore, the designer establishes the quality standards and the contractor in building to the quality standards in the plans and specifications, controls the quality of the work. The purpose of CQM is the Government‘s efforts, separate from, but in coordination and cooperation with the contractor, assure that the quality set by the plans and specifications is achieved. CQM is the combined effort of the contractor and the Government. The contractor has primary responsibility for producing construction through compliance with plans, specifications, and accepted standards of the industry (Agbenyega, 2014).

2.5.5 Principles of Quality Management

Quality Management is based on three fundamental principles (Evans and Lindsay, 2008) as cited in (Sabah, 2011); namely:

1. Focus on customer and stakeholders;
2. Participation and teamwork by everyone in the organization;
3. A process focus supported by continuous improvement and learning.

2.5.6 Project Quality Performance Measurement

Performance measurement is a fundamental building block of quality management and a total quality organization. Historically, organizations have always measured performance in some way through the financial performance, be it success by profit or failure through liquidation. However, traditional performance measures, based on cost accounting information, provide little to support organizations on their quality journey because they do not map process performance and improvements seen by the customer. In a successful total quality organization, performance will be measured by the improvements seen by the customer as well as by the results delivered to the shareholders (bussinessballs.com/dtiresources). According to (Takim, Akintoye, & Kelly, 2003), performance measurement in the manufacturing and construction industries is used as a systematic way of judging project performance by evaluating the inputs, outputs and the final project outcomes. However, very few companies systematically measure their performance in a holistic way. Moreover, the existing systems tend to focus more on product and less on process and design. This can lead to the suboptimal quality of the performance measurement system, the misjudging of relative performance, complacency and the denying of appropriate rewards to the deserving. Previous studies have revealed that performance can be measured in terms of financial and non-financial measures, or the combination of both. When measurements are being implemented, contractors, consultants and the management team‘s performances are blamed as the major reasons for the failure of a particular project. The other project stakeholders such as client, suppliers, trade contractors and the community at large are neglected (Agbenyega, 2014).

2.6 Quality Planning

(Harris & McCaffer, 2001) defined quality planning as a set of activities whose purpose is to define quality system policies, objectives, and requirements, and to explain how these policies will be applied, how these objectives will be achieved, and how these requirements will be met. Subsequent to this definition, (Construx 2003) as cited in (Agbenyega, 2014) stressed that quality plan is different from a test plan. The study continued that quality plan defines the quality goals, is realistic about where defects come from, selects appropriate detection and prevention methods, and has means not to ―go dark". The Project Management Book of Knowledge ―PMBOK" 4 also addressed quality planning from a different position to enhance the thoughts earlier expressed. It said that quality planning has a process input generated by predecessor processes referred to as the Project Scope Statement and Project Management Plan. These processes are introduced by external units like Enterprise Environmental Factors and Organizational Process Assets. PMBOK4 further defined quality planning as the process for "identifying which quality standards are relevant to a project and determining how to satisfy them": In other words, it means planning how to fulfill process and product (deliverable) quality requirements: "Quality is the degree to which a set of inherent characteristics fulfill requirements". By planning the quality one has to respect some principles, and these are:

- **Customer satisfaction comes first**: Quality is defined by the requirements of the customer.
- **Prevention over inspection**: It is better to avoid mistakes than to inspect the result and repair the defects.
- **Management responsibility**: Costs of quality must be approved by the management.
- **Continuous improvement**: Becoming better is an iteratively structured process.

These sentences implicate the rule, that gold plating is not an indicator of quality; it has to be avoided.

2.6.1 Quality Assurance

In recent years, increasing concern has been expressed at the standards of performance and quality achieved in building works. The need for structured and formal systems of construction management to address the aspect of performance, workmanship and quality has arisen as a direct result of deficiencies and problems in design, construction, materials and components. Many of the problems experienced in buildings appear as a range of inadequacies from minor technical and aesthetic aspects to major building defects. Irrespective of their degree of severity, such problems are known to cost the industry so much annually, yet, many difficulties might be alleviated through greater care and attention to standards of performance and quality at the briefing, design and construction stages of the building process (Griffith, 1990). If buildings are to be troublefree, more attention needs to be given to applying quality assurance principles to design and site-work, including project selection and specification, and to supervision of the handling and protection on site (Atkinson, 2005).

(Harris & McCaffer, 2001) defined quality assurance as a set of activities whose purpose is to demonstrate that an entity meets all quality requirements. Quality Assurance activities are carried out in order to inspire the confidence of both customers and managers, confidence that all quality requirements are being met. According to EuroRoadS 2006 cited in (Agbenyega, 2014), the main objective of quality assurance measures in information processes is to fulfill a required quality level. By using described probabilistic model, cause and effect diagram, one is able to analyze existing processes and to detect existing quality gaps within these processes. Reference to Hendrickson (1999) as cited in (Agbenyega, 2014), quality requirements should be clear and verifiable so that all parties in the project can understand them for conformance. (Harris & McCaffer, 2001) continued that Quality assurance (QA) emphasizes defect prevention, unlike quality control that focuses on defect detection once the item is produced or constructed. It was further established that quality assurance concentrates on the production or construction management methods and procedural approaches to ensure that quality is built into the production system.

2.6.2 Quality Assurance in Construction

The importance of Quality Assurance is based on the principles of getting things right first time. By implementing, maintaining, reviewing and continually improving a Quality Assurance System, a construction company can achieve and reap the benefits of having such a system in place. Quality Assurance exists because of the degree of dissatisfaction experienced by the industry's clients over a long period, combined with a growing impatience by some of their advisers to achieve value for money. An increasing number of building companies are also frustrated by the inadequacy of a system which however valiantly they try, leaves their efforts lacking in some regards. A revolution has occurred in the assembly of buildings from what was a craft process to one where the critical work of connecting interdependent units is done in the main by semi-skilled labour from a multiplicity of separate employers. This makes great demands upon supervision and management systems. (www.studymode.com, 2008). A Quality System is designed to provide an assurance to Clients, which can be supported through documented records, that all contracts will be completed in accordance with the agreed time, cost and specification. It should also further ensure that the company personnel, sub-contractors and key suppliers are aware of customer requirements and that they are fully met. Conformance with requirements of the detailed procedures developed in accordance with the Quality Manual has to be mandatory for all staff employed in the company. It is essential to the system that encouragement is given to each employee to develop and maintain an attitude of continuing quality improvement and customer satisfaction. Quality Assurance is concerned with developing and planning the necessary technical and managerial competence to achieve desired results. It is also about attitudes, both of management and of all those for whom they are responsible. (StudyMode.com, 2008) as cited in (Agbenyega, 2014).

2.6.3 Quality Control

Investopedia explains 'Quality Control' as a process through which a business seeks to ensure that product quality is maintained or improved and manufacturing errors are reduced or eliminated. Quality control requires the business to create an environment in which both management and employees strive for perfection. This is done by training personnel, creating benchmarks for product quality, and testing products to check for statistically significant variations. A major aspect of quality control is the establishment of well-defined controls. These controls help standardize both production and reactions to quality issues. Limiting room for error by specifying which production activities are to be completed by which personnel, reduces the chance that employees will be involved in tasks for which they do not have adequate training. Quality Management Systems (2013) stated that quality control is the process of evaluating whether construction projects adhere to specific standards.

The main objective of quality control is safety. Additionally, quality control is also meant to ensure that buildings are reliable and sustainable. The ISO definition also states that quality control is the operational techniques and activities that are used to fulfill requirements for quality. This definition could imply that any activity whether serving the improvement, control, management or assurance of quality could be a quality control activity. What the definition fails to tell us is that controls regulate performance. They prevent change and when applied to quality, it regulates quality performance and prevent undesirable changes in the quality standards. It continued that quality control is a process for maintaining standards and not for creating them. Standards are maintained through a process of selection, measurement and correction of work, so that only those products or services which emerge from the process meet the standards. In simple terms quality control prevents undesirable changes being present in the quality of the product or service being supplied. The simplest form of quality control is illustrated in the Figure below. Quality control can be applied to particular products, to processes which produce the products or to the output of the whole organization by measuring the overall quality performance of the organization.

It is often deemed that quality assurance serves prevention and quality control detection but a control installed to detect failure before it occurs serves prevention such as reducing the tolerance band to well within the specification limits. So quality control can prevent failure. Assurance is the result of an examination whereas control produces the result. Quality Assurance does not change the product, Quality Control does. (Harris & McCaffer, 2001) defined quality control as a set of activities or techniques whose purpose is to ensure that all quality requirements are being met. In order to achieve this purpose, processes are monitored and performance problems are solved. (Scatterfield, 2005) as cited in (Agbenyega, 2014) said quality control is critically important to a successful construction project and should be adhered to throughout a project from conception and design to construction and installation. Inspection during construction will prevent costly repairs after the project is completed. The inspector, engineer, contractor, funding agency, permit agency, and system personnel must work together to inspect, document, and correct deficiencies.

2.6.4 Importance of Quality Control in Construction

Quality Control (QC) in construction is the process of verifying that the project is built to plan, that the tolerances allowable by industry standard and engineering practices have been met or bettered, and that the finished project (and all phases to get there) meet with the quality standards of the architect, engineer, owner, and general contractor. On construction projects there are dozens of subcontractors, all of which have specific responsibilities. Superintendents and project managers try to maintain high quality standards but they cannot be everywhere at once. Required inspections by cities and counties (as well as other jurisdictions, depending on the project) help to ensure safety and code issues. In addition, a good general contractor or developer will have on staff a QC person, someone who is responsible for going through the building or project, ensuring compliance, and maintaining an ongoing list of corrective items that must be accomplished before the contractor who installed it is paid or leaves the job. QC technicians generally keep a very detailed binder, separated by areas/rooms/phases of the project with notes of items that must be either verified or corrected, with sign-off as each is accomplished. This binder becomes part of the project record and is an important element to completing the project on time and with expected quality maintained (Wiki.answers.com cited in (Agbenyega, 2014)).

2.6.5 Quality Improvement

The (Health Foundation, 2009) indicated there is no single definition of quality improvement and no one approach appears to be more successful than another. However, there are a number of definitions that describe quality improvement as a systematic approach that uses specific techniques to improve quality. The most important ingredient in successful and sustained improvement is the way in which the change is introduced and implemented. According to ISO 9000:2000, Quality Improvement is ―Part of quality management focused on increasing the ability to fulfill quality requirements."

Empirical studies on quality management in construction have shown that various quality improvement practices are common among non-residential builders and developers. Most of these practices have been collectively grouped under a successful management philosophy termed, ―Total Quality Management" or TQM, (Shofoluwe et al 2012 as cited in (Agbenyega, 2014).

2.7 Some Past Studies on Quality of Building Materials

2.7.1 Osarenmwinda & Amuchi (2013)

The authors cited in their publication that the use of inferior quality and substandard steel bars are among the causes of construction collapse and failures. Based on this, they conducted quality assessment of commercially available reinforcement steel bars in some Nigerian markets. Specifically they investigated mechanical properties of 10mm and 12mm diameter ribbed reinforced steel bars locally produced and available in the market of Lokoja, Kogi state, Oshodi and Lagos state. They concluded that the mechanical properties of 10mm and 12mm diameter steel bars in those markets met the ASTM A706 recommended standard.

2.7.2 Ejeh & Jibrin (2012)

Similarly, (Ejeh & Jibrin, 2012) conducted an investigation into the tensile behavior of reinforcing steel bars in some Nigerian markets. Samples were obtained from eight Nigerian steel production companies and six foreign companies and made the following conclusion; (1) the characteristic strength values for most of the locally produced bars samples are low compared to the BS4449: 2005 (2009) standards for high tensile steel which is 460N/mm² minimum value. (2) Most of the locally produced bars recorded satisfactory percentage elongation with corresponding unsatisfactory characteristic strength values and vice versa in the case of foreign bars. (3) Seventy One percent (71%) of the samples design strength value failed below the code specified design values.

2.7.3 Kankam & Adom-Asamoah (2002)

The authors carried out an experimental investigation on steel bars and reinforced concrete beams and made the observation that; the Ghanaian steel industry recycle approximately 80% steel bars from scrape metals estimated annually to be 80,000 tonnes. They recorded that physical properties such us yield strength, ultimate strength, Young`s modulus of elasticity, Poison‘s ratio and percentage elongation determine the behavior of reinforcement in concrete. Their samples for the experiment were obtained from three local steel manufacturing companies in Ghana namely, Wahome, Tema Steel Works and Ferro Fabric. Their test results indicated that two out of the three companies did not meet the BS4449: 2005 (2009) maximum limit of 0.25% for carbon requirement for mild steel. They also concluded that the characteristic strength of locally produced mild steel bars are not consistent with specified standard values and hence recommended that a revision of the specification assigned to locally milled steel from recycled metal.

2.7.4 Danso & Boateng (2013)

The authors recommended further studies for identification of sub-standard materials that contribute to building collapse in Ghana after they had concluded that cement produced in Ghana is not the real cause of building collapses. The reiterated the call that sub-standard (poor quality) material is one of the major causes of building collapses worldwide. They further noted that the main materials mostly identified as sub-standard are cement, reinforcement bars, timber and aggregate. Therefore this dissertation work seeks to assess the quality of reinforcing bars in the open market as recommended by the authors.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter explains the procedure for testing the quality of reinforcing steel bars and investigating the sizes of bars obtainable in the open markets of Sekondi-Takoradi and investigating sizes of iron steel bars in the open market. Reinforcement rods were obtained from major retail outlets in the Western Regional capital. Each specimen was cut to 500 millimeter lengths and fixed into a Computer Controlled Universal Testing Machine to evaluate the qualities of the mechanical strength. The testing was conducted in the Mechanical laboratory of Ghana Standard Authority in Accra.

3.2 Samples Collections

The samples were collected from three major retail outlets known as B5 Plus Limited, Sethi Takoradi Limited and K. Ofori, Limited. Samples collected were 12mm, 16mm and 20mm diameter bars from local manufactured companies and imported bars from Ukraine were tested. The researcher had observed that 12mm, 16mm and 20mm diameter rods were the commonly sizes used by civil engineers in design of various building construction projects, hence the decision to use them in the study. In addition available steel bars in the market were listed from the retail companies.

3.3 Samples Labeling

All the three retail companies from where samples were collected were labeled as K, B and S. The samples were therefore identified as KMS_{12}, BMS_{16}, SHT_{20}, KHT_{12} and the like. For example KMS_{12} is defined as; ‗K' implies sample from K. Ofori Limited; ‗MS' implies local manufactured rod or Mild Steel rod and Twelve millimeter diameter rod sample. SHT_{20} also may be defined as; _S' implies sample from Setti Takoradi Limited; _HT' implies foreign manufactured rod or High Tensile Steel rod and Twenty millimeter diameter rod. The order of identification does not imply one is better than the other but just for identification purposes.

3.4 Samples Preparation

Three specimens each was tested for the various (12mm, 16mm & 20mm) steel bars. The specimens were cut with a hacksaw blade to a length of 500 millimeter. For each size of steel rod, three (3) pieces were cut and identified as A, B and C with a blue, black and red permanent pen, marker respectively at one end of the steel rod.

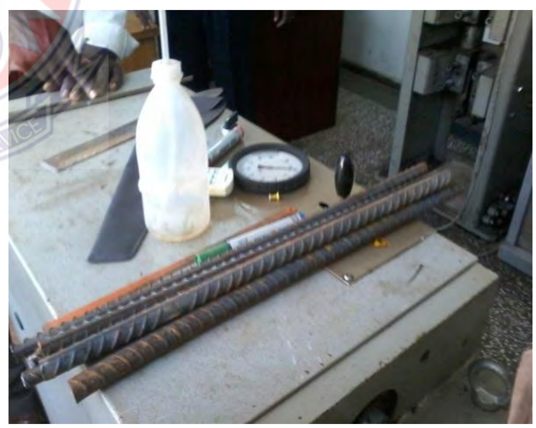


Fig. 3.1: Samples cut to a length of 500mm.

The samples were re-measured with a steel rule to determine the actual size cut and the figures were recorded. The next step was to fix each sample into the marker machine to a graduation of 10mm interval on the steel rod as a requirement of the Computer

Controlled Universal Testing Machine. The tests were conducted at the mechanical laboratory of Ghana Standard Authority in Accra.

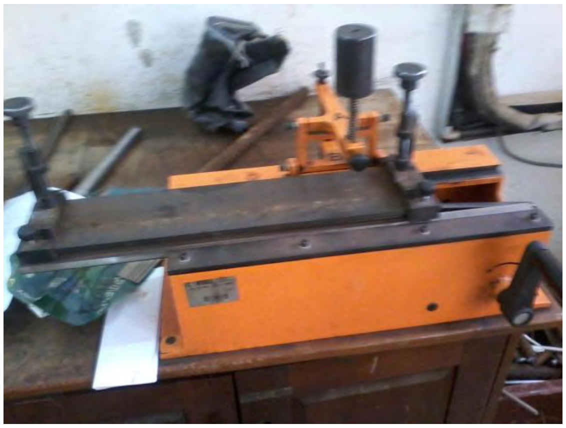


Fig. 3.2: Marking Machine

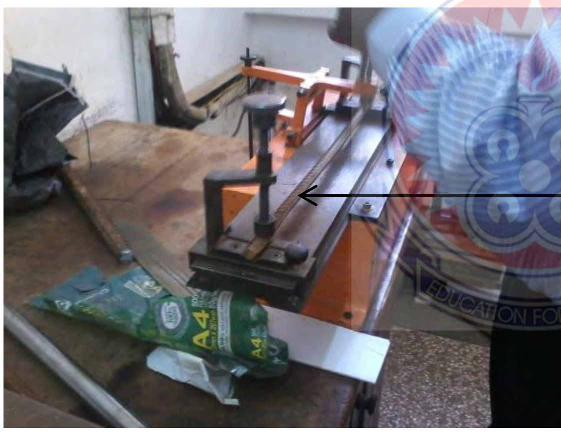
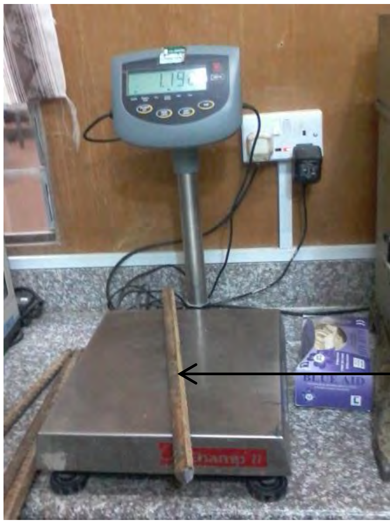


Fig. 3.3: Sample fixed in the marking machine.

The samples were then weighed in kilogram by a weighing machine to record the weight of each sample. The software of the Computer Controlled Universal Testing Machine uses the weight and the length measured to generate the actual diameter of the rod.

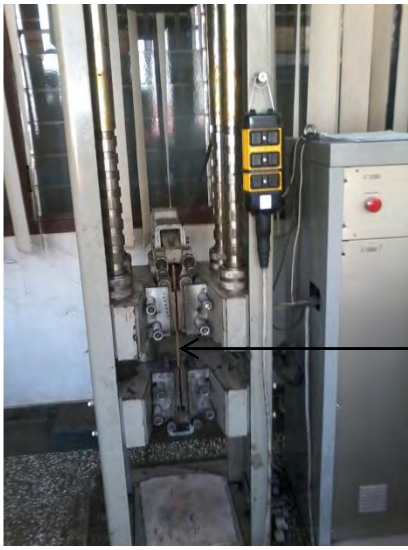


A sample of Steel bar being weighed

Fig. 3.4: Weighing Machine

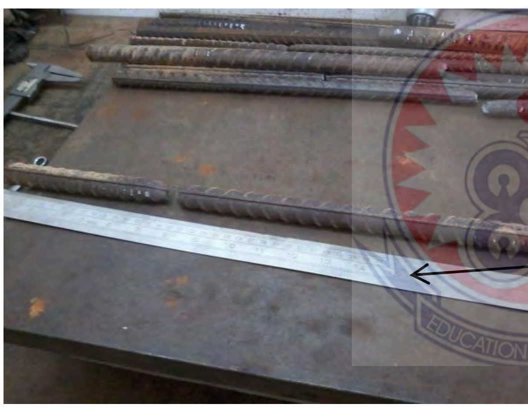
The penultimate step was to fix the iron steel bar sample into the Computer Controlled Universal Testing Machine for the test to begin. The sample was gripped about 150mm in an upper level and about 150mm in a lower level. To determine the original length of the sample, the machine has a constant of 5, which is multiplied by the diameter of the steel rod or sample.

The machine applied a force unto the sample until it broke into two parts. Both parts were then linked or joined together to be able to measure with a steel rule to record the new length of the sample after it had been stretched by the machine. Finally the new length was inputted in the software of the testing machine to determine the stress and elongation values.



500mm Steel bar Sample fixed into the Testing Machine

Fig. 3.5: Computer Controlled Universal Testing Machine.



Steel Rule for measuring sample after fracture

Fig. 3.6: Sample separated after fracture.

In determining the sizes of steel bars in the market, of the retails, the researcher engaged the managers in an informal interview to list the various sizes in the market.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.0 Introduction

The results of the tensile tests indicating yield Strength, ultimate tensile strength, elongation and ductility are presented in this chapter. Yield, tensile and elongation are all measured during a tensile or tension test. A standard size sample is pulled and the associated stress and strain are recorded. Bar mark KMS_{12} is identified as 12mm Diameter Mild Steel samples obtained from K. Ofori limited, while bar mark BMS_{16} is identified as 16mm diameter mild steel bars sourced from B5 Company Limited. SMS_{20} may be recognized as 20mm diameter mild steel bar obtained from Setti Limited.

4.1 Yield Strength Values

Table 4.1: Yield Strength Values

Serial No.	Mark	Yield Strength (N/mm²)	BS 4449:2005 & GS 788-2: 2008 Min. Provisions	Remarks
1	KMS_{12}	327	300	Above Code Value
2	KMS_{16}	308	300	Above Code Value
3	KMS_{20}	308	300	Above Code Value
4	BMS_{12}	318	300	Above Code Value
5	BMS_{16}	326	300	Above Code Value
6	BMS_{20}	306	300	Above Code Value
7	SMS_{12}	323	300	Above Code Value
8	SMS_{16}	344	300	Above Code Value
9	SMS_{20}	303	300	Above Code Value
10	KHT_{12}	483	500	Below Code Value
11	KHT_{16}	552	500	Above Code Value
12	KHT_{20}	723	500	Above Code Value
13	BHT_{12}	474	500	Below Code Value
14	BHT_{16}	544	500	Above Code Value
15	BHT_{20}	698	500	Above Code Value
16	SHT_{12}	479	500	Below Code Value
17	SHT_{16}	548	500	Above Code Value
18	SHT_{20}	711	500	Above Code Value

All bar marks identified as HT are high tensile steel imported from Ukraine into the country; hence bar mark BHT_{12} is identified as 12mm diameter high tensile steel rod sourced from Setti Limited etc.

Table 4.1 shows result of yield strength values compare with the (BS 4449:2005, 2009) & GS 788-2 standard codes values. The average yield strength for mild steel bars derived from the table is 318N/mm², which is 1.06% greater than the minimum value of 300N/mm² as provided by the code.

Again the results indicate that, the 12mm high tensile steel obtained ranged from 474N/mm² to 483N/mm² which is 0.96% less than the value provided by the BS 4449 & GS 788-2 standard of 500N/mm². However the 16mm and 20mm diameter high tensile steel bars recorded average yield strength of 629N/mm² which is 1.26% higher than the minimum provision of 500N/mm² by the BS 4449 & (GS 788-2, 2008) code. Yield strength of a steel bars is said to be the stress at which a material strain changes from elastic deformation to plastic deformation, causing it to deform permanently or the stress at a permanent strain of 0.2%.

4.2 Ultimate Tensile Strength

Ultimate Tensile Strength is the maximum stress a material can withstand when subjected to tension. It is the maximum stress on the stress and strain curve. The results of ultimate tensile strength are shown in Table 4.2. The BS 4449 & GS 788-2 does not give a specific value for the ultimate tensile strength, however the result shows a range of 452N/mm² to 466N/mm² for mild steel rods manufactured in Ghana. Ultimate Tensile Strength for high tensile steel samples contained in the table also range from 575N/mm² to 883N/mm².

Table 4.2: Ultimate Tensile Strength of Steel bars

Serial No.	Mark	Ultimate Tensile Strength (N/mm^2)	BS 4449:2005 & GS 788-2: 2008 Min. Provisions	Remarks
1	KMS_{12}	459	Varies	Satisfactory
2	KMS_{16}	464	Varies	Satisfactory
3	KMS_{20}	454	—	Satisfactory
4	BMS_{12}	453	—	Satisfactory
5	BMS_{16}	465	—	Satisfactory
6	BMS_{20}	453	—	Satisfactory
7	SMS_{12}	456	—	Satisfactory
8	SMS_{16}	466	—	Satisfactory
9	SMS_{20}	452	—	Satisfactory
10	KHT_{12}	580	—	Satisfactory
11	KHT_{16}	704	—	Satisfactory
12	KHT_{20}	883	—	Satisfactory
13	BHT_{12}	575	—	Satisfactory
14	BHT_{16}	705	—	Satisfactory
15	BHT_{20}	851	—	Satisfactory
16	SHT_{12}	578	—	Satisfactory
17	SHT_{16}	705	—	Satisfactory
18	SHT_{20}	867	—	Satisfactory

The provision for no specific value for the standard ultimate tensile strength is consistent with the work by (Tunde & Billihamimu, 2016).

4.3 Elongation of Steel Bars

Elongation is a measurement of ductility. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. Percentage elongation can be expressed as; increase in length x 100 / original length. Table 4.3 shows the percentage elongation for the samples collected. It can be seen that both mild steel and high tensile steel met the minimum code requirement on elongation.

Mild steel bars elongations range from 26% to 33% which exceed the minimum provision of 17% by about 70%. The values of elongation for high yield steel follow similar trend which range from 21% to 30% higher than the minimum of 17%.

Table 4.3: Percentage Elongation of Steel Bars

Serial No.	Mark	Elongation %	BS 4449:2005 & GS 788-2: 2008 Min. Provisions	Remarks
1	KMS_{12}	33	17	Above Code Value
2	KMS_{16}	26	14	Above Code Value
3	KMS_{20}	30	14	Above Code Value
4	BMS_{12}	33	17	Above Code Value
5	BMS_{16}	27	14	Above Code Value
6	BMS_{20}	28	14	Above Code Value
7	SMS_{12}	33	17	Above Code Value
8	SMS_{16}	28	14	Above Code Value
9	SMS_{20}	26	14	Above Code Value
10	KHT_{12}	25	17	Above Code Value
11	KHT_{16}	30	14	Above Code Value
12	KHT_{20}	22	14	Above Code Value
13	BHT_{12}	25	17	Above Code Value
14	BHT_{16}	29	14	Above Code Value
15	BHT_{20}	20	14	Above Code Value
16	SHT_{12}	26	17	Above Code Value
17	SHT_{16}	30	14	Above Code Value
18	SHT_{20}	21	14	Above Code Value

The minimum percentage elongation for 12mm diameter bar is 17% while the minimum percentage elongation for 16mm and 20mm diameter bars is 14%. It is also observed that mild steel bars have an average elongation of 29% which is found to be higher than tensile steel rods with average of 25%.

4.4 Nominal Diameter of Bars

The results of the bar sizes as against the Standard Nominal Diameter of steel bars are presented in Table 4.4 All 12mm and 20mm diameter mild steel bars were below the standard provision.

Table 4.4: Nominal diameters of steel bars

Serial No.	Mark	Diameter	BS 4449:2005 & GS 788-2: 2008 Min. Provisions	Remarks
1	KMS_{12}	11.5	12	Below Code Value
2	KMS_{16}	16.1	16	Above Code Value
3	KMS_{20}	19.6	20	Below Code Value
4	BMS_{12}	11.5	12	Below Code Value
5	BMS_{16}	16.1	16	Above Code Value
6	BMS_{20}	19.6	20	Below Code Value
7	SMS_{12}	11.5	12	Below Code Value
8	SMS_{16}	16	16	Equal to Code Value
9	SMS_{20}	19.6	20	Below Code Value
10	KHT_{12}	11.1	12	Below Code Value
11	KHT_{16}	14.5	16	Below Code Value
12	KHT_{20}	18	20	Below Code Value
13	BHT_{12}	11.1	12	Below Code Value
14	BHT_{16}	14.5	16	Below Code Value
15	BHT_{20}	18	20	Below Code Value
16	SHT_{12}	11.1	12	Below Code Value
17	SHT_{16}	14.5	16	Below Code Value
18	SHT_{20}	18	20	Below Code Value

The 16mm diameter mild steel bars were either little above the code value or were equal to the standard nominal diameter size.

All the high tensile steel bars were found to be below the nominal diameter size as specified by the BS 4449 & GS 788-2 specification. The values obtained are 11.1mm instead of 12mm diameter, 14.5mm instead of 16mm diameter and 18mm diameter instead of 20mm diameter. This result is consistent with the research work conducted by (Tunde & Billihamimu, 2016) in Sokoto state, Nigeria.

4.5 Ductility

Table 4.5 shows the results of Ductility test. All the samples in the Ghanaian market have their ductility ranging from 1.35 to 1.5 for mild steel which exceed the minimum BS 4449 & GS 788-2 standard value of 1.25. The average ductility of 1.44 is 15% higher than the minimum provision.

Table 4.5: Ductility of Steel bars

Serial No.	Mark	Ductility	BS 4449:2005 & GS 788-2: 2008 Min. Provisions	Remarks
1	KMS_{12}	1.40	1.25	Above Code Value
2	KMS_{16}	1.35	1.25	Above Code Value
3	KMS_{20}	1.49	1.25	Above Code Value
4	BMS_{12}	1.42	1.25	Above Code Value
5	BMS_{16}	1.50	1.25	Above Code Value
6	BMS_{20}	1.47	1.25	Above Code Value
7	SMS_{12}	1.41	1.25	Above Code Value
8	SMS_{16}	1.43	1.25	Above Code Value
9	SMS_{20}	1.48	1.25	Above Code Value
10	KHT_{12}	1.20	1.15	Above Code Value
11	KHT_{16}	1.27	1.15	Above Code Value
12	KHT_{20}	1.22	1.15	Above Code Value
13	BHT_{12}	1.21	1.15	Above Code Value
14	BHT_{16}	1.29	1.15	Above Code Value
15	BHT_{20}	1.22	1.15	Above Code Value
16	SHT_{12}	1.21	1.15	Above Code Value
17	SHT_{16}	1.28	1.15	Above Code Value
18	SHT_{20}	1.22	1.15	Above Code Value

Likewise, High Tensile Steel samples surpassed the minimum provision by 8%. The ductility values for the high yield steel range from 1.21 to 1.29 as against the BS 4449 & GS 788-2 standard code value of 1.15.

4.6 Nominal Bar Sizes Available in the Market

Table 4.6: Nominal bars sizes available in the market

B5 Company Limited		**K. Ofori Limited**		**Setti Limited**	
Mild Steel	High Tensile	Mild Steel	High Tensile	Mild Steel	High Tensile
5.5	8	6	8	6	8
7.5	10	8	10	8	10
10	12	10.5	12	10	12
11.5	14	11.5	16	11.5	14
12	16	12	20	12	16
14	18	16	25	14	18
16	20	18		16	20
18	22	20		18	22
20	25			20	25
	28			25	28
	32				32
	40				40

Table 4.6 presents various sizes of steel bars in the open market of Sekondi-Takoradi metropolis. The table indicates that both standard and unstandardized sizes of rods are available in the market. In addition the results indicate that the local manufacturing companies responsible for the production of mild steel bars are not manufacturing 28mm, 32mm and 40mm diameter bars. 25mm diameter mild steel bar is also not common in the market as opposed to 25mm diameter high tensile steel rod.

Another revelation of the results is that 11.5mm diameter bar, which is an unstandardized diameter bar is very common and available in all the retail shops.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter presents the summary of the study, conclusion and recommendations. Also indicated are areas for further research which the researcher recommends. The research on the assessment of the quality of mild and high tensile steel in the open market in the western regional capital has the under listed conclusions.

5.2 Summary

- The test results revealed that 12mm, 16mm and 20mm diameter mild steel reinforcing bars in the market have adequate yield strength compared to the BS 4449 and GS 788-2 standard. Again 16mm and 20mm diameter high tensile steel bars imported from Ukraine had adequate yield strength when compared to the BS 4449 and GS 788-2 standard. Meanwhile the 12mm diameter high tensile steel bars did not meet the required yield Strength.
- Mild steel bars (12mm, 16mm and 20mm) were found to have ultimate tensile Strength greater than the minimum provision provided by the BS 4449 and GS 788-2 standard. Similarly high tensile steel bars (12mm, 16mm and 20mm) had ultimate tensile strength greater than the minimum provision provided.
- Both mild steel and high tensile steel bars samples (12mm, 16mm and 20mm) exceeded the minimum percentage elongation provided by the BS 4449 and GS 788-2 standard.

- Average ductility values of 1.44 and 1.24 were recorded for mild steel and high tensile steel, respectively, which are above the minimum BS 4449 and GS 788-2 standard specification.
- The results also revealed that 16mm diameter mild steel rods exceeded the standard nominal diameter provision while the 12mm and 20mm diameter rods were found to be smaller than the nominal diameter provision. Meanwhile all the high tensile steel bars samples sizes fell below the nominal diameter provided by the BS 4449 and GS 788-2 specification.
- Lastly the research revealed that there are both standard and non-standard steel bars sizes in the Sekondi-Takoradi market. Again it came to light that the local steel manufacturers are not producing 25mm, 32mm and 40mm diameter bars because they were not found in the market.

5.3 Conclusion

The outcome of the research work support the conclusion that mild steel bars in the Ghanaian market are fit for structural purpose after conducting tensile test and may not be responsible for the collapse of buildings. However the outcomes of test on high tensile steel bars were not consistent and there is need for verification.

Hence the failure of buildings in Ghana cannot be attributed to the tensile properties of reinforcement bars in the market. However, the area of steel of reinforcement sizes may partly be attributed to the failure since most sizes in the market are less than the actual.

In addition to the above conclusion, the researcher has observed that some government and institutional building projects use non standardized steel bars for the purposes of increasing contractors profit margin because they are less costly. Furthermore, individuals who build or construct for domestic purposes use these substandard sizes to reduce cost of construction hence their dominance in the Ghanaian market.

5.4 Recommendations

Since some of the samples fell below the minimum provision, it is recommended that regular assessment of steel bars be conducted to eliminate substandard steel bars in the market by the appropriate authority.

It is also recommended that Ghana Standard Authority should vigorously assess all imported steel rods before they are sent to the market. Again importers of steel bars should be supervised by a professional body to ensure steel bars imported are of the required standard specification.

Building and civil engineering consultants and professionals should ensure that all steel rods pass the mechanical test properties before they are used in any building projects in Ghana.

Civil engineers design structures based on standard sizes of steel bars, hence it is recommended that Ghana Standard Authority should make it known whether substandard sizes such as 5.5mm, 7.5mm and 11.5mm are fit for structural purposes or put measures to take them out of the market because they dominate the market as compared to the standard sizes.

It is recommended that further research should be conducted on the quality of sand for construction and the quality of workmanship of building projects to establish whether it may be responsible for the recent collapse of buildings.

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APPENDICES

Tensile Test Raw Data

Serial No.	Mark	Yield Strength (N/mm²)	Ult. Tensile Strength (N/mm²)	Elongation	Ductility	Cross Sectional Area (mm²)
1	KMS_{12A}	327	459	33	1.4	103.4
2	KMS_{16A}	308	464	26	1.5	203.0
3	KMS_{20A}	308	454	30	1.47	300.7
4	BMS_{12A}	318	453	33	1.42	103.9
5	BMS_{16A}	326	465	27	1.43	202.9
6	BMS_{20A}	306	453	28	1.48	301.0
7	SMS_{12A}	323	456	33	1.41	103.7
8	SMS_{16A}	344	466	28	1.35	202.8
9	SMS_{20A}	303	452	26	1.49	301.2
10	KHT_{12A}	483	580	25	1.20	97.3
11	KHT_{16A}	552	704	30	1.27	165.6
12	KHT_{20A}	723	883	22	1.22	249.7
13	BHT_{12A}	474	575	25	1.21	96.8
14	BHT_{16A}	544	705	29	1.29	164.4
15	BHT_{20A}	698	851	20	1.22	252.3
16	SHT_{12A}	479	578	26	1.21	97.1
17	SHT_{16A}	548	705	30	1.28	165.0
18	SHT_{20A}	711	867	21	1.22	251.0