UNIVERSITY OF EDUCATION, WINNEBA

INVESTIGATING THE QUALITY CONTROL MEASURES IN THE PRODUCTION OF REINFORCED CONCRETE; A CASE STUDY OF CONSTRUCTION FIRMS IN THE ASHANTI REGION.

ALBERT MENSAH JEHAR

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UNIVERSITY OF EDUCATION, WINNEBA

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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 fulfilment of the requirement for the award of the degree of

Master of Technology in Construction Technology.

JULY, 2021

DECLARATION

STUDENT'S DECLARATION

I Albert Mensah Jehar declares that this thesis, with the exception of quotations and references contained in the published works which have 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 at the University of Education, Winneba or 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.

Dr. Peter Paa-Kofi Yalley

SIGNATURE ………………………………………

DATE……………………………….……………

DEDICATION

This Dissertation is dedicated to My Mother Nancy Afi Anyomi., My Wife Benedicta Afi Ayibor and my children Daniel Eyram Dzeha, David Kafuie Dzeha and Keziah Dziedzorm Dzeha.

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I wish to express my gratitude and appreciations to JEHOVAH, our creator for granting me all that I need to finish this programme. I also wish to express my gratitude to my supervisor, Dr. Peter Paa Kofi Yalley for his guidance and assistance. I own special thanks to my colleagues at work for their support and encouragement. I also wish to thank all lectures and course mate for their support. Finally, Kumasi Metropolitan Assembly and all the projects site visited for data collection.

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ABSTRACT

Concrete is widely used in construction industry due to its strength. There are several cases where reinforced concrete structures have shown sign of distress and deterioration before their expected service life, which Ghana is no exemption. Ghana have experienced structural failure in recent times resulting in the death of innocent people, infringing permanent disability in many and destroying properties. The current study sought to examine the implementation of quality control measures in the production of reinforced concrete by construction firms using Ashanti Region of Ghana as case study. This current study employed a cross sectional survey as its research design with survey as its research strategy. The target population of the study was construction professionals employed by D1K1 construction companies within the Ashanti Region. A total of 71 construction professionals were sampled from the population through the use of simple random sampling techniques with data gathered from 52 respondents. With regards to quality control practices, the study revealed that all reinforced concrete products were designed to suit fitness for use and are produced in conformity to specifications and standards. The study also revealed that most project team members know the elements of quality assurance measures with durability and reliability as key dimensions for achieving quality concrete. Difficulty to keep permanent key site operatives for reinforce concrete operations due to financial constraints and inappropriate use of construction materials in their right proportions was further reveal by the study as some challenges faced by the firms. The study concluded that some of the construction project team members do not fully appreciate the basic requirements for producing durable reinforced concrete. Also, durability and reliability according to the study are key dimensions for achieving quality in reinforced concrete. The study recommends that project team members of construction companies must strictly stick to satisfying the specified requirement of any kind of project.

CHAPTER ONE

INTRODUCTION

1.1 Background

Quality could be defined as meeting a required standard, mostly quality is set to meet a particular standard or require to meet the purpose of the product. From the perspective of a construction company, quality control or management in construction projects should mean maintaining the quality of construction works at the required standard so as to obtain customers' satisfaction (Padhi, 2013). Concrete is widely used in construction industry due to its strength and relatively low cost of construction and generally what is thought in our schools, concrete is obtained by mixing cement, fine aggregates, and coarse aggregate and water in the right requirement or proportions.

The quality strength and other characteristics of concrete depends upon many factors, such as materials proportions or mix since it is composite produce, other controls during placing, compacting, c workmanship, supervision and method of construction can affect the quality of the structure that can result to structure failures (Rabaratuka,2013). Reinforced concrete is used in combination of steel or reinforcement to take care of tensile strength since concrete is weak in tension and strong in compression whiles the tensile strength of steel is high, it is design.

A structure engineer can design a good structure but unfortunately, they don't have control over the production and casting process, as it depends on the skills of the workers and the control measures exercised on site, an accurate and precise design and good building materials cannot be transformed into good building structures if the workmanship is poor. Major aspect of concrete construction includes formwork, reinforcement methods, materials, batching, mixing, placing and curing can lead to structure failure, and it is obvious that poor workmanship and improper construction methods often lead to concrete failures (Rabaratuka, 2013).

1.2 Problem Statement

Quality control is a procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of quality criteria or meets the requirements of clients or customer (Prodyogi, 2011). In the construction industry, concrete is a most widely used materials, commonly made by mixing of cement with fine aggregate, coarse aggregate, water and admixture, for a building structures to be durable, more strength and also for aesthetic accomplishing a quality concrete is supreme important (Kakadiya, 2015).

According to Rabaratuka, (2013, as cited in Rabaratuka, 2011) there are several cases where reinforced concrete structures have shown sign of distress and deterioration before their expected service life, Ghana is no exemption, Ghana has experienced structural failure in recent times resulting in the killing of innocent people, infringing permanent disability in many and destroying properties (Bediako, 2015).

Meseret (2018) in his study investigated the quality control for concrete materials, his approach was qualitative and his method focused on quality of concrete materials and testing of materials, He found out that sufficient test were not conducted for all ingredients used for production of concrete and also handling of materials were very poor. Meseret (2018) recommended that, concrete materials should passed through the necessary test, regular checking of concrete materials and use of qualified professionals.

The approach and methods of Alan, Habib, Sheikh and Hasan (2016) in thier study of quality control of concrete production were the same, They investigated the existing practice on quality control of concrete production on site, by visiting the site to observed and collected data on site, they found out that most of the production companies were neither aware of the key factors nor follow the quality control concrete measures, Alan *et al.* (2016) also recommended that designers or engineers should specify the concrete materials, in addition to testing the quality of the cement, utilization of qualify and experienced personnel right at the top management level to skilled workers. They also recommended that Construction Company should follow relevant regulation in concrete productions. The gab is the recommendations of the Previous studies to follow the relevant regulations in concrete production and the use of experienced personnel to achieve higher quality concrete, this study seeks to investigate the quality control measures in the production of reinforced concrete by construction firms in Ghana, by targeting the top construction professionals' knowledge on quality control measure in reinforced concrete. The approach and the methodology is quantitative involving questionnaire in quality practice, quality elements, implementation challenges, and measures put in place. Ashanti Region was chosen due to it higher numbers in D1K1 contractors.

When attention is paid to this problem, it will surely reduce most of the risk associated with reinforced concrete like inefficient use of concrete materials, to minimize poor reinforced concrete, avoid huge cost of maintenance (Prodyogi, 2017). This will builds confidence in tenants, property owners and investees.

1.3 Aim of Study (Purpose)

The aim is to examine the quality control measures in the production of reinforced concrete by construction firms in Ashanti Region.

1.4 Objectives of the Study

1. To examine effective quality control measures in reinforced concrete production by construction companies in Ghana;

2. To assess the contractor's knowledge on the elements of quality assurance concerning reinforced concrete production in Ghana;
3. To evaluate the key challenges to implementation of quality control in reinforced concrete production by construction companies in Ghana.
4. To assess measures put in place by construction firms to achieve higher quality in reinforced concrete

1.5 Research questions

1. What are the effective quality control measures of concrete production by construction companies in Ghana?
2. What is the contractors' knowledge of elements of quality control in reinforced concrete works in Ghana?
3. What are the challenges facing construction companies ensuring quality control in reinforced concrete production in Ghana?
4. What are the measures put in place by construction firms to achieve higher quality in reinforced concrete?

1.6 Scope of the Study

The study was focused on in-situ reinforced concrete works both on site and in the yard. The study was limited to professionals of D1K1 contractors in the Ashanti Region of Ghana. This is because the region is one of the highest concentrations of D1K1 contractors in the country. The choice of D1K1 was because they often engage highly trained professionals for a longer period as compared to the other classes of contractors.

1.7 Significance of study

The findings of the study will contribute to greater understanding on the quality of concrete production to practioners. It will assit the government to put down measures to improve quality control in executing construction projects, it will also enhance the role of policy makers and regulatory authorities for effective monitory, and finally it will assits educational institutions to train the students in quality control measures of concrete production.

1.8 Organizations of Work

The research will consist of five (5) chapters. Chapter one introduction, which involves problem statement and objective. Chapter two review of the existing literature on the subject matter. Chapter three considers in detailed the research methodology adopted for the study. The fourth chapter explores how the results from the study where analyzed and discussed. The fifth and last gives summary of findings, conclusion and recommendation regarding to the quality control measures used in producing reinforced concrete in the Ghanaian Construction Industry.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Quality control of producing reinforcement concrete cannot be under estimated since failure of any concrete structure could result to loss of life and property, with this notion it is very important to investigate all quality control processes leading to production of reinforced concrete. Investigation could be described as to try to find out the facts about something in order to lean how it happened (Prodyogi, 2011).

2.2 What Is Quality Control (QC)

As stated by Prodyogi (2011) quality control procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of quality criteria or meets the requirements of the client or customer. It is used to maintain standards in products and services. It is a process through which a business seeks to ensure that the product or service quality is maintained or improved and manufacturing errors are reduced or eliminated (Padhi, 2013).

Concrete quality control is not just during the manufacturing of the concrete. It becomes very important after proper placement. Proper curing of laid concrete is very important. If not, then water that is for concrete bonding will evaporate and henceforth concrete strength drops down from the specified value. Shrinkage is another aspect that occurs if quality control is not assured. Water evaporates and left empty spaces behind. Empty spaces create strain on the surface. Concrete try to restrain these strains but not do so. Therefore, cracks start propagating on the surface of concrete and hence the volume of concrete also decreases (Afsar, 2012).

2.3 Importance of Quality for Construction Projects

A construction project in its life span goes through different phases. The main phases of a project can be described as: conceptual planning, feasibility study, design, procurement, construction, acceptance, operation and maintenance. Quality is one of the critical factors in the success of construction projects. Quality of construction projects is linked with proper quality management in all the phases of project life cycle Design and construction are the two important phases of project life cycle which affect the quality outcome of construction projects significantly. Further, quality of construction projects can be regarded as the fulfillment of expectations of the project participants by optimizing their satisfaction (Heritage, 2016). It is because, since the quality outcomes of the projects are not according to required standards, faulty construction takes place. Hence, quality has become one of the most important competitive strategic tools which many construction organizations have realized it as a key to develop their building products in supporting the continuing success (Mallawaarachi & Senaratne, 2015).

2.4 Workability Test for Fresh Concrete

Workability is the ability of a fresh concrete mix at a plastic stage to fill a formwork or mold properly with the desire work, vibrated without reducing the concrete quality, it depends on the water cement ratio, aggregate shape and size, cementations content and age, can be modify by adding admixtures two main types of workability test are Slump test and compaction factor test (Gilson, 2009; Perdia, 2019). Figure 2.1 and 2.2, are the apparatus for slump and compaction factor test.

Figure 2.1 Slum test.

Reprinted from Prodyogi (2017)

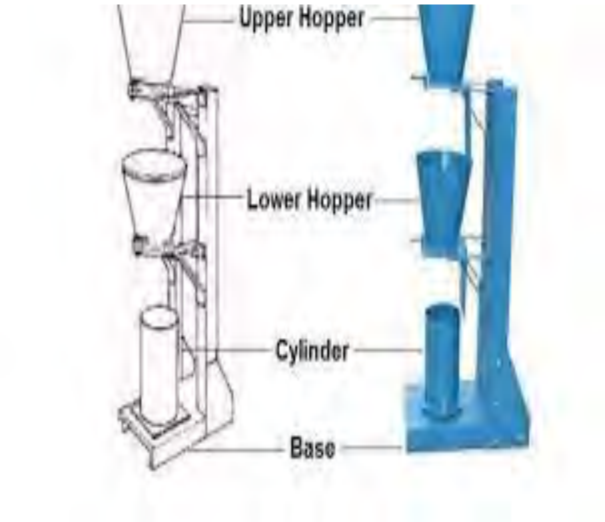

Figure 2.2 Compaction factor test on concrete. Reprinted from Mishra (2019)

2.5 Test for Hardened Concrete

Test for compressive strength is carried out either on cube or cylinder. Various standard codes recommend concrete cylinder or concrete cube as the standard specimen for the test. American Society for Testing Materials ASTM C39/C39M provides Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens (Mishra, 2018). Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size, while in tension, size elongate (Mishra, 2018).

For concrete, the timely conductance of the compressive strength tests is mandatory. The specimens of the concrete (cylinders) are tested to satisfy the conditions required at the construction site. After preparation, cylinders are cured to increase bond strength and to enhance the hydration process. After 28 days, cylinder strength of concrete is tested (Afsar, 2012). Figure 2.3 and 2.4 concrete cube and concrete cylinder test

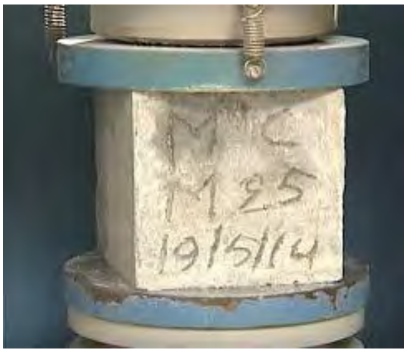

Figure 2.3 Concrete Cube Test

Reprinted from Anand (2016) Compressive strength test for M25 concrete.

Figure 2.4 Concrete Cylinder Test

Reprinted from Afsar (2012) Concrete cylinder testing for compressive strength.

2.6 Quality Control of Materials, Equipment and Workmanship in Concrete Production

The quality control is a corporate, dynamic program to assure that all the aspects of materials, equipment and workmanship are well looked after. The quality control should have conformity to the specification, no more, no less. For the manufacturer of the concrete, the quality control process will involve material, personnel, equipment and workmanship in all stages of concreting (Skider, 2016).

The quality control procedure in construction projects is based on tender documents, specifications, working drawings etc. contained in the contract document, therefore, the pre-tender stage quality and standards of the work should be properly maintained. Therefore, it is important to maintain quality control of the building projects from the inception of its design stage up to the completion of construction including the maintenance period (Skider, 2016).

2.6.1 Quality of Concrete

The concrete is generally produced in batches at the site with the locally available materials at variable characteristics. It is therefore likely to vary from one batch to the other (Prodyogi, 2017).

2.6.2 Personal Factors

The success of the quality control plan is the availability of experienced, knowledgeable and trained workers at all the levels. The designer and the specification writer should have the knowledge of the construction operation as well (Prodyogi, 2017).

2.6.3 Advantages of Quality Control in Concrete

Quality Control means a rational use of the available resources after testing their characteristics and reduction in the material cost (Prodyogi, 2017).

- In the absence of quality control at the site, the designer is tempted to overdesign, so as to minimize the risks. This adds to the overall cost.
- Quality Control reduces the maintenance cost
- In the absence of quality control, there is no guarantee that overspending in one area will compensate for the weakness in another
- Checks at every stage of the production of concrete and the rectification of the faults at the right time expedite completion and reduces delay.

2.7 Concrete Mix Design and Calculations

Concrete mix design is the process of finding right proportions of cement, sand and aggregates for concrete to achieve target strength in structures. So, concrete mix design can be stated as Concrete Mix = Cement: Sand: Aggregates and admixtures

The concrete mix design involves various steps, calculations and laboratory testing to find right mix proportions. This process is usually adopted for structures which requires higher grades of concrete such as M25 and above and large construction projects where quantity of concrete consumption is huge.

Concrete Mix design of M20, M25, M30 and higher grade of concrete can be calculated from example below (Ravindra, 1996).

2.8 Reinforced Concrete

Concrete is obtained by mixing cement, fine aggregates, coarse aggregates and water in required proportions. The hardening is caused by chemical action between water and cement due to which concrete grows stronger with time. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, proportion of the mix and other controls during placing, compacting and curing. In situations where tensile stresses are developed, concrete is normally strengthened /reinforced by steel bars (Rabaratuka, 2013).

2.9 Reinforced Concrete Materials

- **Cement**

The desired strength of concrete and to increase the longevity of structure good quality cement should always be used. Cement is one of the most important materials used in construction. The strength of a structure depends upon several factors; cement quality is one of them. It is necessary to check the quality of cement on site at the time of preliminary inspection. It is not possible to check all the engineering qualities of cement on site but there exists some field test which gives us a rough idea of quality of cement. While on site we can perform these field tests to judge the quality of cement. These field tests are stated by Admin (2019) as follows: Date of packing, Color, Rubbing, Hand Insertion, Float Test, Smell Test, Presence of lumps, Shape Test and Strength Test

2.9.1 How to Test Quality of Cement on Site?

a. **Date of Packing**

The strength of cement decreases with time. First of all, check the manufacturing date in the bag before using. Generally, cement should be used before 90 days from the manufacturing date. Date of manufacture should be seen on the bag. It is important because the strength of cement reduces with age.

Portland cement is based on calcium silicate (CaSiO3) and made from a combination of calcium, silicon, aluminum and iron oxide minerals. Portland cement is hydraulic cement, meaning it sets and bonds due to a chemical reaction between water and the dry ingredients of the cement. Unlike hydraulic cement, non-hydraulic cements will not set in wet conditions. They set and dry based on other technologies. Other non-hydraulic cure technologies include air setting, chemical setting, heat setting, hot melt and two- or multi-component (Admin, 2019). Table 2.1 shows packing time of cement.

Table 2.1. Packing time of cement reprinted from Admin (2019).

Age of Cement	% Reduction in its Strength
3 Months	20-30
6 Months	30-40
12 Months	40-50

2.10 Cement Grade

Ordinary Portland cement (OPC) is available in standard grades. These grades can be specified at the time of purchase.

For general construction jobs in normal environmental conditions, 33 Grade OPC is an appropriate choice. 43 Grade OPC is primarily used for brickwork, foundations, plastering and compound wall applications in home construction. 53 Grade OPC provides early high strength and durability for structures such as skyscrapers, bridges, runways, concrete roads and other heavy-duty construction applications (Thayer, 2018).

2.10.1 Post-Purchase Inspection

Even if all of the pre-purchased items seem satisfactory, you can and should still check the quality once the cement has arrived. Most of these quality checks can be done on-site.

2.10.2 Inspection of Cement on Site

- **Packaging**

If purchased in a bag, verify the stitching is intact and the bags do not have holes in them. Look for certification marks, such as CE or ISI, to make sure the cement conforms to manufacturing standards. Check the date of manufacture that is printed on the bag. The strength of cement degrades over time and should be used as close to the date of manufacture as possible, ideally within 90 days. After three months' cement strength is reduced by 20-30 percent, 30-40 percent after 6 months, and as much as 40-50 percent after 12 months (Adhikari, 2016).

- **Look and Feel**

Scoop up a handful of cement. You can make some quality judgments just by feeling and looking at the cement. The cement should be lump- and dust-free and feel cool to the touch, indicating no hydration reaction is taking place. Lumps are formed due to absorption of moisture from the climate.

- **Colour test**

Look at the color. Cement for building construction should be a uniform greenish-gray, while cement for decorative applications is white. The cement should be uniform in colour. In general, the color of cement is grey with a light greenish shade.

- **Water Tests**

When tossed into a bucket of water, quality cement that is free from impurities should float on the surface for a while before sinking. To ensure that the cement will harden correctly, mix some cement with water to form a paste. Form the paste by hand, place it in a bucket of water and let it sit for 24 hours. The cement should harden and retain its shape (Mishra, 2018).

- **Smell**

If the cement has an earthy smell, it may contain too much clay and silt.

Take a pinch of cement and smell it. If the cement contains too much of pounded clay and silt as an adulterant, the paste will give an earthy smell

- **Strength**

Prepare a cement block of 25 mm x 25 mm and 200 mm in length. Now submerge it in water for 7 days. Now place it on supports 15 cm apart and load it with 34 kg weight. Block made from good cement will not show any signs of failure.

- **Shape Test**

Take 100g of cement and make a stiff paste. Prepare a cake with sharp edges and put on the glass plate. Immerse this plate in water. Observe that the shape shouldn't get disturbed while settling. It should be able to set and attain strength. Cement is capable of setting under water also and that is why it is also called 'Hydraulic Cement'.

- **Rubbing**

Cement should feel smooth while rubbing in between fingers. If it gives a rough feeling that means cement is adulterated with sand (Thayer, 2018).

2.11 Fine Aggregate

Fine aggregate/coarse sand consists of natural sand, crushed stone sand or crushed gravel stone dust. It should be hard, durable chemically inert, clean and free from organic matter, not containing any appreciable amount of clay balls or pellets and other harmful impurities i. e. alkaline, salt, mica, decayed vegetation, lumps (Relan, 2007 & Haseeb, 2017).

It should be passed through I. S. Sieve 4.75 MM. It should have the finest modulus 2.50 to 3.50 and silt contents should not be more than 4%. Coarse sand should be either river sand or pit sand; or combination of the two. It should be obtained from pure Sand or Stone dust obtained by crushing hard stones or gravel.

1. If there is more silt in coarse sand, the strength of cement mortar is reduced from1%to30%.
2. If you take best quality coarse sand, it will give maximum strength.

2.11.1 How to Check the Quality of Coarse Sand at Site

Actual specification for the quality of coarse sand can be obtained by laboratory test but in general we can judge the quality of coarse sand in the field through the following ways as stated by Relan (2007).

- Observe whether there are any lumps of earth or clay balls, grass and decayed vegetation etc. in coarse sand to check silt contents.

- Take some samples of coarse sand in hand and observe the particles of sand should be coarser. Silt contents should be less
- Take some sand in hand and drop it down One can simply check the quality of sand by taking some sand in the hand and then dropping it down. If some finest material sticks with hand, the sand has some silt contents and finer sand.
- Check silts contents with the help of water. Take empty glass and put some sand and water in the glass and stir it well. After some time, the silt layer will be framed between sand and water which shows the quantity of the silt contents present in the sand.

2.12 Coarse Aggregate

Coarse aggregate is one of the essential components of concrete and occupies the largest volume in the mix. That is why it greatly affects the concrete mix design. Its properties such as strength, maximum size, shape, and water absorption influence water demand, the quantity of cement and fine aggregate in concrete mixture (Hamakareen, 2009). It is reported that, high maximum coarse aggregate size leads to lower water demand in the mixture since such aggregate has lower surface area compare with small coarse aggregate size. As far as shape is concerned, rounded shape aggregate provides economical mix design for normal strength concrete.

However, angular coarse aggregate is desired in the case of high strength concrete. This possibility of segregation is minimized if coarser aggregate is properly graded. This explains how important good grading for concrete mix design is (Hamakareen, 2009).

As far as strength is concerned, higher aggregate strength would produce higher concrete strength provided that other controlling factors have been dealt with properly (Hamakareen, 2009).

2.12.1 Maximum Aggregate Size

The maximum size of coarse aggregate is one of the factors that controls water demand to achieve certain workability. It also dictates quantity of fine aggregate content needed for producing cohesive mix.

For a given weight, higher the maximum size of aggregate, lower is the surface area of coarse aggregates and vice versa. As the maximum size of coarse aggregate reduces, surface area of coarse aggregate increases. Higher the surface area, greater is the water demand to coat the particles and generate workability (Hamakareen, 2009).

2.12.2 Grading of Course Aggregate

Grading is the determination of the particle-size distribution for aggregate. It affects the amount of cement and water requirements, workability, pumpability, and durability of concrete. The grading of coarse aggregate is important to get cohesive and dense concrete. The voids left by larger coarse aggregate particles are filled by smaller coarse aggregate particles.

2.12.3 Shape of Coarse Aggregate

Coarse aggregates may be round, angular, or irregular shape. Rounded aggregates have lowest water demand due to lower surface area, and also have lowest mortar paste requirement.

These properties make rounded aggregate to yield the most economical mixes for concrete grades up to M35. However, for concrete grades of M40 and above the possibility of bond failure would tilt the balance in favor of angular aggregate with more surface area (Hamakareen, 2009).

2.12.4 Strength of Coarse Aggregate

Material strength of coarse aggregate is indicated by crushing strength of rock, aggregate crushing value, aggregate impact value, aggregate abrasion value. The IS limits for above tests are; aggregate crushing value, aggregate impact value and aggregate abrasion value (Hamakareen, 2009).

2.12.5 Aggregate Absorption

Aggregate absorption is used for applying a correction factor for aggregates in dry condition and determining water demand for concrete in saturated surface dry condition. Aggregate can absorb water up to 2 % by weight when in bone dry state. However, in some cases, the aggregate absorption can be as high as 5% (Hamakareen, 2009)

2.13 Quality of Water for Reinforced Concrete

Generally, quality of water for construction works is same as drinking water. This is to ensure that the water is reasonably free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete, especially the setting, hardening, strength, durability, pit value, etc.

The water shall be clean and shall not contain sugar, molasses or their derivatives, or sewage, oils, organic substances (Jamal, 2017).

2.13.1 How to check quality of water for reinforced concrete?

If the quality of water to be used for mixing is in doubt, cubes of 75 mm in cement mortar 1:3 mix with distilled water and with the water in question shall be made separately. The latter type of cubes should attain 90% of the 7 days' strength obtained in cubes with same quantity of distilled water. Alternatively, the water shall be tested in an approved Laboratory for its use in preparing concrete (Mishra, 2018). The table 2.2 types of solid in water.

Table 2:2 Solid in water. Retrieved from Mishra (2018)

Type of Solid in water	Permissible Limits for Construction
Organic matter	200 mg/l
Inorganic matter	3000 mg/l
Sulphates (SO4)	500 mg/l
Chlorides (Cl)	a) 1000 mg/l for RCC work and, b) 2000 mg/l for PCC work
Suspended matter	2000 mg/l

Limits of Alkalinity:

To neutralize 200 ml of sample should not require more than 10 ml of 0.1 normal HCI using methyl orange as an indicator as stated by Mishra (2018) as follows,

Limits of Acidity:

To neutralize 200 ml sample of water should not require more than 2 m of 0.1 normal NaOH (Caustic soda). The pH value of water shall generally be not less than 6.

2.14 Batching

Batching is the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally batching is done by volume but most specifications require that batching be done by mass rather than volume. Percentage of accuracy for measurement of concrete materials as follows (Jamal, 2017).

Cement:

When the quantity of cement to be batched exceeds 30% of scale capacity, the measuring accuracy should be within 1% of required mass. If measuring quantity is less than 30% i.e. for smaller batches then the measuring accuracy should be within 4% of the required quantity.

Aggregates:

If the measurement is more than 30% of the scale capacity, then the measuring accuracy should be within 1%. If measurement is less than 30% then the measuring accuracy should be within less than 3% (Jamal, 2017).

Water:

Water is measured in volumetric quantity as 1 litre = 1kg. In case of water, the measuring accuracy should be within 1% (Jamal, 2017).

Admixtures:

For mineral admixtures same accuracy as that required for cement. For chemical admixtures same accuracy as that required for water. Mineral admixtures accuracy is same as that of cement because it is used as partial replacement of cement. As chemical admixtures are liquid or added to water therefore its accuracy is same as that of water (Jamal, 2017).

2.15 What is Volume Batching of Concrete?

Batching of concrete means measuring different ingredients of concrete (i.e. cement, sand, coarse aggregate and water) before mixing it. When this measurement is done on the basis of volume, we call it Volume Batching. Below are mentioned some of important points to remember before adopting volume batching method in field (Anupuju, 2016).

- Volume batching is not a good method for measuring concrete materials.
- It is not applicable in case of large reinforced concrete structure.
- This method of concrete batching may not be economical.
- It can be only used for unimportant concrete or for small concrete works.

2.15.1 How Volume Batching is done in Field?

Padhi (2014) said before batching concrete ingredients in terms of volume, we need to know two things as follows;

1. What is the relative proportion of concrete ingredients in terms of volume?
2. What is the water-cement ratio?

After knowing these two things you can proceed to batch concrete ingredients in field.

Step-1-batching of cement

Cement is always measured by weight. Mostly it is used in terms of bags. One bag of cement weighs 50 kg and has a volume of 35 litres (or, 0.035m3). Cement should not be batched by volume because its weight per unit volume varies according to the way the container is filled.

Step-2-Batching of Aggregate (By Volume)

The main purpose of mixing the concrete is to finally obtain a uniform mixture that shows uniformity in terms of color and consistency.

Step-3-Batching of Water

Water is measured either in kg or liters as may be convenient. In this case, the two units are same, as the density of water is one kg per liter. The quantity of water required is calculated by multiplying water-cement ratio with weight of cement.

2.16 Concrete Mixing

2.16.1 Concrete Mixing by Hand

Carrying out hand mixing of concrete requires special skills and care during the process for quality control of fresh concrete. The precautions and the correct way of performing hand mixing of concrete are to undergo the mixing process as recommended by the standard procedures (Arjun, 2018).

Concrete is mixed by any two methods, based on requirement as per quality and quantity of concrete required. Normally for mass concrete, where good quality of concrete is required, mechanical mixer is used.

Mixing by hand is employed only to specific cases where quality control is not of much importance and quantity of concrete required is less. Stone aggregate is washed with water to remove dirt, dust or any other foreign material before mixing.

The main purpose of mixing the concrete is to finally obtain a uniform mixture that shows uniformity in terms of color and consistency (Ferraris, 2001 & Mishra, 2018).

2.16.2 Concrete Mixing by Mass

Mixing small quantities by mechanical mixer

Concrete can be mixed in one of two ways for household projects: in a mechanical mixer, or by hand on a board or in a wheelbarrow. Mechanical mixing is less strenuous and much more reliable than hand mixing. The latter should therefore be used only for very small quantities. Mixers should not be overfilled and revolve at speeds recommended by the maker.

For small quantities of concrete (around the house and garden for instance) the materials should be batched using a suitable gauge box or bucket – not larger than 10 litres or it will be difficult to handle. The materials should not be batched by shovelful, as a shovelful of sand is not the same volume as a shovelful of cement or aggregate (Ferraris, 2001).

2.16.3 Mechanical Mixing

The mixing operation consists of rotation or stirring, the objective being to coat the surface the all aggregate particles with cement paste, and to blind all the ingredients of the concrete into a uniform mass; this uniformity must not be disturbed by the process of discharging from the mixer (Ferraris, 2001).

- **Batch mixer:**

The usual type of mixer is a batch mixer, which means that one batch of concrete is mixed and discharged before any more materials are put into the mixer. There are four types of batch mixer.

- **Tilting drum mixer:**

A tilting drum mixer is one whose drum in which mixing take place is tilted for discharging. The drum is conical or bowl shaped with internal vanes, and the discharge is rapid and unsegregated so that these mixers are suitable for mixes of low workability and for those containing large size aggregate (Ferraris, 2001).

- **Non tilting drum mixer:**

A non-tilting drum is one in which the axis of the mixer is always horizontal, and discharge take place by inserting a chute into the drum or by reversing the direction or rotation of drum. Because of slow rate of discharge, some segregation may occur.

- **Pan type mixer:**

A pan type mixer is a forced–action mixer, as distinct from drum mixer which relies on the free fall of the concrete inside the drum. The pan mixer consists of a circular pan rotating about its axis with one- or two-stars' paddles rotating about vertical axis of pan.

- **Dual drum mixer:**

A dual drum is sometimes used in highway construction. Here there are two drums in series, concrete being mixed part of the time in one and then transferred to the other for the remainder of the mixing time before discharging.

- **Continuous Mixers:**

These are fed automatically by a continuous weigh-batching system.

- **Charging the mixer:**

There are no general rules on the order of feeding the ingredients into the mixer as this depend on the properties of the mixer and mix. Usually a small quantity of water is fed first, followed by all the solids materials. If possible greater part of the water should also be fed during the same time, the remainder being added after the solids. However, when using very dry mixes in drum mixers it is necessary to feed the coarse aggregate just after the small initial water feed in order to ensure that the aggregate surface is sufficiently wetted.

2.16.4 Mixing time:

It is important to know the minimum mixing time necessary to produce a concrete of uniform composition, and of reliable strength.

The mixing time or period should be measured from time all the cementing materials and aggregates are in mixer drum till taking out the concrete.

Mixing time depends on the type and size of mixer, on the speed of rotation, and on the quality of blending of ingredients during charging of the mixer. Generally, a mixing time of less than 1 to 1.25 minutes produces appreciable non-uniformity in composition and a significant lower strength; mixing beyond 2 minutes causes no significant improvement in these properties (Ferraris, 2001).

2.16.5 Prolong mixing:

If mixing take place over a long period, evaporation of water from the mix can occur, with a consequent decrease in workability and an increase in strength. A secondary effect is that of grinding of the aggregate, particularly if soft; the grading thus becomes finer and the workability lower. In case of air entrained concrete, prolong mixing reduces the air content.

2.16.6 Ready mixed concrete:

If instead of being batched and mixed on site, concrete is delivered for placing from a central plant. It is referred to as ready-mixed or pre-mixed concrete. This type of concrete is used extensively abroad as it offers numerous advantages in comparison with other methods of manufacture:

- Close quality control of batching which reduces the variability of the desired properties of hardened concrete.
- Use on congested sites or in highway construction where there is little space for a mixing plant and aggregate stockpiles;
- Use of agitator trucks to ensure care in transportation, thus prevention segregation and maintaining workability
- Convenience when a small quantity of concrete or intermittent placing is required.

There are two categories of ready-mixed concrete: central-mixed and transit mixed or truck mixed. In the first category, mixing is done in a central plant and then concrete is transported in an agitator truck. In the second category, the materials are batched at a central plant but are mixed in a truck (Ferraris, 2001).

2.16.7 Using a Mechanical Mixer

Turn the mixer on and prime the bowl with approximately 2/3 of the required water, Add the coarse aggregate followed by the sand and then the cement, Blend together until a uniform colour is achieved, add rest of water slowly and sparingly until a workable mix is achieved, continue mixing for at least 2 minutes, Discharge mixer.

Repeat the process until the required amount of concrete has been produced (Jamal, 2017).

2.17 Concrete Placing and Compaction of Concrete

The operation of placing and compaction are interdependent and are carried out simultaneously. They are most important for the purpose of ensuring the requirements of strength, impermeability and durability of hardened concrete in the actual structure. As for as placing is concerned, the main objective is to deposit the concrete as close as possible to its final position so that segregation is avoided and the concrete can be fully compacted. The aim of good concrete placing can be stated quite simply (Jamal, 2017).

It is to get the concrete into position at a speed, and in a condition, that allow it to be compacted properly.

2.18 Compaction

Once the concrete has been placed, it is ready to be compacted. The purpose of compaction is to get rid of the air voids that are trapped in loose concrete (Jamal, 2017).

It is important to compact the concrete fully because:

- Air voids reduce the strength of the concrete. For every 1% of entrapped air, the strength falls by somewhere between 5 and 7%. This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength.

2.19 Vibration:

To compact concrete, you apply energy to it so that the mix becomes more fluid. Air trapped in it can then rise to the top and escape. As a result, the concrete becomes consolidated, and you are left with a good dense material that will, after proper curing, develop its full strength and durability.

Vibration is the next and quickest method of supplying the energy. Manual techniques such as rodding are only suitable for smaller projects. Various types of vibrator are available for use on site (Jamal, 2017).

- **Poker Vibrators**

  The poker, or immersion, vibrator is the most popular of the appliances used for compacting concrete. This is because it works directly in the concrete and can be moved around easily.

- **Sizes**

  Pokers with diameters ranging from 25 to 75mm are readily available, and these are suitable for most reinforced concrete work. Larger pokers are available - with diameters up to 150mm - but these are for mass concrete in heavy civil engineering.

- **Radius of action**

When a poker vibrator is operating, it will be effective over a circle centered on the poker. The distance from the poker to the edge of the circle is known as the radius of action.

However, the actual effectiveness of any poker depends on the workability of the concrete and the characteristics of the vibrator itself. As a general rule, the bigger the poker and the higher its amplitude, the greater will be the radius of action. It is better to judge from your own observations, as work proceeds on site, the effective radius of the poker you are operating on the concrete you are compacting (Jamal, 2017).

2.20 What is Steel Reinforcement?

Steel reinforcement are steel bars that are provided in combination with plain cement concrete to make it reinforced concrete. Hence these structures form steel reinforced cement concrete structure (R.C.C). Steel reinforcement is commonly called as 'rebars'.

Need for Steel Reinforcement

Plain concrete is weak in tension and strong in compression. Tensile property for concrete structures is obtained by incorporating steel reinforcement. The steel reinforcement is strong in both tension and compression. The tensile property provided by the steel reinforcement will prevent and minimize concrete cracks under tension loads (Arjun, 2019).

Types of Steel Reinforcement

The steel reinforcement used in concrete construction is mainly of 4 types. They are:

1. Hot Rolled Deformed Steel Bars
2. Cold Worked Steel Bars
3. Mild Steel Plain Bars
4. Prestressing Steel Bars

2.20.1 Quality of Reinforcement Steel Bars used for Construction of RCC Structure

When a lot of steel received at site, First check the Manufacturer test certificate for its actual properties. With each lot of steel, manufacturer should send a test certificate of same lot for test done at their laboratory. Check for grade of steel mention in certificate and is as per the order or not. Steel bars may have rusting on it, do check closely to know either it is acceptable or not. Steel received should be free from any contamination like, mud, dust, oil and any other foreign material etc. Bars should not have splits and any other deformation on it (Deshmukh, 2017).

2.20.2 What is a mill certificate?

It refers to a quality assurance document that one uses in the metal industry showing a metal product's compliance with the international standards. It has to accompany materials to intermediate suppliers and finished goods manufacturers. It certifies both the chemical and physical properties. This document provides the end user of the raw material verification that the material they receive is per the order requirements. Also, it helps maintain the traceability of the material from inception stage to inclusion in a finished part.

2.20.3 What is Bending Test?

A bend test is an inexpensive qualitative test that is used to determine the flexibility and soundness of materials. Bend tests deform a test steel material midway causing a bend to form without a fracture. Consequently, you specify the material's resistance level. A bend test's goal is to load the sample material into a specific shape (Mades, 2018)

Bend tests help determine whether a material will fail under pressure especially in construction processes. The frequency of bending test is necessary to maintain so that no steel reinforcement with failed bending test reports can be used and prevent it from the possible structural issue.

2.20.4 What is Tension Test?

A tension test of materials is a destructive process that provides information about the tensile strength, yield strength and the elasticity of the sample. This test is done to determine how the material reacts when you apply force on it. Usually, by pulling the metal, you identify the material's tensile strength, yield strength as well as how much it will elongate.

Tension test is one of the critical criteria where you submit a steel bar sample to tension which is under control until failure (Mades, 2018).

2.21 Curing

Curing is the process or operation which controls the loss of moisture from concrete after it has been placed in position, or in the manufacture of concrete products, thereby providing time for the hydration of the cement to occur. Since the hydration of cement does take time, days, and even weeks, rather than hours, curing must be undertaken for some specified period of time if the concrete is to achieve its potential strength and durability. Curing may also encompass the control of temperature since this affects the rate at which cement hydrates (Mishra, 2019).

This period will depend on the properties required of the concrete, the purpose for which it is to be used, and the ambient conditions, that is the temperature and relative humidity of the surrounding atmosphere.

Mishra (2019) stated since curing is designed primarily to keep the concrete moist by preventing the loss of moisture from the concrete during the period in which it is gaining strength, it may be done in two ways:

- By preventing an excessive loss of moisture from the concrete for some period of time, e.g. by leaving formwork in place, covering the concrete with an impermeable membrane after the formwork has been removed, or by a combination of such methods; or
- By continuously wetting the surface thereby preventing the loss of moisture from it. Ponding or spraying the surface with water are methods typically employed to this end.

2.22 Formwork

Formwork is the term used for the process of creating a temporary mould into which concrete is poured and formed. Traditional formwork is fabricated using timber, but it can also be constructed from steel, glass fiber reinforced plastics and other materials.

While formwork is a broad term that is used in relation to the forming process using a wide variety of materials, shuttering is a term that is often used to refer to the process of using plywood to form the mould (Mishra, 2018).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This section examines the research methodology adopted for this study. The Section addresses data collection instruments, methods, and procedures. It discusses core issues related to the conduct of the study notably research design; data collection and instrumentation. Other aspects of this chapter include sample size and sampling; design of questionnaire; distribution of survey instrument to respondents and data preparation and statistical tools for analysis.

3.2 Research Design

Pandey and Pandey (2015) argued that research design is the framework or plan of a study that is employed as a basis for collecting and analysing data. Research design serves as a blueprint that guide the study. Yin (2009) refers to research design as the blueprint for investigating a research problem which takes full account to factors that could interfere with the validity of the findings. It also takes into accounts the context of data collection, processed, analyzed and presentation. Designing a research is very significant since it aids the smooth running of the research procedures and also creates professionalism in the research as possible, yielding high quality of information with a less effort, time and money. (Megel & Heermann, 1993).

This current study employed a cross sectional survey as its research design. This design was used because of the nature of information required to provide insightful answers to the research questions posed in chapter one of the study.

3.3 Research Strategy

Denzin and Lincoln (2000) explain that a "research strategy connects the researcher to specific approaches and methods for collecting and analyzing data". Hence the research strategy outlines the particular research approach to be adopted the research.

Phoya (2012) has pointed out the chief advantage of survey strategy is that it measures the reactions of a great many people to a limited set of questions, thus facilitating comparisons and statistical aggregation of the data, and so the results can be generalized. Also, survey strategy has the advantage of allowing the researcher to reach conclusions with a known degree of confidence about the extent and making of precise statements (Weiss, 1998). The research strategy adopted for the study is the survey research strategy.

3.4 Research Approach

The research approach chosen for this research is the deductive approach which falls in line with the positivist perspective. Gill and Johnson (2002) and Pathrage et al., (2007) argued that the deductive approach has become similar to positivism whiles the inductive approach with social constructionism. The deductive approach starts with the social theory that they find compelling and then test its implications with data (King, Mesner & Baller, 2009). According to Dudovskiy (2011) deductive approach offers the following advantages:

- Possibility to explain causal relationships between concepts and variables.
- Possibility to measure concepts quantitatively.
- Possibility to generalize research findings

The current study adopts inductive as its research approach.

3.5 Population

This study seeks to examine the implementation of quality control measures in the production of reinforced concrete by construction firms in Ghana. The target population of the study comprised construction professionals employed by D1K1 construction companies within the Ashanti Region. Thus the project managers, quality officers, project engineers, site engineers/managers, Works superintendents and site supervisors. Ashanti Region was chosen as a study area because the concentration of D1K1 companies in the Region. The classification of companies according to the Ministry of Water Resources Works and Housing indicates that these companies represent the highest class and have no limit to the size of the project they can undertake.

The decision to use D1K1companies was based on the fact that they are relatively well organized in terms of human capital and other related resources. Again, D1K1 companies characteristically have some permanent professional team members at all times and to some extent have comparatively good administrative structures to ensure quality management practices. Available data at the Ministry of Water Resources, Works and Housing indicate that D1K1 construction firms who are in good standing operating nationwide as of April 2020 were 52. Out of this, 10 of them are currently operating in the Ashanti Region representing 19.2%. A sampling frame was compiled for the construction professionals working in the 10 D1K1 operating in the Ashanti Region in 2020.

3.6 Sample and Sampling Techniques

The concept of sample arises as a result of the inability of the researcher to test all individuals in a given population and must be representative of the population from which it is drawn. The study adopted simple random sampaling technicques, the targeted population of the study is construction professionals in D1K1, contractors operating in the Ashanti Region was determined by simple random sampling, using the sampling frame compiled for the list of professionals. The sample must have a good size to warrant statistical analysis for a specific conclusion (Oskar, 2012). Out of the total construction professional population of 86 in the region, 71 of them representing 82.6% ware chosen as the sample size for the study.

3.6.1 Sample Size Estimation

Sampling refers to the selection of units of analysis for a study (Hunter et al., 2002). The choice of a sampling technique is dependent on the research problem, purpose, design and practical implications of the research topic. The choice of these contractors was based on the availability of contractors working on various construction projects in the part of the region covered in this study. The desire to collect data on projects that are on-going has made the adoption of purposive sampling to be appropriate for the study. The primary consideration in purposive sampling is one's decision as to who can provide the best information to achieve the objectives of the study. (Guba & Lincoln, 1994; Kumar, 2011). Yamane (1967) provides a simplified formula to calculate sample sizes. This formula was used to calculate the sample sizes in the current study as shown in Equation 1.

$$n = [\frac{N}{1 + N(e)^2}]$$

Equation 1 Yamane's formula for calculating sample size (Yamane, 1967)

Where n = sample size

N = Sampling frame = Total Population 52 (Total number construction professionals)

e = Significance level = 5% or 0.05

$$n = \left[\frac{86}{1 + 86\,(0.05)^2}\right]$$

$$n = 70.8$$

$$n \simeq 71$$

From the above calculations, approximately 71 construction professionals were the sample size from the study area.

3.7 Data Collection and Instrumentation

The researcher relied on primary data by considering the nature and the objectives of the study. Hence, the appropriate instrument was a questionnaire. A questionnaire was used because it provided a clear thought of what the researcher desires to obtain from the respondents. This questionnaire consisted of five sections. The first section consisted of respondents' demographic details such as academic level, position in their respective companies, years of experience, and years spent in their current companies. The second section also comprised the items soliciting responses from the respondent about the quality assurance practices in concrete production. The third section, on the other hand, made up of items seeking responses on knowledge of element of quality assurance practices in concrete production from the respondents. The fourth section contained items on challenges to the implementation of quality assurance practices in concrete production while the fifth section considered measures put in place to achieve higher quality concrete.

A 5-point Likert-scale type was used as a response guide on sections B to E. The interpretations of the scale were 5= strongly agree, 4= agree, 3= neutral, 2= disagree and

1= strongly disagree. Sarantakos (1999) asserted that the Likert scale provides single scores, and it is easy to construct, hence its usage.

3.7.1 Validity of the Instrument

The instrument was validated using both face and content validity. The face validity was done by looking at the layout and the structure of the instrument. On the other hand, content validity was determined by experts in the field of supervision who examined whether the items cover all the possible research questions and the extent to which the items measuring the specific construct. The instrument was vetted by the supervisor for his comments and views to establish fair validity.

3.7.2 Ethical Consideration

Ethical considerations form a major element in research. The researcher needs to adhere to promote the aims of the research imparting authentic knowledge, truth and prevention of error (Chetty, 2016). Furthermore, following ethics enables scholars to deal collaborative approach towards their study with the assistance of their peers, mentors and other contributors to the study.

Chetty further explained that this requires values like accountability, trust, mutual respect and fairness among all the parties involved in the study. This, in turn, depends on the protection of intellectual property rights of all contributors established through the implementation of ethical considerations,

In this study before the data collection, ethical clearance will be obtained from the Department of Construction and Wood of the University of Education Winneba, who offered an ethical permit for the research. The researcher also will obtain an introductory letter from the Department of Construction and Wood. This introductory letter will help the researcher to get the needed assistance and co-operation from the respondents. Participants were well informed about the objectives of the study. Informed consent as asserted by Silverman (2006) is a process of negotiation "between the researcher and the study subjects, and not a one-off action". Participants will be informed of the right to withdraw from the study or decline questions. Confidentiality will also be guaranteed to the respondents by making sure that, the study they were not represented by their names (anonymity).

3.8 Data Analysis

The research procedure selected so far followed a deductive approach of quantitative data collection which emphasized finding causal relationships. The statistical package for social sciences version 21 (SPSS) system of statistical analysis.

3.9 Statistical Analysis

Moreover, it employed cross tabulation, chi-square to investigate the relationship between the dependent variable and several independent variables (Jupp, 2006). Analysis of variance (ANOVA) was also employed to compare the views of consultants and contractors

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF RESULTS

4.1 Introduction

This chapter presents the detailed analysis of field data gathered on the topic of evaluating quality assurance practices of concrete production by construction firms in Ghana using D1K1companies in the Ashanti Region, Ghana. Data were gathered from 71 respondents through the use of simple random sampling techniques. The questionnaire was the main instrument used for data collection and the results were interpreted with the help of frequency tables, percentages pie chart, and other statistical tools.

4.2 Response Rate

The response rate was calculated using the completed returned questionnaire per the total number distributed, multiplied by 100 to give a percentage figure. 71 questionnaires were distributed and 52 completed questionnaires were returned representing a response rate of 73.23%.

Thus $RS = \frac{n}{N} \times 100$; where RS is the response rate, n represents the completed questionnaire and N is the distributed questionnaires

(ie $RS = \frac{52}{71} \times 100 = 73.23$ %)

4.3 Demographic Characteristics of the Respondents

The demographic characteristics such as education, job title, experience level, years with the company, and time of joining a particular company were analyzed. The respondents' demographics were required to enable the researcher to understand the details of respondents used in the study.

4.4 Level of Education of Respondents

The level of respondents' education was analyzed. As shown in figure 4.1, 30.1% of the respondents were second-degree holders, 43.8% were first degree holders which represents the majority of the respondents. HND/Diploma graduates were also 19.2% whiles Technicians were only 6.8% representing the least level of education among the total respondents. The results indicate that majority of the respondents are highly educated and well qualified. The distinctions in the educational background of the respondents significantly helped the researcher to obtain diverse views on the topic.

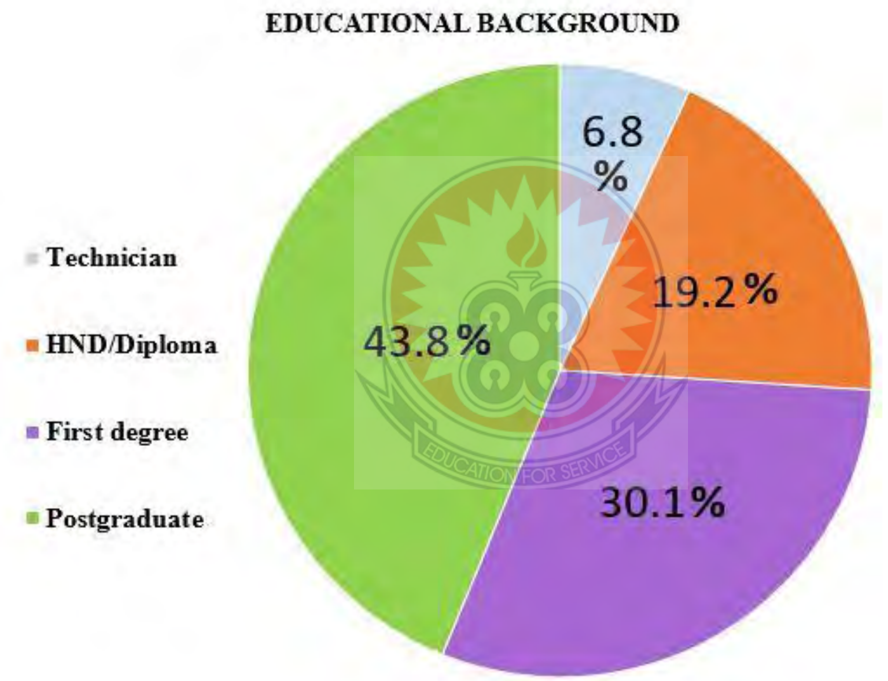

Figure 4.1 Level of education of respondents

4.5 Job title/position of the respondents

The study observed that 19.2% of the respondents were site supervisors, work superintendents were also found to be 19.2%, quality officers were also17.3%, majority of the respondents were project managers representing 23.1%, and 21.2% were also project manager. Thus, the majority of the respondents are well experienced in their area of specialty which gives certainty in the data collected as shown in table 4.1.

Table 4.1 Position of the respondents

Professionals	Frequency	Percent	Valid Percent	Cumulative Percent
Site supervisors	10	19.2	19.2	19.2
Work superintendents	10	19.2	19.2	38.4
Quality officers	9	17.3	17.3	55.7
Project managers	12	23.1	23.1	78.8
Project engineers	11	21.2	21.2	100
Total	52	100.0	100.0	

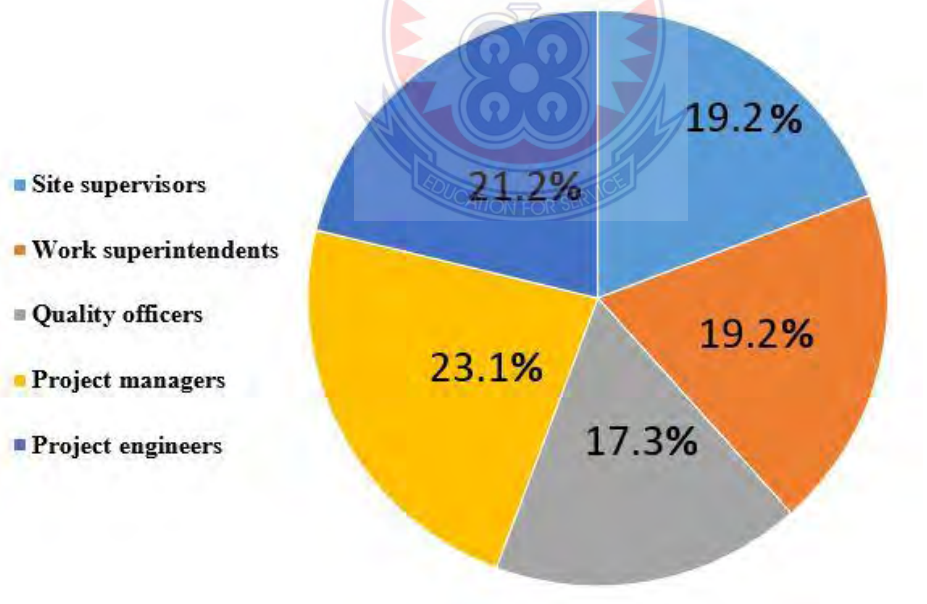

Figure 4.2 Job Title / Position of Respondents

4.6 Years of Experience in the Industry

The study enquires from the respondents the number of years they have spent in the construction industry concerning their experience as far as quality production of reinforced concrete is concerned. It was revealed that 16.4% have spent less than 5 years in the industry. 13.7% have also spent between 5-10 years whiles 21.9% have spent 11-15 years. However, the majority of the respondents thus; 24.7% have spent 16-20 years, yet 20.5% have incredibly spent over 20 years in the industry. This however implies that most of the respondents have had rich experience in the industry. The details are as follows in Figure 4.3 below.

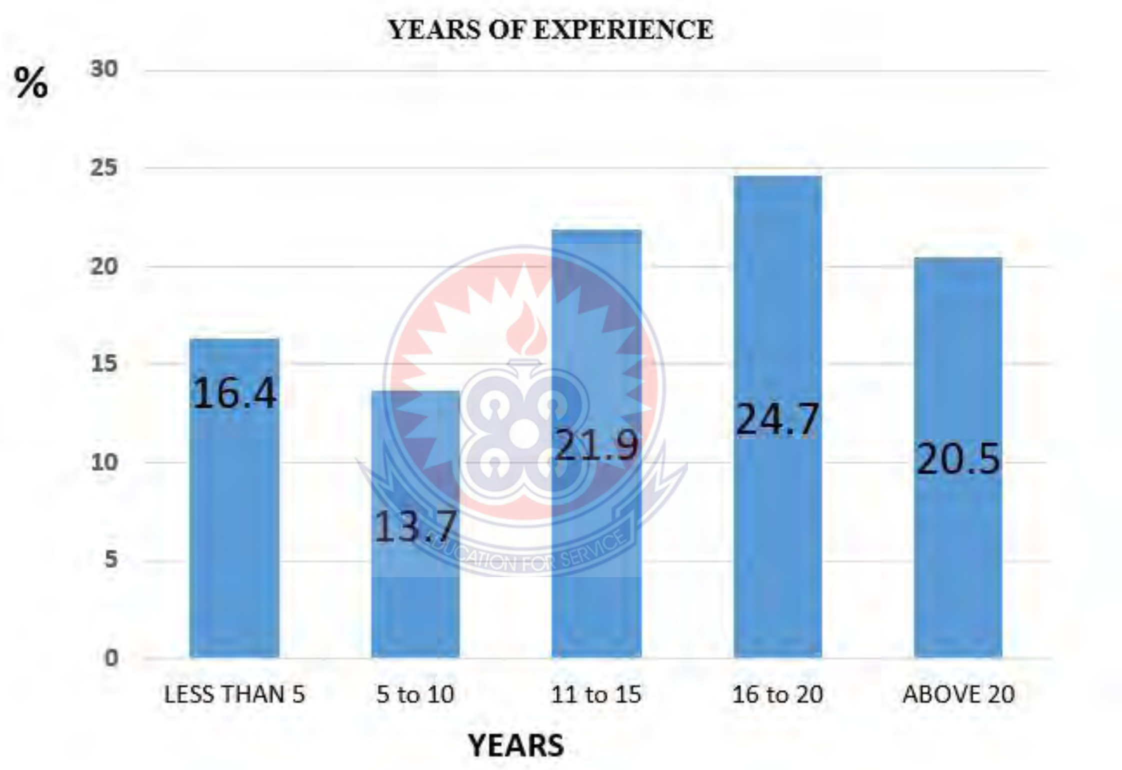

Figure 4.3 Years of experience in the Construction Industry.

4.7 Existence of companies

The results in Figure 4.4 indicate that over 16% of respondents' firms have less than 5 years of work experience, 5.5% have 5-15 years in existence, and 42% are in operation between 16-20 years whiles over 35% have been in existence for over 20 years ago. This is an indication of the fact that most of the companies within which the study was conducted are well established and likely to have the necessary structures in place to practice quality management.

Figure 4.4 Years of existence of construction firms.

4.8 Quality assurance practices in reinforced concrete production on construction projects

Using the mean score to rank the analysed data as indicated in table 4.2 and where there is a tie with items, the one with the least standard deviation is given priority, the results indicate that most of the respondents strongly agree (Mean=4.60, Std.=0.493) that in their companies, all concrete products are designed to suit fitness for use, hence, ranked 1st. Most respondents again strongly agree that their companies ensure all concrete products are produced in conformity to specifications and standards with a significant mean value of 4.38 which is ranked 2nd as shown in table 4.2. In a similar trend, the majority of the respondents strongly agree (Mean= 4.38, Std.=0.628) that their companies rely on experienced supervisors to conduct supervision during concrete production and eventually ranked 3rd. Again, the respondents strongly agree with the mean value 4.08 that some degree of excellence is considered in their respective companies whenever a concrete product is to be produced. 'Specified required proportion of each component as identified in the drawing specification is strictly adhered to' as an item recorded a mean value of 4.03 with standard deviation 0.164 which eventually ranked 5th. Regarding the performance requirement of concrete, it was observed that the majority of the respondents agree (mean= 4.00, Std.=0.624) that most companies check the performance requirement of concrete at its design stage to ensure safety and which eventually became the 6th item. In a similar trend, respondents further agree with mean and standard deviation scores 3.96 and 0.889 that some companies undertake a successive inspection of works during concrete operation. Comparatively, the under-studied companies regard durability and reliability considerations during the concrete production stage as paramount as it observes a mean value of 3.88 with a standard deviation of 0.666 and subsequently ranked 8th on the Table. It was further responded with a mean score value of 3.86 representing agrees to the fact that raw materials to be used for concrete products are well checked against standards and specifications hence, 9th as indicated in table 4.2.

However, respondents showed their disagreement with the following statements with their mean scores as well as standard deviation values;

i. 'Site engineers at the site sometimes reduce some quantity of materials to be used (M= 2.96, Std. 0.920)
ii. The use of substandard materials for concrete production is compromised in my company (M= 2.36, Std. 0.903) and subsequently ranked 10th and 11th respectively as shown in table 4.2.

It is important to note that though there were varied responses especially on the mean scores, all standard deviation values were less than one. This is an indication of the fact that there was a significant level of consistency in responses obtained.

Table 4.2 Quality assurance measures in reinforced concrete production on construction projects

In a study conducted by Artidi and Gungydin (1997), found that most companies strictly

Item	Responses			
	N	Mean	St. Dev	Rank
In my company, all reinforce concrete products are designed to suit fitness for use.	52	4.60	.493	1
All reinforced concrete products are produced in conformity to specifications and standards.	52	4.38	.637	2
My company rely on experienced supervisors to conduct supervision during reinforced concrete production.	52	4.34	.628	3
The degree of excellence is considered in my company whenever reinforced concrete product is to be produced.	52	4.08	.493	4
Specified required proportion of each components identified in the drawing specification are strictly adhered to.	52	4.03	.164	5
Performance requirement of reinforced concrete is checked at its design stage to ensure safety.	52	4.00	.624	6
Successive inspection of works during rein forced concrete operation is considered in my company.	52	3.96	.889	7
Durability and reliability considerations are observed during reinforced concrete production stage.	52	3.88	.666	8
Raw materials to be used for the reinforced concrete product are well checked against standards and specifications.	52	3.86	.822	9
Site engineers at the site sometimes reduce some quantity of materials to be used.	52	2.96	.920	10
The use of substandard materials for reinforced concrete production is compromised in my company	52	2.36	.903	11

adhered to the specified required proportions of each component as identified in the drawing specification. This is to ensure that quality not compromised. The results further showed that most companies check the performance requirements of reinforced concrete at its design stage to ensure safety. This has affirmed what was established by Artidi and Gungydin (1997) that the project requirements for quality at starts at the project inception phase. Regarding durability and reliability considerations during reinforced concrete production stage as being paramount, companies strongly agree. It is important to note that construction firms always ensure that their projects are of desirable quality state and have already been endorsed by Chetty and Datt (2015) in literature. As reviewed in the literature, Alexander (2008) was of the view that quality assurance is all about plans and systematic actions necessary to provide adequate confidence that a particular structure, system, or component will perform satisfactorily and conform to the project requirements.

4.9 Knowledge of element of quality assurance in reinforced concrete production

It was very crucial to determine the understanding and opinion of the construction professional team on the essential factors necessary to constitute elements of quality assurance in reinforced concrete production. Eleven (11) main variables in a form of a statement with varying degrees of the agreement were listed. Responses obtained were ranked in terms of relative importance; thus strongly agree to strongly disagree with 4.01 and above is the most important (strongly agree) and 2.40 and below is the least, thus strongly disagree. The variables listed are shown in table 4.3.

From table 4.3, most respondents strongly agree with the mean value 4.40 that they regard durability and reliability as key dimensions for achieving quality in reinforced concrete was ranked first. It was further observed that most of the under-studied companies strongly agree (M=4.11, Std. 0.657) that, they ensure that drawings and specifications are concise, clear and void of other information hence, ranked 2nd. The respondents further revealed in their responses that their companies design the correct mix ratios of each category of reinforced concrete prescribed for the work under each contract with a mean score of 4.11 representing strongly agree and eventually ranked 3rd. In a similar development, ‘achieving excellence through high-quality reinforced concrete product is the main objective of my contractor' as a statement recorded mean value of 4.10 representing strongly agree which subsequently ranked 4th.

However, respondents agreed with the following three statements with mean scores 3.93, 3.78, and 3.73 and therefore ranked 5th, 6th and 7th respectively.

i. *I carefully weigh the reinforced concrete production process against the serviceability of concrete elements.*

ii. *The contractor defines the responsibility of personnel who manage, perform and verify work that affects quality of the reinforced concrete to be produced.*

iii. *In my company, strict measures are adopted to deal with suppliers of materials used in the reinforced concrete production.*

That notwithstanding, respondents remain neutral with mean values of 3.26, 3.14 and 3.03 in that order on the statements below and ranked 8th, 9th and 10th respectively as shown in table 4.3.

i. *The contractor understands the implications of compromising the specified specifications in the drawings*

ii. *There is the existence of a communication system notifying all staff about the quality responsibilities of every individual in my company*

iii. *Every employee in my company feels the contractor provides full support to process and project quality improvement*

Conversely, respondents disagree with the statement 'The contractor makes the adequate provision of standard and required material resources for the production of concrete' with a mean score of 2.77 and standard deviation of 1.264.

The responses in Table 4.3 have also shown another level of consistency with less variability as most of the values for the standard deviations were less than one.

Table 4.3 Knowledge of element of quality assurance in reinforced concrete production

Item	Responses N	Mean	St. Dev	Rank
I regard durability and reliability as a key dimensions for achieving quality concrete	52	4.40	.493	1
My company ensures that drawings and specifications are concise, clear and void of information	52	4.11	.657	2
I design the correct mix ratio of each category of concrete prescribed for the work under each contract	52	4.11	.621	3
Achieving excellence through the high quality concrete product is the main objective of my contractor	52	4.10	.988	4
I carefully weigh the concrete production process against the serviceability of concrete elements	52	3.96	1.086	5
The contractor defines the responsibility of personnel who manage, perform and verify work that affects quality concrete to be produced	52	3.78	.975	6
In my company, strict measures are adopted to deal with suppliers of materials used in concrete production	52	3.73	.449	7
The contractor understands the implications of compromising the specified specifications in the drawings	52	3.26	1.041	8
There is the existence of a communication system notifying all staff about the quality responsibilities of every individual in my company	52	3.14	.962	9
Every employee in my company feels the contractor provides full support to process and project quality improvement	52	3.03	.552	10
The contractor makes the adequate provision of standard and required material resources for the production of concrete	52	2.77	1.264	11

4.9.1 Analysis of Variance on knowledge on element of quality assurance in reinforced concrete production

The study further considered the analysis of variance (ANOVA) test to determine whether there is a level of significance difference associated with the mean scores obtained from the first four ranked variables in Table 4.3. It was therefore hypothesized that;

H_0: There are no statistical differences in the response obtained from the first three variables.

H_1: There are no statistical differences in the response obtained from the first three variables.

From Table 4.4, it was clear that there exists no significant difference in from the various responses in respect to the variables 'durability and reliability as a key dimension for achieving quality and 'the correct mix ratio of each category of concrete prescribed' with p values ($p=0.001$ & $p = 0.040$) respectively which is less than the usual threshold of 0.05. This suggests that the H_1 (There are statistical differences in the response obtained from the first four variables) is rejected in favor of H_0 (There are no statistical differences in the response obtained from the first four variables).

However, it revealed that there was significant difference ($p=0.757$ and $p= 0.061$) in respect to the variables; the company ensures that drawings and specifications are concise, and achieving excellence through high-quality concrete product is the main objective' Since the *p-value* obtained are greater than the usual threshold value ($p=0.05$), it, therefore, suggests that H_1 (There are statistical differences in the response obtained from the first four variables) is accepted.

It can therefore be concluded that the response obtained from the project team professionals are not the same indicating that knowledge on elements of quality assurance practices differs from one respondent to another.

Table 4.4 ANOVA on knowledge on element of quality assurance in reinforced concrete production

Variable	Position	Mean	St.dev	F	P value
I regard durability and reliability as key dimension for achieving quality concrete	Project Manager	4.38	.495	5.074	0.001
	Quality Officer	4.13	.352		
	Project Engineer	4.30	.483		
	Site Engineer	4.82	.393		
	Work Superintendent	4.00	.000		
	site supervisor	4.25	.500		
My company ensures that drawings and specifications are concise, clear and void of information	Project Manager	4.12	.797	0.525	0.757
	Quality Officer	4.00	.535		
	Project Engineer	4.20	.632		
	Site Engineer	4.24	.562		
	Work Superintendent	3.67	.8.577		
	site supervisor	4.00	.816		
I design the correct mix ratio of each category of concrete prescribed for the work under each contract	Project Manager	3.83	.381	2.490	0.040
	Quality Officer	4.47	.640		
	Project Engineer	3.90	.738		
	Site Engineer	4.29	.772		
	Work Superintendent	4.00	.00		
	site supervisor	4.24	.957		
Achieving excellence through high-quality concrete product is the main objective of my contractor	Project Manager	3.58	1.018	2.229	0.061
	Quality Officer	4.47	.834		
	Project Engineer	4.30	.823		
	Site Engineer	4.35	1.115		
	Work Superintendent	4.00	.00		
	site supervisor	4.25	.500		

The right materials needed to constitute good concrete is well known, however, merely selecting the right aggregates do not guarantee quality even though it is essential (Nawy, 2008). Thus, several factors that affect the quality of concrete must be well understood and practiced to achieve quality concrete. The results also revealed that the contractor defines the responsibility of personnel who manage, perform and verify work that affects quality concrete to be produced. This implies that each department in the company plays its specific role to achieve the desire results. All these are done to ensure that a quality product is finally achieved.

Respondents believe that in their respective companies, strict measures are adopted to deal with suppliers of materials. This is done to reduce the patronage of inferior materials used in concrete production. With this revelation, Alam et al. (2016) asserted that, for uniform quality concrete to be produced, the ingredients (particularly the cement) shall preferably be used from a single source. They further elaborated that, ingredients from different sources are likely to change the strength and other characteristics of the concrete.

Another extremely important factor that eventually leads to the production of a weaker concrete product is a result of compromising with the specified materials. With this statement, thus; the contractor understands the implications of compromising the specified specifications in the drawings, the results remained neutral. This probably means that some mix ratios are not followed sometimes per the designed specification. It is very important to note that there exists a communication system notifying all staff about the quality responsibilities of every individual in each company.

4.10 Challenges to the implementation of quality assurance measures in reinforced concrete production

The study expediently explores some challenges that militate against the implementation of quality assurance practices in reinforced concrete production. The responses revealed varied opinions from the respondents as shown in table 4.5.

The study revealed that respondents strongly agree to the statement 'difficult to keep permanently employed key site operatives for reinforced concrete operations due to financial constraints' is a major challenge. This statement observed a significant mean score of 4.25 with a standard deviation of 0.434 hence, ranked first. Again, respondents agree with mean value 3.89 and standard deviation score 0.614 that inappropriate use of construction materials in their right proportions is considered another key challenge that militates against the implementation of quality assurance practices in producing a concrete product and therefore ranked 2nd on the Table.

Respondents further agree (Mean =3.84, St. Dev. 0.313) that it is sometimes difficult to get certain skill personnel for a specific task. Inadequate material and financial resources constraints as a statement ranked 4th with recorded mean score 3.63 and standard deviation of 1.184. Though this statement observed inconsistency in the responses, respondents agree that it is a challenge to the implementation of quality assurance practices in producing a quality concrete product.

However, respondents remained neutral with the following four statements;

i. *Adverse weather conditions sometimes make it difficult for concrete to achieve its required strength (Mean=3.26, St. Dev=1.131)*
ii. *Sometimes, financial constraints make it difficult for some contractors to buy from the right source (Mean=3.26, St. Dev=1.000)*
iii. *Effective access to obtain the reviewed construction detailed drawings and specifications are sometimes difficult (Mean=3.23, St. Dev=0.979)*

iv. *Lack of proper planning of site operations often resulting in issues many of which border on quality (Mean=3.01, St. Dev=1.112) and were consecutively ranked 5th to 8th.*

Conversely, respondents disagree with the following statements; '*Procurement officers purchase materials and components from suppliers who do not put in place quality assurance measures* and '*Test that ought to be done to ascertain the required needed strength of concrete are ignored*' with mean and standard deviation values (Mean= 2.99, St. Dev=.993) and (Mean=2.79 and St. Dev.=1.213) respectively. It is significant to note that though the last statement recorded inconsistent result, the respondents disagree.

Table 4.5 Challenges to the Implementation of Quality Assurance measures in Concrete Production

Item	Responses			
	N	Mean	St. Dev	Rank
It is difficult to keep permanently employed key site operatives for concrete operations due to financial constraints	52	4.25	.434	1
Inappropriate use of construction materials in their right proportions is resorted to in the face of challenges	52	3.89	.614	2
It is sometimes difficult to get certain skill personnel for a specific task	52	3.84	.373	3
Inadequate material and financial resources constraints	52	3.63	1.184	4
Adverse weather conditions sometimes make it difficult for concrete to achieve its required strength	52	3.26	1.131	5
Sometimes, financial constraints make it difficult for some contractors to buy from the right source	52	3.26	1.000	6
Effective access to obtain the reviewed construction detailed drawings and specifications are sometimes difficult	52	3.23	.979	7
Lack of proper planning of site operations often resulting in issues many of which border on quality	52	3.01	1.112	8
Procurement officers purchase materials and components from suppliers who do not put in place quality assurance measures	52	2.99	.993	9
Test that ought to be done to ascertain the required needed strength of concrete is ignored	52	2.79	1.213	10

Haupt and Whiteman (2004) and Bubshait and Al-Atiq (1999) had it that total quality assurance as a management system has not been effective in the construction industry as much as it has been in other industries. This is because of inadequate budget, failure to plan for quality, inadequate training at all levels except for top or senior management positions (Gunning & McCallion, 2007), and little recognition to those who strive for quality improvement on their projects.

Again, inappropriate use of construction materials in their right proportions seems another challenge and difficulty in getting certain skill personnel for a specific task and inadequate material and financial resources constraints. It has been asserted by some experts in various literature, for example, Alam et al. (2016) concluded that the basic requirements for the success of quality assurance are the availability of experienced knowledgeable and trained personnel at all levels.

4.11 Measures put in place to achieve higher quality in reinforced concrete production

The results on measures put in place to achieve higher quality assurance in producing reinforced concrete products by the respondents' companies indicate that materials used in the concrete mix are free from impurities (mean = 4.68, St. Dev=0.468). This statement ranked first among the other 10 statements. Well, graded aggregates are used for the concrete mix to produce concrete also emerged 2nd on the ranking column with mean value 4.30 and 0.462 standard deviation. Again, respondents strongly agree (mean = 4.11, St. Dev=0.657) that checking and control of water-cement ratio proportions correctly is a key to ensure quality concrete production.

In another development, it revealed that the majority of the respondents agree (mean = 3.73, St. Dev=0.932) that records of testing are well kept for future references. As a measure to ensure quality concrete product, respondents agree that mixing of concrete is supposed to be strictly done on-site using a concrete mixer with a mean value of 3.59 and 1.188, hence 5th on the ranking column. Respondents again maintained that frequent checking of material quality is always done (mean=3.56, St. Dev =0.957) and positioned 6th. Respondents further agree that batching of materials is sometimes varied either by weight or volume with a mean score of 3.55 and 0.972 standard deviation which ranked 7th. Similarly, respondents agree (mean=3.55, St. Dev=0.501) that companies usually engage in full production test to ascertain the desired quality.

However, in soliciting responses on whether companies have been conducting baseline studies to ascertain the practical limit to the strength of the concrete depending on the specifications, respondents neither agree nor disagree with the statements with mean values of 3.23 and 0.717 standard deviation. This response however positioned the statement in the 9th place. Responses further maintained in a neutral position as to whether companies do conduct pre-testing of material strength to achieve the desired quality of concrete product to be produced.

On the contrary, respondents disagree that companies do frequent monitoring of reinforced concrete processing using Shewhart control chart with mean value 2.82 and 1.378 standard deviation and eventually ranked 11th. It was disagreed (Mean=2.60, St. Dev. = 1.152 and ranked 12th. Respondents disagree that ready mixed concrete is transported onto the site depending upon the type of work. This statement was however the last and the 13th statement. It is important to note that, consistently, all statements that respondents disagree with observed inconsistent responses. Table 4.6 shows measures put in place to achieve higher quality in reinforced concrete.

Table 4.6 Measures put in Place to Achieve Higher Quality Concrete

Item	Responses			
	N	Mean	St. Dev.	Rank
Materials used in the concrete mix are free from impurities	52	4.68	.468	1
Well graded aggregates are used for concrete mix	52	4.30	.462	2
Water cement ratio proportions are correctly checked and controlled	52	4.11	.657	3
All records of testing are well kept for future references	52	3.73	.932	4
Mixing of concrete is strictly done on-site using a concrete mixer	52	3.59	1.188	5
Frequent checking of material quality is always done	52	3.56	.957	6
Batching of materials are sometimes varied using either batching by volume or by weight	52	3.55	.972	7
Full production test is usually done to ascertain the quality desired	52	3.55	.501	8
Baseline studies are conducted to ascertain practical limits to the strength of the concrete depending on the quality specifications	52	3.23	.717	9
Pre-testing of material strength is frequently done to achieve the desired quality	52	3.22	1.627	10
Frequent monitoring of concrete processing using Shewhart control chart	52	2.82	1.378	11
Employees sometimes receive training related to their duty prior to the commencement of the project	52	2.60	1.152	12
Depending upon the type of work, ready mixed concrete are transported onto the site	52	2.55	1.248	13

Best practices and measures cannot be ignored especially when talking about concrete production made by construction companies. It plays a very crucial role in the production of concrete by these construction companies. The results on measures put in place to achieve higher quality assurance in producing the concrete products were phenomenal. It revealed that the materials used in the concrete mix are free from impurities. It was again endorsed that companies use well-graded aggregates for concrete mix. The aggregates have to be graded so the whole mass of concrete acts as a relatively solid, homogenous, dense combination with the smaller particles acting as an inert filler for the voids that exist between the larger particles (Alam et al., 2016). This, therefore, suggests that the selection and proportioning of aggregates must be given due attention as it does not only affect the strength but the durability and structural performance of the concrete also. Aggregates provide better strength, stability and durability to the structure made out of cement concrete than cement paste alone.

Results further revealed that a good proportion of adequate water-cement ratio is correctly checked and controlled. Mixing water with the cement, sand and stone form a paste that binds the materials together until the mix hardens. The strength properties of the concrete are inversely proportional to the water/cement ratio. This means the more water used in the mix, the weaker the concrete. The less water used to mix the concrete (somewhat dry but workable) the stronger the concrete mix. Accurate concrete mixing ratios can be achieved by measuring the dry materials using buckets or concrete mix throughout your project (Alam et al., 2016).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary, conclusion and recommendations of the study. The summary, conclusion and recommendations are based on the specific objectives of the study. The study however aimed to examine the implementation of quality assurance measures in the production of reinforces concrete by construction firms in the Ashanti Region of Ghana and develop strategies for effective quality assurance practices in reinforced concrete production. Relevant related literature was reviewed to find out the existing practices and principles of quality assurance especially in reinforced concrete production in the construction industry. In other to achieve the aim of the study, the study used the following specific objectives:

- to determine effective quality assurance practices in concrete production on a construction project in Ghana;
- to assess the contractor's knowledge of the elements of quality assurance concerning concrete production in Ghana;
- to identify key challenges to implementation of quality assurance in concrete production by construction companies in Ghana; and,
- to propose practical measures for the implementation of quality assurance in concrete works.

5.2 Summary of the Quality Assurance Measures

The following findings revealed as the top quality assurance practices in most D1K1 companies in Ghana;

i. All reinforced concrete products are designed to suit fitness for use.

ii. All reinforced concrete products are produced in conformity to specifications and standards.

iii. Companies rely on experienced supervisors to conduct supervision during reinforced concrete production.

iv. The degree of excellence is considered whenever a reinforced concrete product is to be produced.

v. Specified required proportion of each component as identified in the drawing specification is strictly adhered to.

vi. The performance requirement of reinforced concrete is checked at its design stage to ensure safety.

5.3 Knowledge of the element of the Quality Assurance Measures

The study revealed that most project team members know the elements of quality assurance measures hence, the following statements ranked accordingly.

i. Durability and reliability are key dimensions for achieving quality concrete

ii. Companies ensure that drawings and specifications are concise, clear and void of information

iii. Companies design the correct mix ratio of each category of concrete prescribed for the work under each contract

iv. Achieving excellence through high-quality concrete product is the main objective of my contractor

v. Carefully weigh the concrete production process against the serviceability of concrete elements.

5.4 Challenges to the implementation of the Quality Assurance Measures

The following were considered as the most top pressing challenging factors by the project team members.

i. Difficult to keep permanently employed key site operatives for concrete operations due to financial constraints
ii. Inappropriate use of construction materials in their right proportions is resorted to in the face of challenges
iii. Difficult to get certain skill personnel for a specific task sometimes
iv. Inadequate material and financial resources constraints

5.5 Practical Measures for the Implementation of Quality Assurance

The following according to the project team members are some measures for the implementation of quality assurance measures.

i. Materials used in the concrete mix must be free from impurities
ii. Well graded aggregates must be used for concrete mix
iii. Water cement ratio proportions should be correctly checked and controlled
iv. All records of testing should be well kept for future references
v. Mixing of concrete should strictly be done on-site using a concrete mixer
vi. Frequent checking of material quality should be always done

5.6 Conclusion

Based on the findings the following conclusions are drawn:

Though concrete products are designed to suit fitness for use and are produced in conformity to specifications and standards, the research revealed that some of the construction project team members belonging to D1K1 companies do not fully appreciate the basic requirements for producing durable concrete. Also, durability and reliability according to the study are key dimensions for achieving quality concrete. As a result, some companies ensure that drawings and specifications are concise, clear and devoid of information which is likely to cause any misunderstanding. Again, the study further revealed that difficulty in keeping permanently employed key site operatives for concrete operations due to financial constraints and sometimes difficult to get certain skill personnel for a specific task as well as inappropriate use of construction materials in their right proportions are the major challenges to some companies.

The onus, therefore, lies on design professionals, constructors and construction project team members in the construction industry to appropriately develop programs and principles that will necessarily affect quality assurance practices in all types of projects.

5.7 Recommendations

The following are the recommendations based on shortcomings observed from the respondents.

i. Implementation of formal quality management systems by all construction companies must be encouraged.

ii. Project team members of construction companies must strictly stick to satisfying the specified requirement of any kind of project.

iii. Rather than depending on experienced supervisors, personnel should focus on satisfying specifications and requirements. This can be achieved by applying quality management principles in concrete works.

iv. Companies should be able to keep key skill operatives for quality work done.

v. Variability of concrete materials and concrete should be controlled by encouraging the maintenance of good record keeping. The use of the slump test for instance is recommended for maintaining consistency with previous batches.

vi. Top management must show commitment and leadership in concrete works quality.

vii. All team members must be encouraged to get involved to achieve quality and not leave it to low-level personnel.

5.8 Further Research

The researcher further recommends total quality management practices of concrete production as future research.

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APENDIX A

QUESTIONNAIRE FOR CONSTRUCTION firms MANAGERS AND QUALITY OFFICERS

This questionnaire is designed for a Master of Technology research titled "**investigating the quality control measures in the production of reinforced concrete; a case study on construction firms in the Ashanti region of Ghana**". It is meant to solicit information from construction project team members with the aim of examining the quality assurance practices observed by the construction firms and perception of the factors necessary for successful quality management in reinforced concrete production. The respondent's information provided will be treated as confidentially as possible since this study is meant for academic discourse.

SECTION A PARTICULARS OF RESPONDENTS

1. What is your level of education?

Postgraduate ☐ First Degree ☐ HND/ Diploma ☐ Technician ☐

Other ☐ Please, specify____

2. What is your job title/position in this company?

Project Manager ☐ Quality officer ☐ Project Engineer ☐

Site Engineer ☐ Work Superintendent ☐ Site Supervisor ☐

3. How many years of experience do you have in the industry?

Less than 5 years ☐ 5-10 years ☐ 11-15 years ☐ 16-20 years ☐

over 20 years ☐

4. How long has your company been in existence?

0-5 years ☐ 6 -10 years ☐ 11-15 years☐ 16-20 years ☐ over 20years ☐

5. At what stage, did you join the current project?

Pretender-pre-planning stage ☐ Post tender stage ☐ Start of project ☐

SECTION B QUALITY ASSURANCE IN REINFORCED CONCRETE PRODUCTION

Please indicate the extent to which you agree or disagree to the following statement on quality assurances practices in reinforced concrete production by ticking (√) the appropriate option as your response.

Key: 1- strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree.

ITERM	RESPONSE				
Quality assurance practices in reinforced concrete production on construction projects	**1**	**2**	**3**	**4**	**5**
The degree of excellence is considered in my company whenever a reinforced concrete product is to be produced					
Successive inspection of works during reinforced concrete operation is considered in my company					
In my company, all reinforced concrete product is designed to suit fitness for use					
All reinforced concrete product is produced in conformity to specifications and standards					
Performance requirement of reinforced concrete is checked at its design stage to ensure safety					
Durability and reliability considerations are observed during reinforced concrete production stage					
Specified required proportion of each component identified in the drawing specification are strictly adhered to					
My company rely on experienced supervisors to conduct supervision during reinforced concrete production					

Raw materials to be used for concrete product are well checked against standards and specifications					
The use of substandard materials for reinforced concrete production is compromised in my company					
Site engineers at the site sometimes reduce some quantity of materials to be used					

To what extent do you agree on the following statements on elements of quality assurance in concrete production as applies to your firm?

Please rate using a scale of 1 to 5 where 1= strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree.

Knowledge of elements of quality assurance in concrete production	1	2	3	4	5
The contractor understands implications of compromising the specified specifications in the drawings					
The contractor defines the responsibility of personnel who manage, perform andverify work that affect quality concrete to be produced					
The contractor makes adequate provision of standard and required material resources for the production of concrete					
Every employee in my company feels contractor provides full support to processand project quality improvement					
There is existence of a communication system notifying all staff about the quality responsibilities of every individual in my company					
I regard durability and reliability as key dimensions for achieving quality concrete					
I design the correct mix ratio for each category of reinforced concrete prescri worksof for the works under each contract.					
In my company, strict measures are adopted to deal with supplies of materials used in concrete production.					

I carefully weigh the reinforced concrete production process against servicea of the concrete elements.					
Achieving excellence through high quality reinforced concrete products is th objective of my objective of my company.					
My company ensures that drawings and specifications are concise, clear and void of conflicting information.					

To what extent do you agree on the following statements on challenges to implementation of quality assurance in you your company?

Please rate using a scale of 1 to 5 where 1= strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree.

Challenges to the implementation of quality assurance practice in concrete production	1	2	3	4	5
Inadequate material and financial resources constraints					
Effective access to obtain the reviewed construction detailed drawings and specifications are sometimes difficult					
It is sometimes difficult to get certain skill personnel for a specific task					
It is difficult to keep permanently employed key site operatives for concrete operations due to financial constraints					
Sometimes, financial constraints make it difficult for some contractors buy from the right source of suppliers					
Procurement officers purchase materials and components from suppliers Who do not put in place quality assurance measures?					
Inappropriate use of construction materials in their right proportions is resorted to in the face of challenges.					

Adverse weather conditions sometimes make it difficult for concrete to achieve its required strength					
Tests that ought to be done to ascertain the required needed strength of concrete are ignored.					
Lack of proper planning of site operations often resulting in Issues many of which border on quality.					

To what extent do you agree on the measures put in place by your organization for achieving higher quality standard of concrete? Please rate using a scale of 1 to 5 where 1= strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree.

Measures put in place to achieve higher quality concrete	1	2	3	4	5
Materials used in the concrete mix are free from impurities					
Well graded aggregates are used for concrete mix					
Water cement ratio proportions are correctly checked and controlled					
Batching of materials are sometimes varied using either batching by volume or by weight					
Mixing of concrete are strictly done on site using concrete mixer					
Depending upon the type of work, ready mixed concrete is transported onto the site					
Pre-testing of material strength is frequently done to achieve the desired quality					
Employees sometimes receive training related to their duty prior to the commencement of the project					
Full production test is usually done to ascertain the quality desired					
Frequent checking of material quality is always done					

Frequent monitoring of concreting processes using Shewhart control chart					
All records of testing are well kept for future references					
Baseline studies are conducted to ascertain practical limits to the strength of concrete depending on the quality specifications.					